WATER AUTHORITY OF WESTERN AUSTRALIA
GNANGARA MOUND GROUNDWATER RESOURCES

Report of Advisory Group
to the
Environmental Protection Authority

Environmental Protection Authority
Western Australia
Bulletin No 273 March 1987

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ENVIRONMENTAL PROTECTION AUTHORITY
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SUMMARY

LAND AND WATER USE

1 **The Gnangara Groundwater Mound is a major water resource in the Perth Region.** There are complex inter-relationships between the water resource and the major land uses (urban development, rural activities, pine plantations and public water supply) and the natural environment. **Management of this resource and associated land uses is essential if the maximum sustainable benefit is to be derived for the whole community.** A balance must be found between the conflicting demands for water required for development and conservation of the environment. A balance must also be found between the use of water for urban, agricultural and silivicultural purposes.

2 Perth's steady population growth is expected to continue and will result in expansion of the urban area within the North West Corridor. **Continued growth in demand for public water supplies is considered to be inevitable.** However, the Water Authority should continue its efforts to encourage water conservation and thus reduce the rate of growth in demand for water.

3 Urban development will have little direct effect on water table levels except in localised areas. Urbanisation is likely to result in degradation of water quality and will also affect the nature and extent of activities in the rural and forestry areas and the wetlands to the east. **It is highly desirable to restrict urban expansion to the North West Corridor, an area where degradation of quality and any impact on water table levels will not affect other uses.**

4 Changes to groundwater quality are particularly important in relation to public water supplies and the wetlands. The main defense of the groundwater system against degradation is its ability to disperse and dilute contaminants. **Careful planning and management of land use and waste disposal will be required to minimise groundwater quality degradation.**

5 Extractive industries quarry sand, limestone and other materials from the Mound. These activities are usually limited in extent and no direct impact on the groundwater is known. Legislation requiring environmental review and management programmes should provide the protection necessary.

6 The main land uses in the rural area are irrigated horticulture, pastoral activities and hobby farms. **Of these, market gardening is the major water using activity.** Expansion of market gardening in the area, due primarily to increased export demand, is predicted but the rate and extent of growth is uncertain. **The proposed allocation of 36 million cubic metres per year in the Wanneroo Groundwater Area should be adequate to meet growth in demand for water for agricultural activities for at least the next ten years and possibly much longer.**

7 Many market gardens are located near wetlands and their impact on both water levels and quality is potentially significant. Accordingly, water use is regulated where necessary, with the aim of preventing problems rather than having to cure them. This has resulted in concern among some landowners about restrictions on land use and the effect on property values.

8 In the longer term, growth of irrigated horticulture in the Wanneroo area is likely to ease or cease in response to rising land values due to adjacent urban expansion, and to relocate elsewhere. Most other agricultural activities have much lower water requirements and thus have more limited

implications for the water resource. Fertilisers, pesticides and herbicides used in rural activities all have adverse implications for water quality, particularly for wetlands.

9 **State Forest 65 has a strategic role in protecting the quality, and ensuring the availability, of groundwater in the region.** Pine plantations occupy one half of State Forest 65 with much of the balance reserved for conservation of flora and fauna. **Variations in the density of pines have a significant effect on rainfall interception and transpiration and thus on net recharge of the Mound.** Silviculture has little or no detrimental effect on water quality.

10 **The priority purposes of State Forest 65 are conservation and water production.** Fortuitously timber returns are maximised at or near the pine density that equates to native woodland. Reduction of high density plantation areas would significantly increase net recharge with only a marginal impact on timber returns. Approximately one third of the area under pines will, in any case, produce low volumes of timber and these areas, in particular, should be thinned to low densities to increase recharge. **A comprehensive detailed long-term management plan for both the plantation and conservation areas of State Forest 65 should be developed within 12 months.**

11 Management of State Forest 65 for the priority purpose of water, while it will have some impact on timber returns, is supported by the Department of Conservation and Land Management. The major need is to plan and fund a plantation thinning and management programme to produce maximum benefits at least cost.

12 Because there has been no market for some types of forest thinnings, considerable areas of plantation currently have excessive densities. If a market could be established, this work could be undertaken at no net cost to the State. There is a possiblity that such a market may be established, however, delays in thinning will increase the cost of this work if it eventually has to be done non-commercially. **If a market for pine thinnings cannot be established in the near future annual funding should be allocated for this work, as required for water resource management.**

NATURAL ENVIRONMENT

13 **The large remnants of native vegetation including the extensive wetland system on the Mound are environmentally important.** Much of the native vegetation remaining on the Mound occurs in State Forest 65 and on Crown land to the north and east. This native vegetation can be broadly categorised as uplands and wetlands. The uplands are areas of net recharge and the wetlands areas of net loss of water. **The water table declines described in the Gnangara Mound Groundwater Resources Environmental Review and Management Programme (ERMP) will have little effect on the extensive areas of upland native vegetation (and pine plantations) on the Mound.**

14 Wetlands are a surface expression of the water table. They comprise dynamic and inter-dependent systems subject to seasonal and longer term climatic variations, geological and other natural processes and the effects of Man's activities. **Wetlands are constantly changing and have, in the past been both more and less extensive than at present.** It is possible that a warming of the Earth's climate in the decades ahead may result in a significant contraction of wetlands.

15 **Retention of wetlands is the major constraint in managing the groundwater resources of the Mound.** Without this constraint much more water could be abstracted for both public and private supplies.

16 Urban wetlands are primarily valued for aesthetic reasons; less modified wetlands are more important for ecological reasons. The wetlands of the Swan Coastal Plain are important for a number of reasons including their value as refuges for wildlife in dry periods and as habitats for transequatorial migratory waders. Preservation of a range of natural habitats on the Mound is important ecologically and socially. The System Six Study recommended reservation of extensive areas for the protection of flora and fauna. **Consolidation and formalisation of the most important conservation areas should be finalised as a matter of priority.** Other major areas of native vegetation in State Forest 65 and on adjoining Crown Land could form extensions to these areas and compensate for environmental impacts which may occur elsewhere.

17 **Modification of wetlands is inevitable as land and water resource development proceeds; ephemeral wetlands are especially difficult to deal with because of their dispersed nature.** The aim of co-ordinated land use and water resource management should be to contain impacts within acceptable limits. **There is a need to develop criteria for wetland changes.**

FUTURE DEVELOPMENTS

18 Within the constraint on total withdrawals imposed by wetlands conservation, there is a need to plan and manage use of the groundwater for agriculture, silviculture and public supply. The approach proposed by the Water Authority provides for a 50% increase in the water available for agricultural purposes within the Wanneroo Groundwater Area, reduction in the use for pine production and sufficient abstraction to meet growth in urban demand for the next 25 years.

19 The issue of agricultural water demand is complicated by the uncertainty of demand projections and the question of allocation is influenced by the local impact of intensive users on the environment. **Overall, the proposed allocation of 36 million cubic metres per year in the Wanneroo Groundwater Areas should be adequate to meet growth in demand over the next ten years and possibly for much longer.** However, in some areas, environmental considerations mean that some demands will not be able to be met and conflicts will have to be resolved.

20 The scope for increasing the allocation of unconfined groundwater to agriculture by reducing abstraction for urban supply or further thinning of pines is limited. This is because the distance between the "problem" and the "solutions" is considerable.

21 **Participative management of the Wanneroo Groundwater Area, where demand approaches availability, has proved successful in finding solutions to most of the problems and conflicts associated with allocation of water among private users in this sensitive area.** While there is scope for assessing alternative water allocation mechanisms, continuation of the Wanneroo Groundwater Advisory Committee and existing allocation and control arrangements is considered to be the most appropriate at this time.

22 Many of the possible problems and conflicts which may be associated with development of the Mound will not occur for decades and will arise progressively. Accordingly, it is important not to make decisions or take

actions earlier than is necessary for operations to proceed. To do so would forego the benefits of increased knowledge that will be available as the result of further research and investigation.

23 Some decisions and actions associated with groundwater development and management are reversible. This is particularly true of private and public abstraction. **Where unforeseen consequences arise or impacts are greater than predicted, there is scope, at a cost, to take remedial action with the expectation that wetlands will recover.**

24 **The ERMP is a comprehensive and sound document bringing together for the first time much of the information required to plan and manage this important resource and its associated land uses.** The model used to evaluate alternative development strategies is the most powerful tool available. **The model predictions are considered to be a sound basis for decision making.**

25 Additional information is required in some areas and will improve future decision-making. This will require the planning and execution of a research and assessment programme. However, decisions which need to be made now can be made on a far more informed and balanced basis than was the case before the ERMP was prepared.

26 The long term strategy proposed in the ERMP is considered to provide a reasonable balance between the needs associated with development, and conservation of the environment. It provides a sound basis for strategic planning and policy formulation by the many individuals and organisations with an interest in Mound land use and water resources. **The long term strategy proposed by the Water Authority in the ERMP should be the basis for planning and management.**

27 Development of the Gnangara groundwater resources is the least cost alternative for satisfying growth in demand for public water supplies, particularly in the North West Corridor. The proposal is to construct groundwater schemes in stages to match the growth in demand while at the same time minimising the impact on the environment. It is planned to locate future wellfields within State Forest 65 where water quality is protected and water table changes have generally less impact on the natural environment, particularly the wetlands. **The proposed programme of staged development of public water supply schemes in State Forest 65 is a sound and conservative approach.**

PLANNING AND MANAGEMENT

28 **To minimise the impact on the natural environment it is essential that an integrated approach to management should be progressively implemented.** To achieve this it will be necessary to co-ordinate the planning and operations of the various organisations with a strategic interest and influence. **This process could be initiated by establishing a Gnangara Mound Planning and Management Committee under the auspices of the Western Australian Water Resources Council.** The Committee should comprise senior representatives of the:

City of Wanneroo;
Department of Agriculture;
Department of Conservation and Land Management;
Environmental Protection Authority;
Mines Department;
State Planning Commission; and
Water Authority of Western Australia.

The role of the Committee would be to ensure that, for the Gnangara Mound region, each organisation develops and implements policies and plans for its area of responsibility within a co-ordinated framework.

29 The objectives of the Committee should be to:

(i) develop and co-ordinate integrated planning and management by the various agencies involved;

(ii) monitor and report on the implementation of both individual agency and overall plans;

(iii) advise on research and investigation priorities; and

(iv) promote community participation in planning and management.

30 **The commitments given by the Water Authority in the ERMP provide a sound basis for managing the complex issues arising from water resource and land use development.** There is a need to formalise commitments, and to develop more specific programmes and plans to put some commitments into effect. Successful management along the lines described in the report also requires formal commitments from other organisations, particularly CALM.

31 **Consideration needs to be given to overall funding arrangements for Gnangara Mound environmental research and management.** While it is reasonable for the Water Authority to bear some of the cost, particularly for work directly related to water supply and water resource management, it should not be required to fund all investigation work, much of which arises out of the land and water use activities of others.

THE PINJAR SCHEME

32 The Pinjar Scheme is the next public water supply development planned for the Mound. Various options have been examined within the context of the longer term strategies described in the ERMP. **There is no clearly superior alternative to the proposed scheme, the first stage of which must be commissioned in 1989 to satisfy growing demand for urban water.** The Water Authority has sought approval to proceed with detailed planning, design and construction.

33 Predicted changes in water table levels beneath the Lake Pinjar plain due to pumping from the proposed scheme will be quite substantial. However, this land is in private ownership, largely cleared and heavily degraded from an ecological point of view. **Water level changes in environmentally sensitive areas to the west and east are generally expected to be small and to have limited effect on the environment.**

34 **The proposed Pinjar Scheme should be approved subject to the management commitments given in the ERMP, comments made in this report and, in particular, on condition that:**

(i) the Water Authority develops, within 12 months, a model to allow the local effects of the Pinjar Scheme to be better defined, monitored and managed;

(ii) the Department of Conservation and Land Management formally agrees to thin the pines in the vicinity of Lake Pinjar to average basal areas with recharge equivalent to natural vegetation, as required by the Water Authority;

(iii) private abstraction in the Wanneroo Groundwater Area north of Flynn Drive does not exceed 15 million cubic metres per year unless further monitoring and modelling shows the impact on water table levels to be acceptable;

(iv) the Water Authority and the Department of Conservation and Land Management, in conjunction with the Environmental Protection Authority, prepare a long term programme for assessing and monitoring environmental impacts in the area; and

(v) the unconfined and confined aquifers are developed concurrently to provide some capacity for managing water table declines under severe drought conditions.

1. INTRODUCTION

ADVISORY GROUP

1.1 The Water Authority of Western Australia has prepared an Environmental Review and Management Programme (ERMP) for proposed water supply developments on the Gnangara Mound (Mound). The ERMP presents a general strategy for managing the unconfined groundwater resource and also more detailed plans for the proposed Pinjar Scheme.

1.2 The Mound is a major water resource in the Perth Region. The complex and dynamic relationships between land use and groundwater give rise to important environmental, economic and social issues. To assist in its consideration of these issues, the Environmental Protection Authority convened an advisory group to provide an overview of issues affecting the Mound so that a general policy for management could be developed.

TERMS OF REFERENCE

1.3 The terms of reference for the Advisory Group were to advise on:

(i) the nature, extent and utilisation of the Gnangara Groundwater Mound;

(ii) the relationships between land uses, the conservation of wetlands and native vegetation, and the groundwater resource;

(iii) the options and trade-offs between alternative land use strategies;

(iv) other issues and strategies which may contribute to the determination of the most appropriate balance between competing demands on the Gnangara Mound groundwater resource;

(v) the adequacy and accuracy of the information contained in the ERMP report;

(vi) the adequacy of the environmental management commitments contained in the ERMP report; and

(vii) the environmental acceptability of the proposed Pinjar Scheme.

MEMBERSHIP

1.4 The Advisory Group members were:

Mr C W Burton (Chairman)
Dr A D Allen
Mrs P A Clay
Mr W R Stevens
Mr J F Thomas

1.5 The members of the Advisory Group were chosen by the Environmental Protection Authority for their personal expertise and experience. This report reflects the views of the individuals and not the policies of the organisations with which they are affiliated.

ACKNOWLEDGEMENTS

1.6 The Group was greatly assisted in its work by briefings given by officers from the following Government and other organisations:

Department of Agriculture	Mr J Gallagher Dr B Stynes Mr G Luke
City of Wanneroo	Mr O Drescher Mr P Thompson
Department of Conservation and Land Management	Mr T Butcher Dr E Hopkins
Environmental Protection Authority	Dr J Arnold
State Planning Commission	Mr R Bulstrode Mr J Jenkins Mr J Singleton
Wanneroo Groundwater Advisory Committee	Mr R Green
Water Authority of Western Australia	Mr G Cargeeg Mr R Harvey Mr D Hopkins Mr B Sadler
Wetlands Conservation Society	Prof P Jennings

1.7 Special assistance was provided to the Advisory Group by the following:

Department of Conservation and Land Management	Dr E Hopkins
Environmental Protection Authority	Mrs C McDavitt Mr C Murray Mr B Stewart Miss C Craster
Mines Department Geological Survey	Mr T Bestow
Water Authority of Western Australia	Mr G Cargeeg

METHODOLOGY

1.8 This report is the outcome of two weeks intensive consideration and discussion of information obtained from published documentation, expert briefings and a field inspection. It assumes a knowledge of the contents of the Gnangara Mound Groundwater Resources ERMP. Other publications containing useful background information are listed in the bibliography.

2. THE GNANGARA GROUNDWATER MOUND

GENERAL DESCRIPTION

2.1 The Gnangara Mound is a shallow body of groundwater occurring between the Swan River and Gingin Brook. It originates from rainfall and occurs in sediments forming the Swan Coastal Plain. The upper surface of the Mound is the water table and its base is formed by older sedimentary rocks (Figure 1). The groundwater in the unconfined aquifer flows slowly outwards from the crest of the Mound to discharge into the ocean and the bounding rivers.

2.2 The sandy sediments of the coastal plain favour rapid infiltration of rainfall. The water table rises as it is recharged during winter and falls during summer as some of the stored groundwater is depleted. The natural factors affecting net recharge of the unconfined aquifer are the amount of rainfall, usage by vegetation, loss of water by direct evaporation from intercepting surfaces and wetlands, and leakage to underlying aquifers.

2.3 The Mound is a major water resource in the Perth region and extends over an area of 2091 square kilometres. The unconfined aquifer ranges in thickness from 10 to 100 metres and is estimated to contain about 19 500 million cubic metres of groundwater in storage.

2.4 The current water balance of the Mound, expressed in millions of cubic metres per year (assuming no change in storage), is:

IN		OUT	
Rainfall	1675	Evapotranspiration	1165
Water Imported from Surface Sources	80	Leakage to Underlying Aquifers	107
		Outflow to Ocean and Rivers	372
		Abstraction from Wells	111
	1755		1755

A relatively modest reduction of the evapotranspiration consumption would significantly increase the quantity of water available for public and private abstraction.

2.5 The groundwater of the Mound is readily accessible and large quantities can be abstracted for public and private use at relatively low cost. As Perth expands northward, the groundwater resources of the Mound are proposed to be further developed for public water supply in stages, as required. The amount of groundwater which can be obtained from the Mound is determined primarily by the desire to limit the impact on the environment, particularly the wetlands.

2.6 In addition to the unconfined groundwater resources of the Mound, artesian and sub-artesian groundwater resources occur at depth below the coastal plain. These resources are more saline and, while large quantities of groundwater are in storage, their annual recharge is approximately one third of that of the Mound. Depth, salinity and legislative control restrict the development of these resources for private use but they are important supplementary resources mainly for public supply. Abstraction from the confined aquifers provides some scope to minimise the effects of pumping from the unconfined aquifer in times of drought.

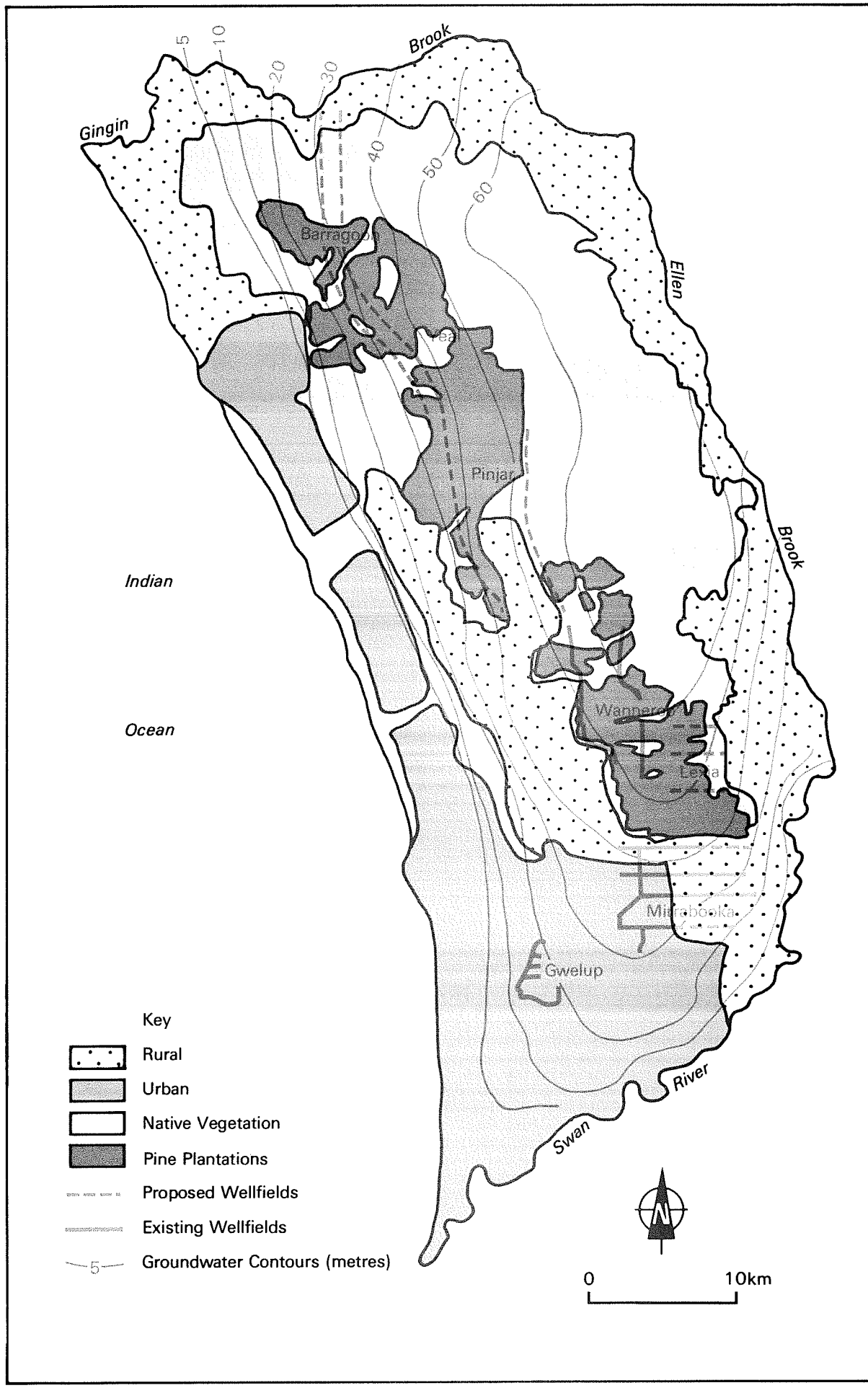

Figure 1. Gnangara Mound Water Resource and Selected Land Use Zones

LAND USE

2.7 There are four major land uses on the Mound (Figure 1). These are:

- urban development;
- rural activities;
- forestry; and
- the natural environment

2.8 Urban development has grown outwards from the original settlement of Perth and has been based on access to commercial centres, proximity to the Swan River and the coast, and areas of prominent topography. With the rapid growth in the post-war period, it was recognized that Perth should not grow without planning. The Corridor Plan and Metropolitan Region Scheme provide the basis for present day development. The first major review for some 15 years is in progress and will set the framework for development of the Perth region into the next century.

2.9 Rural land has generally been located on the fringes of urban development and in favourable areas in the hinterland. Market gardening was first developed on peaty soils near wetlands and later on favourable soil types on higher ground. Over the years market gardeners have moved outwards to the north and south as the urban area expanded. Pastoral activities have been developed depending on the availability and price of freehold land.

2.10 State Forest 65 is located on land that was considered to be useless for agriculture. Numerous problems have had to be overcome since planting of pines commenced in 1918 and it was not until the early 1940s, and particularly since the 1960s, that extensive plantations have been established.

2.11 Some of the largest remnants of native vegetation in the Perth Region are located on the Mound. In the past areas with outstanding natural attributes (eg Yanchep National Park) or areas unsuited for agriculture or pine-growing have been set aside for preservation. Recently, as part of the System Six Study, further areas have been recommended for reservation to preserve habitats and viable examples of coastal plain bushland (Figure 2).

GROUNDWATER USE

2.12 The groundwater resources of the Mound provided the main source of Perth's water for the first half of its history. This included supplies for market gardens which were developed around lakes and swamps. The moist margins of those areas were cultivated in a shifting pattern as groundwater levels rose and fell. More recently, growers have adopted new techniques including overhead sprinkler irrigation using groundwater pumped from wells. Many new market gardens are on higher ground where larger lots are available.

2.13 Most of the market gardens on the Mound are located within the City of Wanneroo and many of these lie within the Wanneroo Groundwater Area. In the Wanneroo Groundwater Area some 1 000 hectares is currently being used for vegetable growing and floriculture. Estimated water use for these and other rural activities in the area is some 24 million cubic metres per year. The rate and extent of growth of agriculture is uncertain but it seems likely that total demand will rise to about 36 million cubic metres per year over the next ten years. Water use may continue to increase in the following

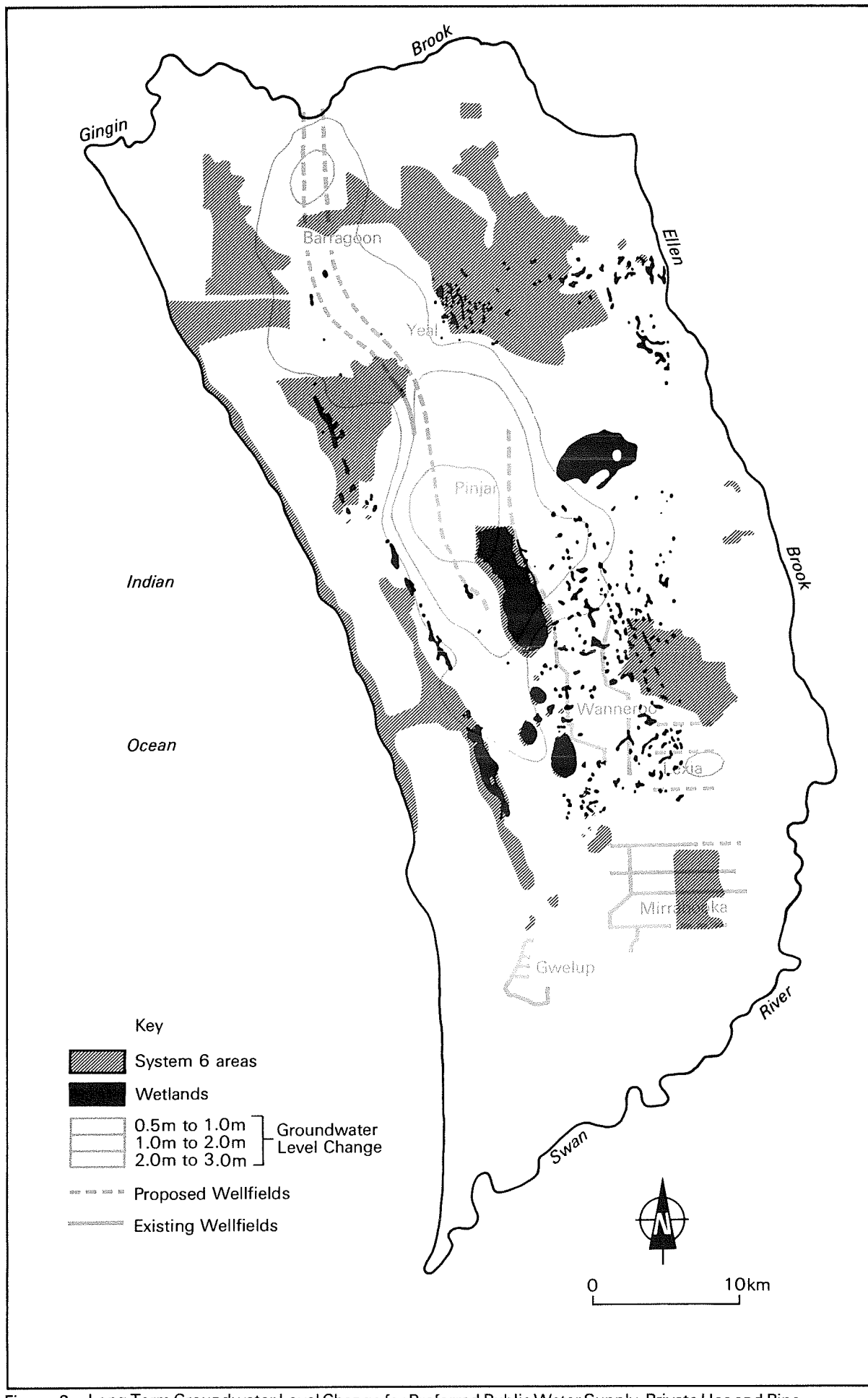

Figure 2. Long Term Groundwater Level Change for Preferred Public Water Supply, Private Use and Pine Management Strategies.

following decade but could stabilise at or about that level as a result of urban development pressures and improved water use efficiency.

2.14 Development of public water supply schemes on the Mound commenced in 1971 when the Mirrabooka Groundwater Scheme began production. This was followed by the Gwelup Scheme in 1974, and the Wanneroo Scheme in 1976. Production quotas from the unconfined aquifer are:

Mirrabooka	12.2	
Gwelup	5.5	
Wanneroo	12.2	
Total	29.9	million cubic metres per year.

The Mirrabooka and Wanneroo Schemes are the only sources of water supply for the North West Corridor.

2.15 Planned quotas for public abstraction of unconfined groundwater from schemes, which are proposed to be developed in stages over the next 25 years to match growth in demand as the North West Corridor expands, are:

Pinjar	14.0	
Lexia	6.5	
Yeal	9.6	
Barragoon Stage 1	3.5	
Total	33.6	million cubic metres per year.

In addition there will be increasing abstraction from artesian aquifers.

3. LAND USE AND GROUNDWATER

GENERAL RELATIONSHIPS

3.1 The groundwater resources of the Mound are derived from rainfall. The amount of rainfall that becomes groundwater is determined by factors such as the intensity of storms, the nature of the soil, the depth to the water table, the vegetation cover and other land use parameters.

3.2 The level of the water table fluctuates in response to seasonal, annual and longer term variations in rainfall. The main factor contributing to the general decline in water levels of the region over recent years has been the extended period of below average rainfall. Only two of the last twelve years have been above average.

3.3 Changes in land use such as clearing of native vegetation, water abstraction, drainage and urban development also affect the water table. When these changes occur equilibrium is eventually re-established with water levels at a new position. In some situations water levels rise while in others they decline. Thus the water resource and land use form a dynamic system, changes in one affecting the other.

3.4 Land use and water resource development have both regional and local implications. While changes have regional consequences, the greater the distance between land use or water supply developments and sensitive areas

such as wetlands, the less the impact is likely to be. What may be an unacceptable development in close proximity to a sensitive area may be satisfactory in a more remote location. Thus there is generally limited scope to increase water availability in one area by reducing demand in another. For example, reducing proposed public abstraction or water use by pines in State Forest 65 would tend to have local effects and would not greatly affect the availability of groundwater for private abstraction to the west.

3.5 By far the greatest consumption component of the water balance is evapotranspiration which accounts for almost 70% of rainfall. This consists of two principal components: a diffuse and widespread loss from plants in the relatively extensive upland areas (57%), and intensive direct evaporation from open water and transpiration from the fringing vegetation of the relatively small areas of wetlands (13%).

3.6 Retention of wetlands is the major constraint in managing the groundwater resources of the Mound. Without this constraint, much more water could be developed for both public and private supplies.

URBAN DEVELOPMENT

3.7 The removal of native vegetation and the construction of roads, roofs and paths causes a significant increase in the proportion of rainfall recharging the groundwater resource and results in a rise in water table levels (eg Lake Claremont). In some cases this has led to a need for a drainage scheme to be constructed to reduce local groundwater levels to prevent flooding of private property. Elsewhere, land previously subject to periodic wetting has become a permanent water body. Conversely, as urban areas become established, water table levels may decline as the number of wells for irrigating private gardens and public open space increases.

3.8 In the longer term, as development stabilises, a new equilibrium is established. With the compensating changes associated with urban development, the net effect on the water table will generally not be significant. However, there may be some local exceptions: for example, within the urban zone, recreation areas are often associated with wetlands and there may be competing demands for groundwater for public open space irrigation and for the wetlands. High densities of private well ownership adjacent to wetland areas may also contribute to lower water levels in urban lakes (eg Perry Lakes).

3.9 Some forms of urban development such as Special Residential developments on 2 000 square metre lots may result in high groundwater demands. The tendency to locate these prestige developments close to aesthetic attractions such as wetlands increases the likelihood of adverse effects.

RURAL ACTIVITIES

3.10 Horticultural developments utilize large quantities of groundwater and can significantly affect the water balance of an area because the irrigation requirements for each hectare cultivated exceed the local recharge by a factor of up to ten. The close proximity of many existing and proposed horticultural developments to the wetlands increases the likelihood of adverse environmental effects.

3.11 Vegetable production in the Perth Region, about half of which occurs on the Mound, is part of the supply chain from Carnarvon in the north to

Albany in the south, a distance of some 1250 kilometres with different climatic conditions. Its value to the central market of Perth and overseas export markets is well known to the industry.

3.12 The first spring crops from Perth come into the market after Carnarvon and Geraldton have finished their season. These spring crops include tomatoes, beans, pumpkin, capsicum and cucumbers; with other crops (lettuce, cauliflowers, carrots, cabbage and, celery) grown year-round. The metropolitan area produces the first of the new season's potato crop supplying a portion of the State's requirements for October and November. There is also high production of strawberries.

3.13 Western Australia is self-sufficient for most fresh produce and expansion of production to satisfy growth in local demand can be expected. Export production is becoming increasingly important and floriculture has expanded rapidly in recent years. While continued growth in these two areas is expected, predictions of the rate of growth vary considerably and the outcome is uncertain.

3.14 Other intensive rural activities such as turf farms and piggeries also have the potential to significantly affect the groundwater. Conversely, the clearing of native vegetation for pastoral activities causes water levels to rise.

3.15 Special Rural Zones generally consist of lots with a land area of one to two hectares. The current groundwater allocation of 1500 cubic metres per year for each lot is sufficient for the domestic needs of a rural lifestyle but is not sufficient for commercial development or irrigation of a significant portion of the land. Conflicts have arisen when unsuitable land has been released or where purchasers have water use expectations that cannot be supported by groundwater availability. Nevertheless, with careful selection of sites, appropriate Town Planning Scheme texts and effective management, Special Rural Zones can be preferable to some other rural land uses.

FORESTRY

3.16 State Forest 65 covers some 50 000 hectares, or nearly one quarter of the Mound. Pine plantations occupy some 23 000 hectares, or about half of State Forest 65, and the remainder is native vegetation. To establish pines the native vegetation is cleared and the land cultivated prior to planting. For the first ten years the recharge beneath the pines exceeds recharge under natural conditions.

3.17 Modern silvicultural practice involves thinning at ages 15, 20 and 30 years, when basal areas (the cross-sectional area of stems, measured 1.3 metres above the ground, per unit land area) are about 16 square metres per hectare, to basal areas of about 7 square metres per hectare. Under this management strategy, the average stand density over the 40 year cropping period is 11 square metres per hectare.

3.18 The net groundwater recharge of pines with a basal area of 11 square metres per hectare approximates the recharge occurring under native vegetation. Pines managed to higher densities can significantly affect the region's water resources. This occurs through reduction in recharge by interception of rainfall and transpiration of water from both the saturated and unsaturated zones of the soil profile. Pines managed to less than 11 square metres per hectare increase recharge.

3.19 About one third of the area of pines in State Forest 65 is located on sites that are now known to be poor for timber production. The pines on these sites can be thinned to low basal areas and maintained as open forest to increase recharge without significantly reducing the return from timber production.

NATURAL ENVIRONMENT

3.20 The ERMP describes eleven vegetation types, contributing to a diverse flora and fauna on the Mound. Several factors determine the vegetation complexes and these include the range of soil types, climatic conditions, depth to groundwater and the activities of Man. Deep-rooted species rely on the water table but shallow rooted species do not.

3.21 Upland flora obtain most of their water from the unsaturated soil zone and lowering of the water table has little or no effect on either the vegetation or net recharge. (Sudden tree deaths within a few tens of metres of a Water Authority well were recorded in 1977-78. This was a period of drought and tree deaths in areas remote from wells and in the pine plantations were also recorded at this time). Periodic controlled burning in managed areas of upland may result in increased recharge for a limited period due to reduction of interception loss.

3.22 Wetlands are areas of seasonally, intermittently or permanently waterlogged soil or inundated land. On the coastal plain they are generally surface expressions of the water table and their size and extent varies depending on the level of the water table. Wetlands are temporary geological features tending, in the long term, to fill with peat and sediment.

3.23 A network of wetlands with varying morphology and resources is required to serve the fauna throughout the year. Birds move from one wetland to another depending on availability of food and habitat. Three distinct morphological types of wetland occur within the Mound area. These are the linear lakes, circular lakes and swamps.

3.24 The linear lakes are steep-sided and relatively permanent. These lakes, which include Joondalup, Goollelal, Neerabup and Loch McNess are deeper and their free water areas are less susceptible to reductions in groundwater levels than other wetland types. The circular lakes such as Jandabup, Mariginiup and Gnangara are shallow with gentle slopes. Because of their shallowness and sloping floors these lakes are more susceptible to both rises and falls in the water table. Swamps occur where the water table lies close to the ground surface. In winter they are occasionally flooded. They support plants at the wet end of the vegetation continuum and are susceptible to water table changes.

3.25 While wetlands can be grouped, the groundwater regime of each wetland is affected by water depth, area, presence of lake sediments, and inflow and outflow mechanisms. Thus no two wetlands are exactly alike and they may react differently to changing groundwater conditions. As a consequence of the variation in salinity, and in extent and duration of water levels, the aquatic biota and the fringing vegetation may vary considerably between apparently similar wetlands.

3.26 The fringing vegetation around lakes and swamps is important as well as the free water surface. While small amounts of nutrients can sometimes be beneficial in increasing biological productivity fringing vegetation can

intercept nutrients that may cause pollution to wetlands. It also acts as a buffer preventing midges and mosquitoes from being blown from the free water surface into residential areas.

3.27 The System Six Report identified sixteen areas on the Mound for their high conservation and recreation value and recommended that they should be reserved as national parks and conservation areas. Many of these areas are large and/or include extensive wetlands (Figure 2). The Government has made a commitment to implement the recommendations of the System Six Report as opportunities arise and subject to financial constraints. Implementation of these recommendations would facilitate planning and management of the Mound land and water resources, and ensure preservation of areas with high conservation value.

WETLAND CHANGES

3.28 Study of the sediments in some lakes shows that in the last few thousand years wetlands have been both more and less extensive than at present. Descriptions of some of the lakes at time of first settlement indicate that they were less extensive than at present and this is confirmed by fencelines across some lakes. The flora and fauna associated with wetlands are adapted to seasonal flooding and drying. Elements of flora and fauna will vary from one wetland to another, particularly fauna which moves in response to seasons and availability of food and habitat.

3.29 The wetlands are probably more resilient to water level change than is generally accepted. However, changes in water quality, particularly nutrients, may have a more profound effect. There are a number of examples (Lake Joondalup and Lake Monger) where algal blooms, eutrophication, odours and botulism death of birds, can be attributed to changed water quality.

3.30 The Water Authority has data on water levels and water quality from some wetlands. It has also commissioned specific studies of the biota of wetlands to identify invertebrate fauna that can be used to monitor changes in wetland regimes. The object of this work is to obtain some scientific reference against which changes in wetlands can be measured. No generally accepted level or indice has yet been determined. Furthermore available data does not sway public opinion which is largely based on selective memory of wetlands as they were and the expectation that wetlands should always be full of water. The latter situation may in fact lead to degradation of some wetlands.

3.31 Recognising that the wetlands are a system requiring both geographical spread and diversity for sustained viability, more general guidelines for the wetlands as a whole are required. The Environmental Protection Authority has recently published draft guidelines for wetland conservation in the Perth metropolitan area.

3.32 Because of the complexity of wetlands and the factors affecting them, defining acceptable change remains somewhat arbitrary and non-scientific. Water level and quality criteria need to be developed. As they are not yet available, a 0.5 metre change in water level has been adopted by the Water Authority as an interim criterion for the most environmentally sensitive areas. This raises two issues:

. the level from which the decline is to be measured; and

. the variable impact of a 0.5 metre decline on different wetlands.

3.33 The ultimate resolution of these issues may be the determination for individual wetlands of a minimum water level that is tolerable. In established urban and rural areas and in undeveloped areas, recent historic low water levels may be the most appropriate datum. In areas undergoing development, criteria may have to be established after a period of investigation and monitoring. In the meantime, determination of what is acceptable remains an ill-defined and subjective matter with 0.5 metre decline from "current" levels as the framework for assessment.

3.34 There is mounting, but not universally accepted evidence, that the burning of fossil fuels and the release of carbon dioxide into the atmosphere will produce a warming of the Earth's climate in the decades ahead. The effects predicted for south-western Australia are for an increase in temperature, lower rainfall (particularly in the winter) and increased storm frequency.

3.35 If these predictions are correct then the water balance will be changed due to reduced groundwater recharge. This may result in contraction of wetlands both in areas unaffected by pumping and in urban and rural areas where there will be increased groundwater usage to maintain horticulture and urban life-styles. Decreased rainfall and higher temperatures may place additional stresses on the region's water resources. To enable Perth's public water supply requirements to be met, demand may have to be reduced or additional sources developed.

PUBLIC WATER SUPPLIES

3.36 Public water supply developments reduce groundwater levels around areas of abstraction with a decrease in evapotranspiration and groundwater outflow, and a consequent increase in recharge. Some existing and all proposed groundwater schemes are located primarily within areas of land under Government control. The location of many wellfields within State Forest 65 provides an opportunity to develop joint management strategies for the public water supply schemes and pine plantations. Any land use change for State Forest 65 and adjoining areas must be carefully considered to ensure that neither the quality nor the quantity of the groundwater resource is diminished.

MINING

3.37 The sediments of the coastal plain contain deposits of silica sand, limestone, clay, peat, diatomite, phosphate and heavy mineral sands. Extractive industries already quarry sand, limestone, clay and peat. These activities are usually located in relatively small areas and no direct impact of them on the groundwater is known. However, some of the disused quarries are convenient sites for landfill and if these are not regulated some undesirable point-source contamination of groundwater may occur.

3.38 Peat and diatomite deposits are located in wetlands. For example, large diatomite deposits are known in Lake Gnangara. Depending on the circumstances mining of these may be beneficial by deepening a wetland and providing permanent open water or they may be ecologically undesirable. Legislation requiring environmental review and management programmes should provide the necessary protection.

WATER QUALITY

3.39 Under changed land use conditions, chemicals can be added to the groundwater from point sources such as landfill and industrial disposal sites, and from non-point sources such as septic tanks, road run-off, and agricultural chemicals and fertilisers. The low rates and infrequency of fertiliser applied to pine plantations present no potential groundwater quality problems. However, the drift of aerially-spread fertiliser may cause elevated nutrient levels within adjacent wetlands.

3.40 Changes to water quality are particularly important considerations on the coastal plain where the water table is generally shallow and where the sands have a low ability to adsorb or exchange contaminants. The main defence of the groundwater system is its ability to disperse and dilute contaminants. While the size of the resource means that any massive degradation is unlikely, groundwater contamination which does occur may be very expensive or impossible to remove. The contamination may take many years to flush out of the system and, in the meantime, the use of the resource may be severely restricted.

3.41 There are various examples of groundwater contamination or degradation on the Mound. Increased nitrate levels from septic tanks and garden fertilising are the most pervasive of these and have the greatest implications for wetlands. The possible effect of some long-lived insecticides and herbicides may also be important.

3.42 Some chemicals, such as phenols, heavy metals and organic compounds, even in minute concentrations, may introduce unacceptable odour or taste or be detrimental to public health. Consequently the location of public water supplies in areas not subject to urban, industrial or intensive rural use is desirable if the long-term quality of water supplies is to be preserved. Where the groundwater is being used for urban or agricultural irrigation, the same degree of constraint does not apply.

3.43 Existing waste and effluent disposal sites on the Mound are generally small, are monitored where required and do not pose a major threat to public water supplies or regional wetlands. Imminent development of a new major facility located near the coast at Mindarie will meet the waste disposal needs of the region for at least the next 50 years and limit any contamination to an acceptable area.

4 PLANNING AND MANAGEMENT

4.1 Increasing demands for groundwater, environmental conservation, and urban and other land development are making water resource management progressively more complex. It has become clear that decisions and activities in such matters as urban planning, forestry, main roads, horticultural development, industrial, commercial or extractive land use and wetlands conservation can have significant impacts on, or be materially influenced by, water resource management. However, these linkages have not yet been adequately reflected in institutional arrangements for planning and management of the land and water resources of the Mound.

WATER AUTHORITY

4.2 The Water Authority of Western Australia has a two-fold responsibility in planning and management of water resources:

- as the public water utility, it is charged with providing adequate volumes of high quality water to consumers at the lowest cost; and

- as the manager of the overall resource, it must ensure that development is compatible with protection of the productivity and quality of the resource, that allocation between users is in the best interests of the State and that environmental impacts are minimised.

4.3 The Water Authority has a commitment to long term forward planning at several levels including a State Water Plan, Corporate Development Plan and Sources Development Plan as well as plans such as the Gnangara Mound Groundwater Resources ERMP.

4.4 Groundwater Areas are established where management of the resource is required. Committees with local representation have been established to advise the Authority on water allocation and management within these areas (eg Wanneroo Groundwater Advisory Committee).

WATER RESOURCES COUNCIL

4.5 The Western Australian Water Resources Council provides advice to the Minister for Water Resources on general questions relating to water resources. Its objectives include:

- to co-ordinate water resource matters which influence other planning initiatives, particularly those relating to land use; and

- to prepare long-term strategies for co-ordinating the allocation and utilisation of water resources most effectively for all uses that have a benefit for the community, including public and private water supplies, conservation of the environment and recreation.

4.6 The Council has a number of Committees including:

- Planning and Management;
- Groundwater Management; and
- Conservation and Education.

The Council and its Committees have wide representation to ensure informed advice on diverse and complex water resource and land use issues. It has vigorously pursued its purpose and has undertaken a number of important initiatives. These include commissioning a study of groundwater management strategies and a study of water allocation and water use strategy options for the Perth to Bunbury Region. The latter includes a sub-project on horticultural demand for water and land.

STATE PLANNING COMMISSION

4.7 Land use is controlled by the State Planning Commission primarily through the Metropolitan Region Scheme and local Town Planning Schemes. Provision is made for input from other bodies, including the Water Authority, in the planning process. The Commission, through its influence on land use, has the potential for major impacts on the groundwater resources of the Mound.

4.8 The Commission is currently undertaking a major review of the Corridor Plan and Metropolitan Region Scheme which have guided development since 1971. A document describing the main options for metropolitan development is expected to be released for public comment by mid-1987. A range of scenarios is being considered to accommodate an expected population of around 1.6 million by the year 2021. It seems likely that more concentrated forms of development will be favoured with thickening of the existing corridors and some urban infill at the base of the rural wedges. Despite efforts to reverse the decline in population in the inner metropolitan areas the best that can be hoped from planning initiatives is that population of inner areas can be maintained at existing levels.

4.9 Key issues considered in developing alternative scenarios have included the need to provide affordable housing for all sections of the community, protection of water resources, preservation of vegetation and heritage values, provision of adequate regional open space, waste disposal, forestry and agricultural activities, energy conservation, the role of rural wedges and the possibility of significant climatic change.

4.10 The main implications of these issues for land use on the Mound are:

- there will be continuing rapid growth of population in urban areas on the southern and western flanks of the Mound;

- the Mirrabooka wellfield area may become urbanised, like that of Gwelup;

- the wetlands, natural bushland and pine plantations will become even more important as recreational areas for urban residents;

- agriculture will become a "dominated" use, giving way to urban development as markets for land evolve at the metropolitan fringes. In the long term, some water may become free for re-allocation as market gardens leave fringing areas and are replaced by urbanisation;

- no major industrial development appears to be likely on the Mound, but some mining claims are expected to be developed;

- the status of State Forest 65 as a strategic regional feature, is not expected to change;

- large remnants of native vegetation on Crown Land may be consolidated into a continuous system of regional parks and vegetation complexes; and

- protection of wetlands, especially ephemeral swamps, will become increasingly difficult but regulation, land planning and management of development can assist.

4.11 In the current review the Mound had been assigned a low level of land use constraint against urban development and this had been applied to only the area above the 30 metre groundwater contour. This contrasted with the highest level constraint against urban development designated for surface catchment areas. Overseas experience has shown that, despite introduction of controls, urbanisation over groundwater catchment areas would inevitably threaten the resource as, over a period of time, nutrients, and toxic discharges enter the unconfined aquifer. A higher level and more appropriately defined land use constraint has now been assigned to the Mound water resources.

4.12 The emphasis of the review has been on urban development. In future, there will be a need for more regular review of regional plans from a wider perspective, particularly in view of the expected pace of development and the complex relationships between land uses and the major groundwater resources of the coastal plain.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

4.13 Over much of the Mound, the principal land planning and management agency is the Department of Conservation and Land Management (CALM). This Department operates State Forest 65 within the guidelines set out in the General Working Plan of 1982 and a Timber Strategy which is currently in preparation.

4.14 CALM has three main areas of responsibility on the Mound:

. planning and management of State Forest 65;

. management of wildlife; and

. management of conservation reserves.

4.15 The State's timber supply strategy relies heavily on pine production over the next 25 years. However, though the existing stock of maturing trees contains valuable logs, the Pinus pinaster plantations of State Forest 65 are stated not to be strategically critical to long term timber production plans.

4.16 Pinaster pines were first planted at Gnangara in 1918 to provide import substitution and to find a profitable use for the Bassendean Sands system. Research addressed and overcame problems of nutrient supply, genetic selection and land preparation. Plantings rose from around 500 hectares per year in the 1945-60 period to about 1 000 hectares per year in the 1960s. Pines now cover about 50% of State Forest 65. Clearing of native vegetation and planting of new areas of pines has almost ceased.

4.17 Successful pine growth in State Forest 65 depends on soil-water-plant relationships. A substantial proportion of earlier plantings produced poor trees due to inadequate site selection and poorly controlled seed stock. Land within the Bassendean system that would be suitable for pine planting was later identified by site-vegetation mapping which essentially differentiated zones of different soil moisture conditions. The early trial and error plantings can be seen today as areas of poor-quality trees, particularly in upland areas and areas prone to water logging. Until the 1970s there was no concept of large scale groundwater abstraction, and no account was taken of this possibility in planning.

4.18 As a result of this history of State Forest 65, a 40-year pine cropping cycle with sustained yield has yet to be achieved. A viable sawn timber industry requires at least 55 000 cubic metres per year of logs covering the full range of saw log sizes. At present only 34 000 cubic metres per year of small to medium sized saw logs are available. The higher level of production will be attained within five to ten years. Because considerable areas of pine have only recently been planted, the first cropping cycle will continue for another 40 years.

4.19 Following changes in policy and priorities, and also in silvicultural practices, State Forest 65 is now managed with conservation and water

production as principal objectives. The strategy for timber production can generally fit in with this, but some silvicultural requirements still have to be met: for example, all plantations need the competition of densely planted trees in the first 15 years in order to produce straight stems. Heavily thinned, closely managed pines seem to be the best form of catchment management for the area. Broadscale heavy thinning or even clear felling the pines over a few years is plainly uneconomic and not needed. It would be expensive not to do this and some viable alternative land use would have to be found.

4.20 At present the main obstacle to economic operation of State Forest 65 for the primary purpose of water production is the lack of a local market for some types of pine thinnings. While the cost of non-commercial thinning may only be in the order of $150 000 per year for several years this expenditure would be offset by receipts if a market could be established. If this is not possible in the near future it will be necessary to plan and implement a programme of non-commercial thinning where benefits to sensitive environmental areas would result. One example of this is the plantation immediately east of Lake Jandabup where stand densities are high and the Water Authority has virtually ceased pumping from three production wells to ease pressure on the adjacent wetlands.

4.21 It appears that the next decade will be a period of much greater harvesting activity. Also, many younger stands will be thinned, hopefully with some commercial return. This increase in forestry activity will coincide reasonably well with increasing abstractions of groundwater by the Water Authority and market gardeners. The evolving management of State Forest 65 will then seek to yield a level of recharge at least as high as that of native vegetation.

4.22 CALM planning and management recognises other multiple-use benefits of State Forest 65, including recreation (eg walking, trail bikes, horse riding, gun clubs), and isolated sites for various public utility installations. This approach is endorsed by the City of Wanneroo. Conflicts between forest management and recreational use via fire risks can be overcome. State Forest 65 also contains large areas of native vegetation where prescribed burning and other management activity occurs as part of forestry operations.

4.23 Approval of the ERMP would clear the way for CALM planning to proceed. It is currently developing an economic model which, for given assumptions about tree growth, management regime, recharge, recreational use, market parameters and forestry costs, will optimise social return. Finalisation of an economic model should be given a high priority, as it will determine the possibilities for strategic change within future plantation management. There is a need to produce detailed land use management plans for State Forest 65 as a matter of priority.

4.24 In view of the strategic importance of the large remnants of natural vegetation on the Mound, and the possible impacts of water resource development on wetlands, there is a need to produce detailed management plans for conservation reserves and adjoining areas outside State Forest 65. It is understood that the management plan for the northern forest recommends that Management Priority Areas within State Forest 65 should be changed to A Class Reserves. Other major areas of native vegetation in State Forest 65 could form extensions to these areas and possibly compensate for environmental impact which may occur elsewhere. A Class status may reduce the freedom of the Water Authority to undertake some activities in these areas.

ENVIRONMENTAL PROTECTION AUTHORITY

4.25 The Environmental Protection Authority (EPA) is responsible for assessing all developments that have environmental implications. The Gnangara Mound ERMP has been submitted as a part of this process. In the past, not all developments with an environmental impact have been referred to, or considered by, the Authority. Broad scale planning policy and continued clearing of native vegetation in State Forest 65 are just two significant examples. Under new environmental legislation all proposals with a significant impact on the environment are required to be referred to the EPA. This legislation also brings control of all pollution of land or water, including groundwater, under the Environmental Protection Authority. In view of its requirement for water protection, the EPA has delegated its pollution control licencing provisions to the Water Authority.

4.26 In 1977, as part of its environmental protection role, the Department of Conservation and Environment (now EPA) published guidelines for protection and management of wetlands, based on general principles. The objective was to inform planners, local authorities and land owners about desirable approaches to land use if surviving wetlands were to be conserved. In December 1986 the EPA produced draft guidelines specifically for wetlands in the Perth region. Key objectives are to assist in identifying the attributes and ecological functions of particular wetlands and to provide directions as to management priorities. However, there is currently no ongoing, formal framework within which the EPA can offer advice about emerging issues of wetlands planning and management.

LOCAL GOVERNMENT AUTHORITIES

4.27 Local government authorities, through their town planning schemes and other activities, have the capacity for considerable direct and indirect impact on groundwater resources. Much of the area of the Mound in which horticultural and public supply schemes are located falls within a single local authority: the City of Wanneroo (ERMP Figure 10). The City, through its Town Planning Scheme, is working towards the development of a rural land use policy. Other influences on land planning include local authority by-laws and other powers under the Local Government Act. Water Authority restrictions on groundwater use, and policies on main drainage and sewerage, also influence land use decisions by the City of Wanneroo.

DEPARTMENT OF AGRICULTURE

4.28 Agricultural production is a highly fragmented activity and there is not the same level of integrated planning and management as for other land use activities on the Mound. While the Department of Agriculture does play a part, its role has been primarily one of undertaking technical research and providing advice to individual farmers. However, in recent years the Department, through its Marketing and Economics Branch, has paid increasing attention to the questions of future demand, value, and transfer of irrigation water for horticulture.

MINES DEPARTMENT

4.29 The Mines Department is involved in exploration of the resources of the region including groundwater resources. It also has an administrative and regulatory role in relation to commercial mining proposals and operations.

INTEGRATION

4.30 As outlined, planning and managing the land and water resources of the Mound involves various Government agencies with State-wide responsibilities, and other local agencies. The timing of major policy reviews, detail of policy assessment, and technical approaches differ between agencies. For example, water resource development has been assessed largely on the basis of cost effectiveness within the framework of the Water Authority Sources Development Plan. Conservation planning has proceeded mainly through a growing inventory of characteristics of areas with conservation significance, as in the System Six Study. Urban planning has tended to follow the principle of fitting projected needs into the landscape by sieve mapping within the general framework of the Corridor Plan.

4.31 To date, metropolitan planning has tended to accommodate the requirements of water resources planning and wetlands conservation by rough and ready inclusion of the implied constraints without detailed evaluation of the trade-offs involved nor with a specific objective of protecting potable water resource. As the urban area expands into the Mound area, such evaluation will be harder to avoid in future, regardless of whether the trade-offs are to be considered in physical, biological, economic or social terms.

4.32 Consideration must be given to appropriate organisational arrangements to achieve integration of planning and management within the Mound area. These will be needed on a long term basis. At least the following agencies should be involved:

. City of Wanneroo;
. Department of Agriculture;
. Department of Conservation and Land Management;
. Environmental Protection Authority;
. Mines Department
. State Planning Commission; and
. Water Authority.

Representation of other selected local authorities may also be desirable in future.

4.33 An initial integrating mechanism, with little or no additional direct expenditure implications, would be to establish a Gnangara Mound Planning and Management Committee of senior representatives from each of these organisations under the auspices of the Western Australian Water Resources Council and drawing on the various agencies for resources as required. The role of the Committee would be to provide a framework within which each organisation can develop and implement policies, plans and programmes for its area of responsibility, and to facilitate more effective working relationships.

4.34 Responsibilities of the Committee could be:

(i) develop and co-ordinate integrated planning and management by the various agencies involved;

(ii) monitor and report on the implementation of both individual agency and overall plans;

(iii) advise on research and investigation priorities; and

(iv) promote community participation in planning and management.

4.35 The proposed Committee could operate under the auspices of several existing organisations, including the State Planning Commission and the Environmental Protection Authority, and there is no clearly preferable option. The Water Resources Council is proposed, initially at least, because of its effective and vigorous efforts to identify and resolve inter-related water resource and land use issues.

5. WATER ALLOCATION

EXISTING MECHANISM

5.1 In allocating water, three separate purposes (economic efficiency, social equity, and environmental protection) are often confused but need to be distinguished. Social equity considerations dominate the existing allocation mechanism, which is administrated by the Water Authority within the legislative framework of the Rights in Water and Irrigation Act and the Metropolitan Water Supply Sewerage and Drainage Act.

5.2 Perhaps the most important aspect of groundwater law in Western Australia is that rights to water are vested in the State. Water rights do not form part of any title to land. However, until recently, the State has seldom practised its water allocation policies in a manner that would emphasise this legal situation. Thus, for example, expansion of horticulture on the Mound was initially based on what amounted to common property access to groundwater.

5.3 Exploratory drilling in the 1960s and the declaration of the Gnangara Water Reserve in the early 1970s signalled the State's long term interest in the resource. The water reserve covers the whole of State Forest 65 and large areas of Crown and Commonwealth Land to the north and east. It forms a statutory basis for long term co-ordination of developments so as to protect the water resource.

5.4 The Swan and Gingin Groundwater Areas on the south eastern and north eastern margins of the Gnangara Water Reserve have been established to deal with allocation between private users. There is no significant public abstraction within these areas.

5.5 Development of the Mirrabooka, Gwelup and Wanneroo Groundwater Schemes during the 1970s involved proclamation of Public Water Supply, Underground Water Pollution Control and/or Groundwater Areas. These give the Water Authority powers to:

- abstract groundwater found in the area;
- licence private use;
- place conditions on licences and issue instructions to licencees;
- suspend, amend or revoke licences;
- install meters on private wells;
- control polluting activities through by-laws; and
- prosecute offenders.

5.6 Gwelup and Mirrabooka Schemes have not led to major conflict and there has been no need to invoke most of these powers. Proclamation of the Wanneroo Groundwater Area in 1982, and its extension in 1986, has led to concern on the part of the rural community that its access to groundwater would be restricted. In fact, overall, restriction has not occured. Indeed a 50% expansion of the total allocation for private use is proposed.

5.7 Environmental factors have been included as part of the determination of quotas. Within the Wanneroo Groundwater Area, the principal quota has been subdivided and these specific quotas have taken account of proximity to wetlands and the relationship of the groundwater flow and wetland. In one part of the Wanneroo Groundwater Area (the eastern margin of Lake Jandabup) the full quota has now been allocated so some people are unable to obtain groundwater, other than for domestic purposes, or to increase their use. In some other parts of the Area, allocations are approaching the quota.

5.8 The Wanneroo Groundwater Advisory Committee provides advice to the Water Authority on water allocations to private users in the Wanneroo Groundwater Area. The Wanneroo Committee includes local community representation. Decisions of the Water Authority based on the advice of the Committee are subject to appeal to the Minister for Water Resources: this has occurred on three occasions. In time, other advisory committees may need to be set up within the Mound area.

ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS

5.9 For economic efficiency, water should be allocated according to its value to users. According to this principle, the uses with the least economic value would be the first to be reduced in conditions of local or regional water scarcity. Also, water abstraction would never take place unless somebody was prepared to pay the costs. Willingness of each user to pay the cost of supply would be the criterion for water allocation.

5.10 Where the level of water abstraction resulting from free market forces exceeds some safe environmental level, possible courses of action include:

- setting a quota limiting abstraction to the safe level; and
- imposing a resource rental tax which yields a level of water use which is consistent with environmental protection.

5.11 Currently, allocation of Gnangara Mound water is based on quotas. While this provides an effective mechanism for controlling the spatial distribution of abstraction, it assumes that the overall allocation between major user groups is "correct". Within the private sector, concerns include defining the criteria of allocation both overall and to individual applicants, reallocation where area quotas are fully allocated, and insecurity regarding future water availability.

5.12 Mechanisms for water transfer between private rural users pose problems in groundwater management. Uncontrolled transfers may lead to spatially concentrated withdrawals with effects on other users, quotas may still be needed in drought periods, and hoarding of water "rights" may occur in conjunction with land speculation. On balance, at this time, there appears to be limited potential benefits from a transferable water right system between private rural users on the Mound.

5.13 The ERMP assumes that abstraction will continue to be determined by quotas. Within this system there is little economic justification for additional imposition of environmental charges on private water users located on the Mound since the charges would redistribute income rather than changing pumping rates or environmental effects. While environmental monitoring and forestry operations should be taken into account in public water supply costing and pricing, the argument for environmental charges on private users turns solely on equity issues as long as the quota system applies.

5.14 As the total resource of the Mound is developed and allocated, further careful thought needs to be given to water pricing and allocation mechanisms.

6. ADEQUACY OF ERMP REPORT

STRENGTHS

6.1 The Gnangara Mound Groundwater Resources ERMP prepared by the Water Authority is a most comprehensive and effective document. For the first time it provides baseline data and a starting point for expanding or establishing management principles for a natural region comprising an important part of the Swan Coastal Plain.

6.2 The ERMP is a significant compilation of existing information as well as containing results of some new work. Nevertheless, there are some large deficiencies in information mainly concerning ecosystems and their importance and inter-relationships.

6.3 The ERMP does not seek to maximise groundwater abstraction for public water supply but to allocate the groundwater between all users consistent with constraints imposed by the size of the resource and the environment. It is a balanced, practical effort to plan and manage within known deficiences in knowledge, and should be judged accepting these limitations.

6.4 The model used to predict the likely impacts is very sophisticated and is the best available tool for assessing regional groundwater level changes under varying climatic, land use and groundwater demand situations. Model development and data uptake took about ten person years. The model outputs should be regarded as a reliable guide to likely effects except that in most cases they represent "worst case" situations. In judging the environmental acceptability of predicted water level declines, the estimated model error of up to 0.5 metre should not be added to the model predictions. This would be excessively conservative and may result in distorted decision making.

6.5 The management philosophy and four-stage management strategy described in the ERMP embody the Water Authority's experience in groundwater management. The approach proposed is based on the premise that management should be introduced to avoid problems, rather than to manage problems once they have arisen. It is conservative and if followed should ensure safeguards for water users and the environment.

6.6 The management programme proposes to continue monitoring groundwater levels in some 900 existing observation wells and also continuing or initiating monitoring at a number of selected wetlands. On-going water level monitoring is considered to be essential.

6.7 The brief annual reports, complemented by more comprehensive triennial reports, on the operation and impact of the existing groundwater schemes are considered an appropriate way of accounting to the Environmental Protection Authority and of disseminating information. The frequency of the reports will enable any changes to operations, monitoring or management as required. In addition there is a need for broad overviews of the Mound to be made about once every five years, and when new groundwater schemes are planned or other major land use changes are proposed.

SHORTCOMINGS

6.8 While the Water Authority has funded considerable research, and other work has been done by CALM, the Environmental Protection Authority and others, knowledge of the biological environment is deficient. There has been inadequate mapping of flora; identification and listing of vertebrate and invertebrate species is incomplete; and relationships between and within ecosystems are inadequately understood. A comprehensive long term programme of biological study should be developed and priorities set so that research is co-ordinated and directed to the most important issues first.

6.9 This work, which will require the effort of both botanists and specialist biologists, should have an initial focus on the area affected by the Pinjar Scheme. The work could be supported in part by the Water Authority, co-ordinated by CALM and carried out using private consultants or by supporting appropriate university research. It will require a research programme of at least five years.

6.10 Lowering of the water table and its consequent effect on water levels in the wetlands has an effect on water quality within the wetlands. There is little information in the ERMP concerning this aspect, yet its implications for wetland fauna may be substantial. Specific water quality data for monitoring vegetation and fauna should be discussed with experts. The main need appears to be for a wider geographical spread of sampling rather than a more extensive range of chemical analyses.

6.11 Consideration needs to be given to overall funding arrangements for Gnangara Mound environmental research and management. While it is reasonable for the Water Authority to bear some of the cost, particularly for work directly related to water supply and water resource management, it should not be required to fund all investigation work, much of which arises out of the land and water use activities of others.

6.12 Discussion of the groundwater model is too brief. Reports in preparation should largely alleviate this problem.

6.13 Adequate management of the groundwater resources is dependent on modelling capability but the ERMP contains no commitment to maintain and improve modelling. A commitment is required from the Water Authority that the model will be maintained and appropriate personnel will be available for its operation and refinement. As part of the detailed planning of each future scheme, a model should be developed to allow the local effects to be better defined, monitored and managed. This information will complement the regional perspective obtained from the Gnangara Mound model.

6.14 The relationship between the unconfined groundwater of the Mound and the confined aquifers needs more assessment to confirm the extent to which lowering of the water table will reduce recharge to the confined aquifers and pumping from the confined aquifers will affect the water table. Because

the intake areas of the confined aquifers occur mainly beneath the upper part of the Mound, where only small lowering of the water table is predicted, there is unlikely to be any significant reduction in recharge. Also, because the confined aquifers are thick and composed of interbedded sandstone and siltstone, drawdown effects will be largely taken up by leakage and slight compression of the aquifer. Any effects on water table levels of pumping from the confined aquifers will be propagated over most of the intake area and will be very small and probably not detectable. These expectations need to be confirmed by further study.

6.15 ERMP Figure 22, which shows the basal area of pines in State Forest 65, is out of date and has been superceded by information gathered by CALM since the report was prepared. However, the ERMP information was not used directly as input to the predictive model and thus its results are not affected. Basal areas of pine plantations need to be regularly and systematically monitored by CALM.

6.16 Information about the location of the various rural activities, and statistics about crops and their water use are a deficiency in the report. There is scope for the Department of Agriculture to have a stronger role in this area. A report being, prepared by consultants for the Water Resources Council may help clarify and focus on factors affecting rural activities.

6.17 The report does not provide an overall map or statistical summary of land use on the Mound. The Metropolitan Region Scheme map is too broad-scale to identify all land uses, particularly horticulture, and covers only part of the area. The City of Wanneroo carries out a detailed annual survey which would provide much of the data required.

6.18 Numerous reports and papers on aspects of monitoring and management will be generated. A computerised data base of these and of previous work needs to be established. Whenever possible, this information should be available to the public.

6.19 Undertaking all the work required to overcome present information deficiencies, will take years. In the meantime the practical reality is the need to meet demand for water supplies with minimum environmental impact.

7. FUTURE DEVELOPMENT OF THE MOUND

GENERAL

7.1 Assuming that population increases as predicted, urban expansion occurs along the North West Corridor and all the proposed groundwater schemes are developed, then the groundwater resources of the Mound will be largely committed within 25 years.

7.2 A likely and most desirable scenario is that most of the Mound will continue to be protected by State Forest 65 and adjoining native vegetation. This will depend on planning decisions affecting State Forest 65 and large areas of Crown land on the eastern side of the Mound which together comprise the Gnangara Water Reserve.

7.3 Every water development project has environmental impacts and a balance must be found between:

- maintaining ecological processes, preserving genetic diversity and ensuring sustainable utilisation of species; and

- the need to provide for the essential economic and social needs of individuals and society.

Forcing the development of surface water resources or more remote groundwater resources merely transfers the environmental impact to possibly more sensitive areas.

7.4 Many of the possible problems and conflicts which may be associated with development of the Mound will not occur for many years and will arise progressively. Accordingly, it is important not to make decisions or take actions earlier than is necessary for operations to proceed. To do so would forego the benefits of reduced uncertainty, and increased knowledge that will be available as the result of further research and investigation.

7.5 Furthermore, some decisions and actions associated with groundwater development and management are reversible. This is particularly true of private and public abstraction. Where unforeseen consequences arise or impacts are greater than predicted, there is scope, at a cost, to take remedial action with the expectation that wetlands will recover. An example of this is the decision to virtually cease pumping from three Water Authority wells on the eastern margin of Lake Jandabup.

7.6 Significant climatic change has been predicted over the decades ahead and if this occurs it may have important implications for land and groundwater use on the Mound. No specific action in anticipation of this possibility is considered appropriate at this time.

7.7 The model predictions are for a situation occurring more than 30 years from now. Lowering of the water table is likely to be less than predicted. Furthermore, the only scheme proposed to be constructed in the next ten years is the Pinjar Scheme. By the time it is operating, more complete information will be available about the performance of the aquifer and about the ecosystems. This will permit refinement and modification of development proposals and management strategies.

EFFECTS

7.8 The groundwater schemes, private abstraction, forestry, and bushland cover described in the ERMP are expected to result in a regional decline of the water table of 0.5-2.5 metres parallel to the wellfields (Figure 2). The greatest water level decline is expected to occur in an upland area to the north west of Lake Pinjar where there will be little or no impact on vegetation. This effect may be less than indicated if horticultural activities become more dispersed than the ERMP assumed.

7.9 Lake Pinjar is an extensive plain of originally swampy land that has been dry for many years; some wetland areas remain, particularly on the eastern margin. The model results indicate that with the exception of the Pinjar plain most wetlands which may be affected by lowering the level of the water table are within State Forest 65 and have already been considerably affected by clearing for and growth of pine plantations.

7.10 The conceptual wellfield layout proposed in the ERMP seeks to minimise effects on environmentally sensitive areas. Consequently, wetlands within areas recommended for reservation in the System Six Study will generally be

subject to minor water level changes. To some extent any impacts of development may be offset by an area of wetlands in the vicinity of the Wanneroo Scheme where the water table is expected to rise by up to 1.5 metres as a result of thinning the pine plantations (ERMP Figure 50).

7.11 While a range of alternatives has been investigated, more detailed consideration of the Yeal, Barragoon and Lexia Schemes, when they are due for development, may reveal variations that either increase sustainable yield or reduce environmental effects. For example, it may be desirable to modify the lines of wells in the proposed Yeal and Barragoon Schemes to avoid the Ridges and Wabling Management Priority Areas. This could include extending the Barragoon Scheme parallel to Gingin Brook. Some re-alignment of the proposed wells in the Lexia Scheme to intercept throughflow over a wider front may also be desirable.

FINDINGS

7.12 If public water supply development on the Mound proceeds along the lines proposed in the ERMP, and land use and water resource planning and management are integrated, then:

- good quality, low cost water supplies to meet growing urban demands will be assured;
- wetlands, National Parks and nature reserves will be afforded protection;
- State Forest 65 will become a viable source of softwood with the added advantage of providing some public amenities;
- rural water supplies will be secure subject to licencing; and
- groundwater supplies will continue to be available in urban areas.

8. THE PROPOSED PINJAR SCHEME

NEED

8.1 To satisfy demand for water in the rapidly expanding North West Corridor, the Water Authority must commission a new source by 1989. Current demand management initiatives are unlikely to reduce demand for water sufficiently to defer the need for additional supplies.

8.2 The Pinjar Scheme, the next stage of development of the groundwater resources north of Perth, is the Water Authority's least cost alternative for satisfying the projected demand arising from continuing population growth and urban development. Deletion of Pinjar from the sources development plan would cost $13 million at 1985 prices. Alternatives such as constraining growth in the North West Corridor, using treated effluent, pumping groundwater to surface storages in winter and developing other water sources are not considered to be sound on economic, practical and/or environmental grounds.

8.3 In arriving at a preferred option which reflects a balance between cost to the community and impact on the environment, the Water Authority has evaluated a range of variations to the Pinjar Scheme. The proposed scheme comprises a line of wells on each side and extending north of the Pinjar

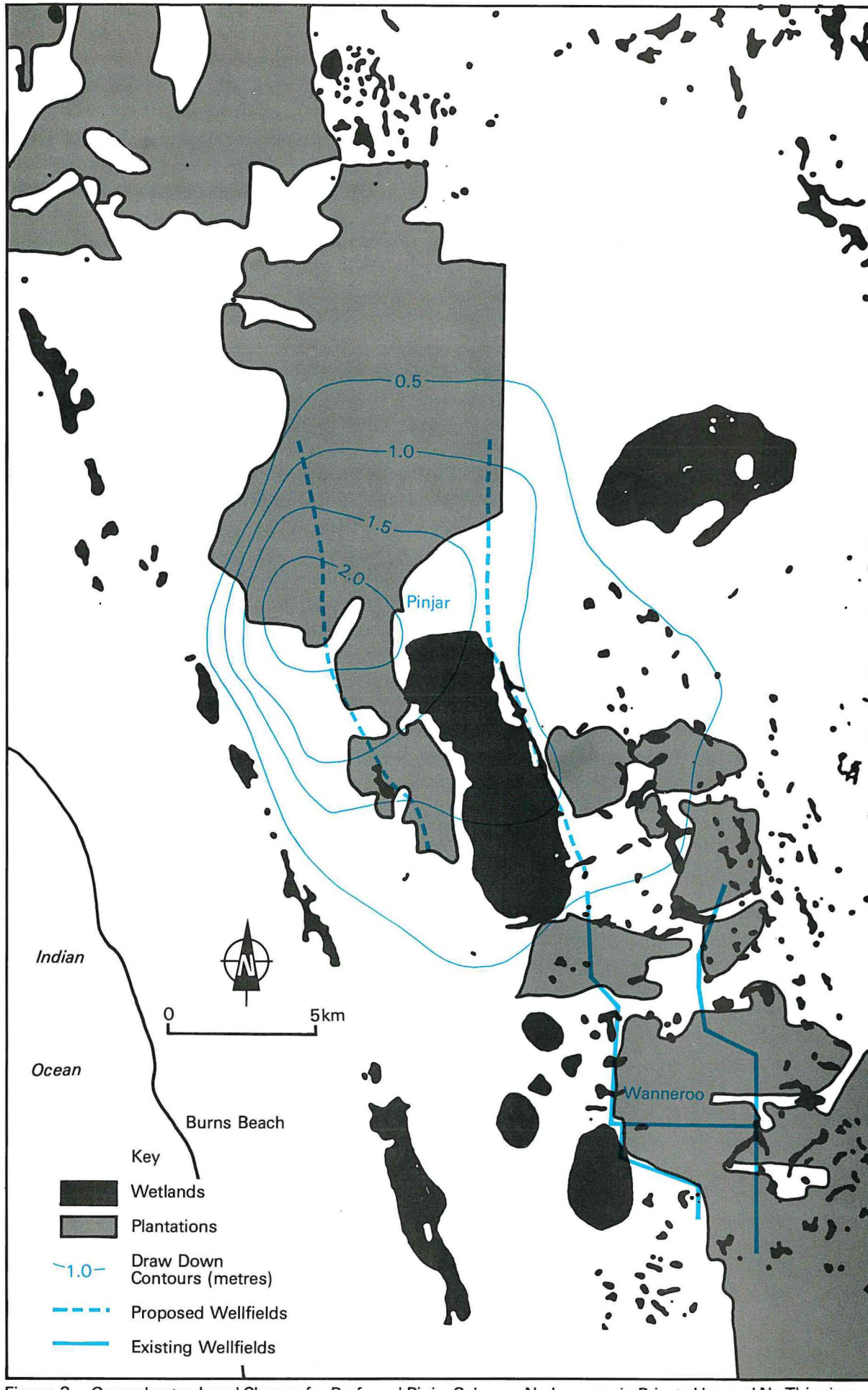

Figure 3. Groundwater Level Change for Preferred Pinjar Scheme, No Increase in Private Use and No Thinning of Pines.

plain. Of the ultimate Scheme yield of 32 million cubic metres per year, the unconfined aquifer will supply 14 million cubic metres per year with the balance coming from the confined aquifers.

8.4 Development will occur progressively with the first stage due for completion in 1989 and the last in 1997. The mix of aquifer development for each stage has not been finalised and is partially dependent on testing of the quality of water from the confined aquifers. However, it currently provides for concurrent development of the unconfined and confined aquifers to allow monitoring of the effects of abstraction from each resource.

EFFECTS

8.5 Pumping of groundwater from the confined aquifers will have negligible effect on water levels in the unconfined aquifer. Pumping of water from the unconfined aquifer will lower water table levels (Figure 3 and ERMP Figure 44). Much of the decline in water levels will occur under areas of pine plantation or upland native vegetation where the environmental impact will be acceptable, and beneath Lake Pinjar itself. Some water level change is also predicted in the vicinity of the linear lakes to the west and some ephemeral wetlands to the east.

8.6 To reduce the potential effect on the linear lakes (Carabooda, Nowergup and Neerabup), the Water Authority proposes to reduce the pumping originally planned from the southern half of the western line of wells by two-thirds and to increase abstraction from the eastern line of wells. This modification, together with management of private abstraction and pine plantation densities in the area, will reduce the water level decline in the vicinity of the linear lakes with little additional impact elsewhere. The characteristics of the linear lakes are such that the predicted decline in the water table level on their eastern margin of 0.5 metres is considered to be environmentally acceptable.

8.7 The Pinjar plain is a large area of freehold land bounded to the west, north and south east by State Forest 65. Most of this land has been cleared for agriculture. The hydrogeology of the area is complex and the depth to the water table varies from zero to some 3 metres from east to west. The reduction in water levels beneath Pinjar as a result of pumping from the scheme are predicted to range from 0.5 metres in the south to 2 metres in the north.

8.8 Pinjar was identified as a conservation area in the System Six Study but was rated lowest in priority for reservation. While the environmental value of Pinjar is difficult to assess, parts of it have value as a wetland ecosystem. Some impact on these areas can be expected. Conversely, the swamp gum woodland developing on the south western side may in fact expand with a slight lowering of the water table. With the limited knowledge available it is not possible to predict the full implications of the predicted water level changes. Because it has been heavily degraded over the years, further modification to the preferred Pinjar Scheme that would increase environmental impacts elsewhere as well as increasing the cost, is not advocated.

8.9 Drawdowns of up to 0.5 metres are predicted for some upper Mound swamps to the east of Pinjar. Many of these are within State Forest 65 and have been affected by plantation development. With the gradual drawdown expected at this distance from the Pinjar wells, the impact on these ephemeral wetlands will be a move towards plants that are more adapted to drought conditions. There will be no detectable effect on the wetlands of Melaleuca Park.

8.10 Plants may adapt to the changing water table if their root systems are given a chance to adjust over a period of time to changed soil moisture levels. Recognizing that there will be some impact in the Pinjar area, and that there is a more significant impact if the water table is suddenly dropped, pumping should be introduced gradually.

FINDINGS

8.11 On balance the proposed Pinjar Scheme should be approved subject to the management commitments given in the ERMP, comments made in this report and, in particular, on condition that:

(i) the Water Authority develops, within 12 months, a model to allow the local effects of the Pinjar Scheme to be better defined, monitored and managed;

(ii) the Department of Conservation and Land Management formally agrees to thin the pines in the vicinity of Lake Pinjar to stand densities with recharge equivalent to native vegetation, as required by the Water Authority;

(iii) private abstraction in the Wanneroo Groundwater Area north of Flynn Drive does not exceed 15 million cubic metres per year unless further monitoring and modelling shows the impact on water table levels to be acceptable;

(iv) the Water Authority and the Department of Conservation and Land Management, in conjunction with the Environmental Protection Authority, prepare a long term programme for assessing and monitoring environmental impacts in the area; and

(v) the unconfined and confined aquifers are developed concurrently to provide some capacity for managing water table declines under severe drought conditions.

9. CONCLUSIONS

9.1 The Gnangara Mound is a major water resource in the Perth region. Management of this resource and associated land uses is essential if the maximum sustainable benefit is to be derived for the whole community. To achieve this, there is an urgent need to establish a body for integrating planning and management on a regional basis. A Committee of the Western Australian Water Resources Council is recommended.

9.2 The ERMP is a most comprehensive and effective document. Nevertheless, there are some large deficiencies in the information available mainly concerning ecosystems and their importance and inter-relationships. These deficiencies can be overcome by a programme of research and investigation.

9.3 The long term strategy proposed in the ERMP provides a reasonable balance between the needs associated with development, and conservation of the environment. If this strategy is implemented within a framework of integrated land use and water resource planning and management, then:

. good quality, low cost water supplies to meet growing urban demands will be assured;

- wetlands, National Parks and conservation areas will be afforded protection;

- State Forest 65 will become a viable source of softwood with the added advantage of providing some public amenities;

- rural water supplies will be secure subject to licensing; and

- groundwater supplies will continue to be available in urban areas.

9.4 The commitments given by the Water Authority are a sound basis for the management of the complex issues arising for water resource and land use developments. However, there is a need to formalise commitments from other organisations and to develop more specific programmes and plans to put various commitments into effect.

9.5 Approval to proceed with the proposed Pinjar Scheme on a staged basis should be given, subject to the commitments in the ERMP and some additional specific conditions. Monitoring developments and impacts, together with on-going research and investigation, will enable corrective action to be taken, if required.

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