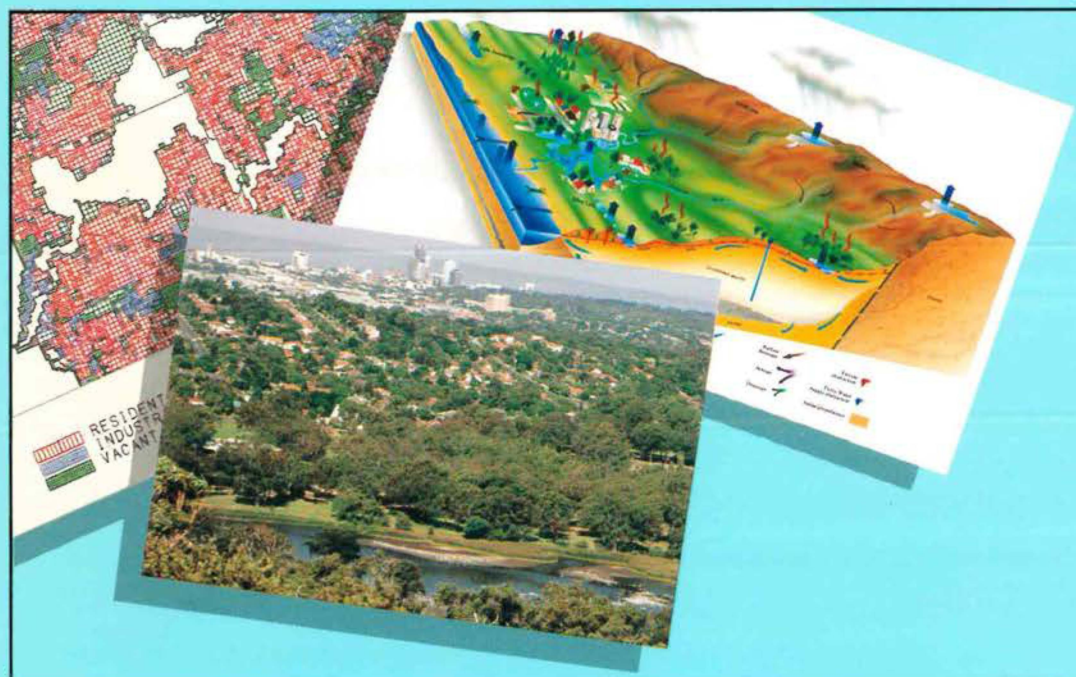
Water Authority
of Western Australia



PERTH URBAN WATER BALANCE STUDY

Executive Summary

May 1987

CENTRE FOR WATER RESEARCH
UNIVERSITY OF WESTERN AUSTRALIA

GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

DEPARTMENT OF CONSERVATION
AND ENVIRONMENT

Water Authority
of Western Australia

in conjunction with

Centre for Water Research
University of Western Australia

Geological Survey of
Western Australia

Department of Conservation
and Environment

PERTH URBAN WATER BALANCE STUDY

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

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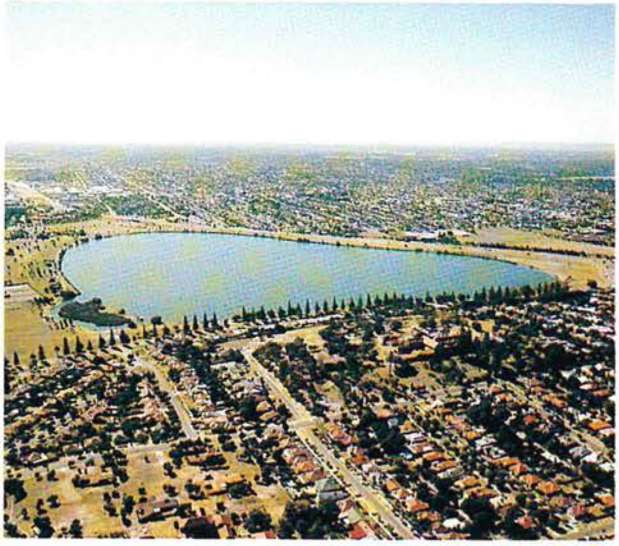
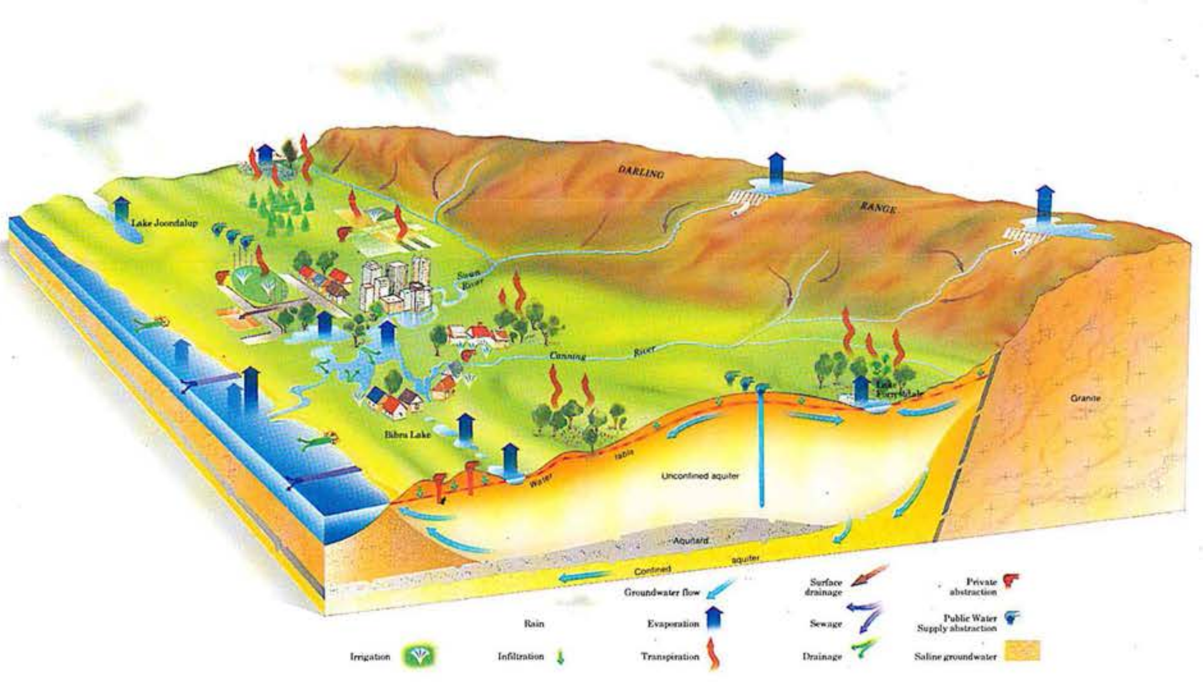
INTRODUCTION

The shallow groundwater underlying the Perth metropolitan area is a major water resource which meets a large proportion of Perth's domestic, irrigation and industrial water supply demands. This groundwater resource occurs in an unconfined aquifer which is formed by a superficial layer of permeable sediments beneath the Swan Coastal Plain. These superficial sediments occur as a thin veneer, about 60 m thick, overlying 13 000 m of sediments which contain confined freshwater aquifers to a depth of about 1000 m (Figure 1).

While forming an important source of water for man's activities, the shallow groundwater is also an integral part of the natural coastal plain environment, supporting vegetation where the water table is shallow and indigenous flora and fauna at the many wetlands where the water table intersects, or is just below, the ground surface.



Approximately 223 million cubic metres of water are withdrawn each year from the unconfined aquifer of the Perth region for private domestic irrigation, commercial irrigation, local government and institutional irrigation, industrial use and public water supply. Private domestic irrigation draws about 77 million cubic metres each year. Other private water supplies and irrigation utilise about 113 million cubic metres. Public water supplies



SWAN COASTAL PLAIN HYDROLOGY

Figure 1

provided by the Water Authority draw about 33 million cubic metres.

In the below-average rainfall years of the late 1970s, the quantities of groundwater being drawn by the Water Authority, for public reticulated supplies, increased markedly because of reduced availability from surface water resources. Water restrictions were also needed to reduce demand on surface water resources, leading to a significant increase in the number of private domestic bores and wells. There are currently about 77 000 domestic bores in Perth, plus other private bores used for irrigating market gardens and public open space and for industrial purposes. This extensive private development of the resource has formed a significant secondary water supply system, effectively reducing demand on the public water supply system.

The accelerated use of groundwater in Perth resulted in concern being expressed within the community that water table levels were being lowered, wetlands were drying up and bores in coastal suburbs were drawing more saline water.

In 1981, an investigation by the Water Authority concluded that this concern was justified but that practical management of the groundwater system in the urban area was feasible. The Perth Urban Water Balance Study was therefore initiated in June 1982 with the following objectives:

(i) to identify areas where the unconfined groundwater resource may be at risk;

(ii) to investigate the areas of greatest risk; and

(iii) to identify groundwater management options for risk areas.

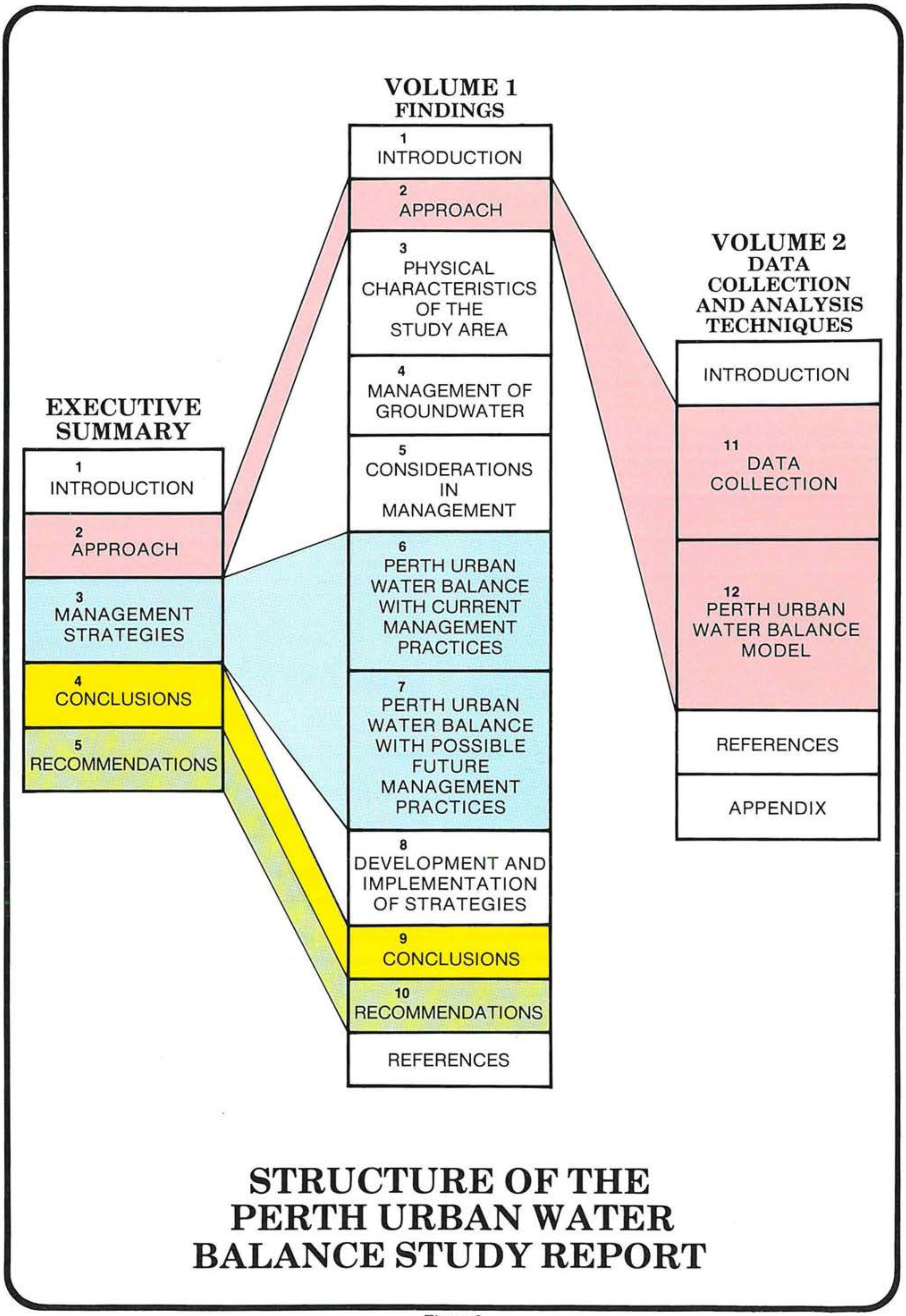
To cater for a broad range of readers, the outcome of the Study is reported in the following forms:

- this executive summary, which contains brief explanations of the findings and recommendations; and
- the full report, which presents, in two volumes, a detailed analysis of the methods, findings and recommendations.

Volume 1 of the full report provides an account of the groundwater systems and their need for management, including the conclusions and recommendations of this Study.

Volume 2 contains a full discussion of the techniques and methods used to derive the findings and recommendations of the Study.

Figure 2 is a diagrammatic representation of the contents of each volume and shows the relationship between the different parts of the report.



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STRUCTURE OF THE PERTH URBAN WATER BALANCE STUDY REPORT

Figure 2

2

APPROACH

It was recognised from the outset that effective groundwater management requires consideration of many issues, covering a number of disciplines and involving the responsibilities of many government and local government agencies. A multi-disciplinary team was therefore formed for the Study, comprising personnel from the Water Authority, the Centre for Water Research at the University of W.A., the Geological Survey of W.A. and the Department of Conservation and Environment[1]. Close liaison was also maintained with other government agencies and local government authorities.

STUDY AREA

A study area was defined comprising the Swan Coastal Plain from Moore River and Gingin Brook in the north to Warnbro Sound and the Serpentine River in the south (Figure 3). The shallow groundwater system within the study area is divided into three discrete and distinct groundwater flow systems by the Swan and Canning Rivers. These systems are known as the Gnangara Mound in the Northern Perth Area, the Jandakot Mound in the Southern Perth Area and the smaller Cloverdale Groundwater Flow System in the Eastern Perth Area.

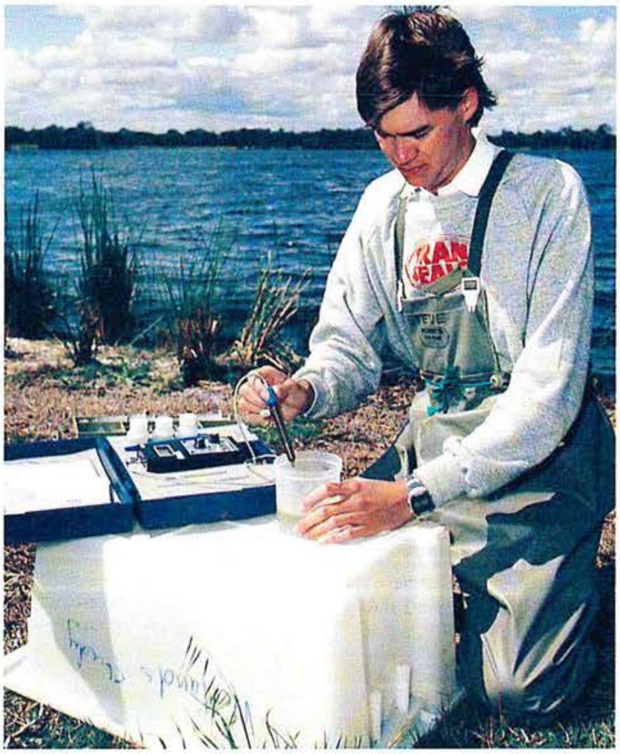
The study area extends to the hydraulic boundaries of the groundwater system. The conclusions and recommendations of the Study, however, relate to the existing and proposed urban areas within the Perth region.

AREAS AT RISK

To identify areas where the shallow groundwater resource may be at risk, it is necessary to understand and be able to predict the responses of the system to its various influences. These responses relate to water levels, water availability and water quality.

To understand the groundwater system, it was necessary to collect regionally synoptic groundwater level and groundwater quality data, and to assemble information on hydrogeology, climate, topography, land use and groundwater use. Considerable information was available from government departments and from earlier studies, and monitoring points were established to supplement existing monitoring networks to provide data on groundwater levels and groundwater quality. The data provided comprehensive regional information on the state of the groundwater system for the period from 1976 to 1985 and were used when evaluating groundwater responses to changes in climate, land use and groundwater use.

More intensive studies of the hydrogeology and the water balance in localised areas, such as Applecross, and of specific problems, such as saltwater intrusion, were also undertaken.



WATER BALANCE CONCEPT

The concept of a water balance is fundamental to the management of a groundwater resource. For a specific area and time interval, the water balance can be expressed as:

Change in water storage =

Sum of inflows — Sum of outflows.

Inflows include rainfall, groundwater inflow and artificially imported water from other sources (Figure 4). Outflows include evapotranspiration, surface drainage, sewage disposal and groundwater outflow. Change in storage is reflected as changes in the elevation of the groundwater surface or water table.

1. In February 1987, the Department of Conservation and Environment and the previously existing Environmental Protection Authority were reconstituted to form the new Environmental Protection Authority

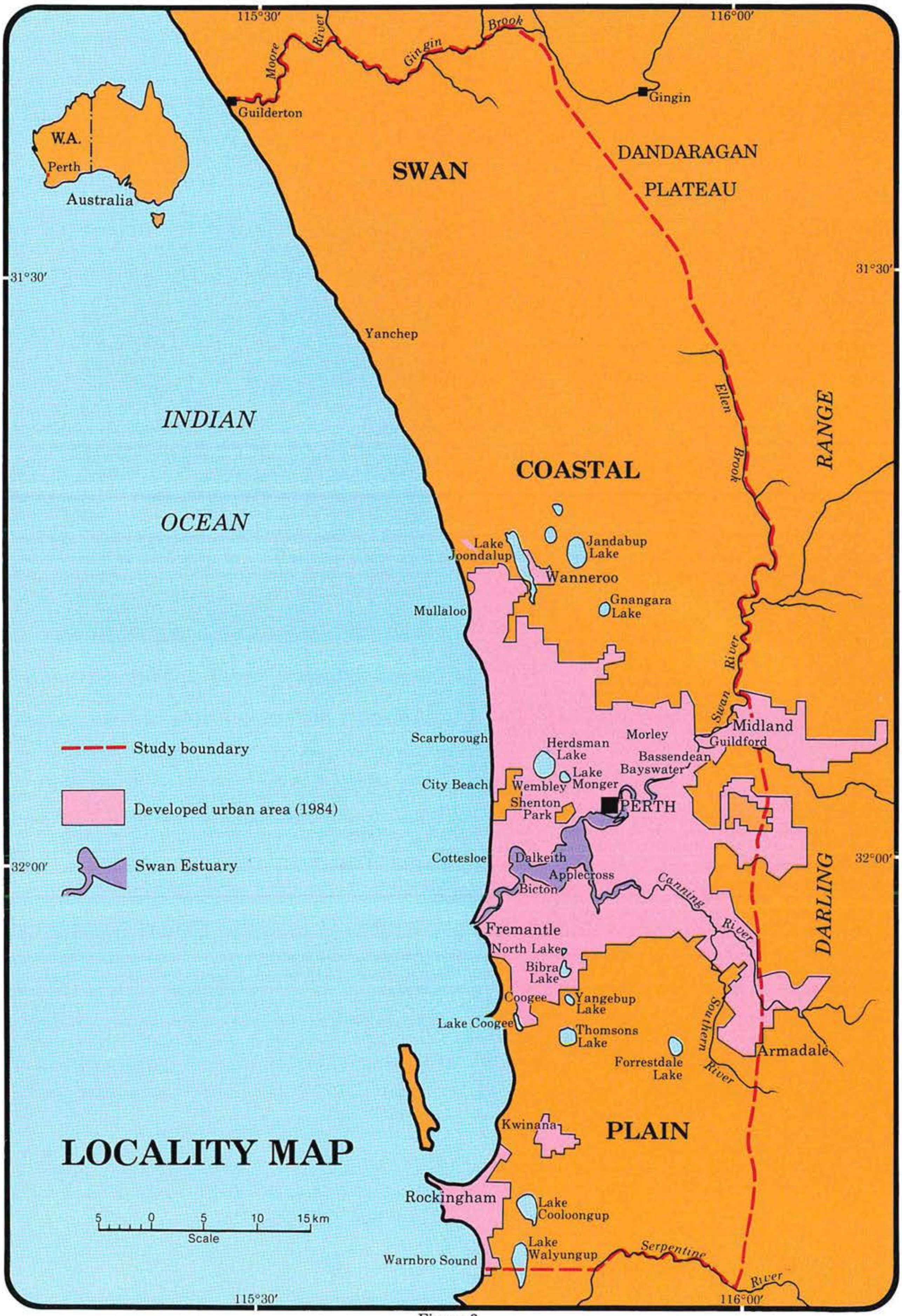

LOCALITY MAP
INDIAN
OCEAN
SWAN
COASTAL
PLAIN
DANDARAGAN
PLATEAU
DARLING
RANGE
W.A.
Perth
Australia
115°30′
116°00′
31°30′
32°00′
Moore River
Gingin Brook
Guilderton
Gingin
Yanchep
Ellen Brook
Lake Joondalup
Jandabup Lake
Wanneroo
Gnangara Lake
Mullaloo
Swan River
Midland
Guildford
Scarborough
Herdsman Lake
Morley
Bassendean
Bayswater
City Beach
Wembley
Lake Monger
Shenton Park
PERTH
Cottesloe
Dalkeith
Applecross
Bicton
Canning River
Fremantle
North Lake
Bibra Lake
Coogee
Yangebup Lake
Lake Coogee
Thomsons Lake
Forrestdale Lake
Southern River
Armadale
Kwinana
Rockingham
Lake Cooloongup
Lake Walyungup
Warnbro Sound
Serpentine River
Study boundary
Developed urban area (1984)
Swan Estuary
5 0 5 10 15 km
Scale

Figure 3

A major thrust of the study was the quantification of all components of the water balance for the three shallow groundwater flow systems within the study area. Because of the particularly complex processes associated with many of the water balance components, a number of intensive studies were carried out.

The result was a sophisticated computer model which can evaluate groundwater level variations caused by changes in climate, land use and groundwater use throughout the study area. The model is a detailed numerical representation of the processes within the water balance.

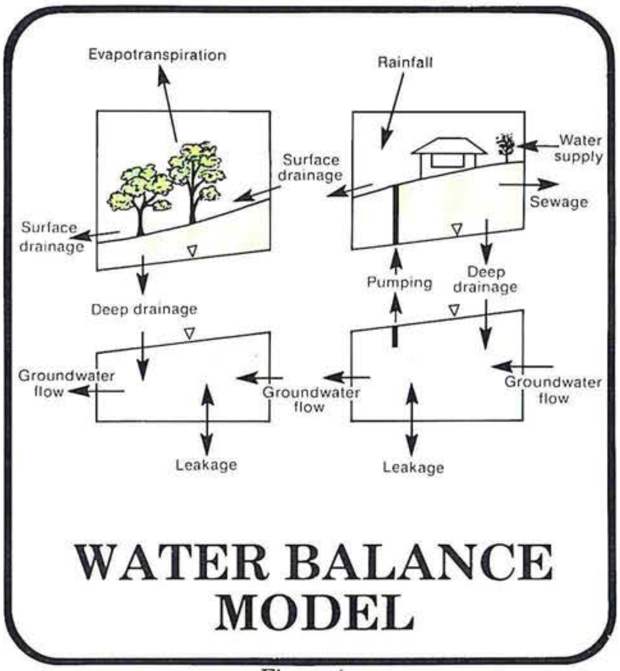


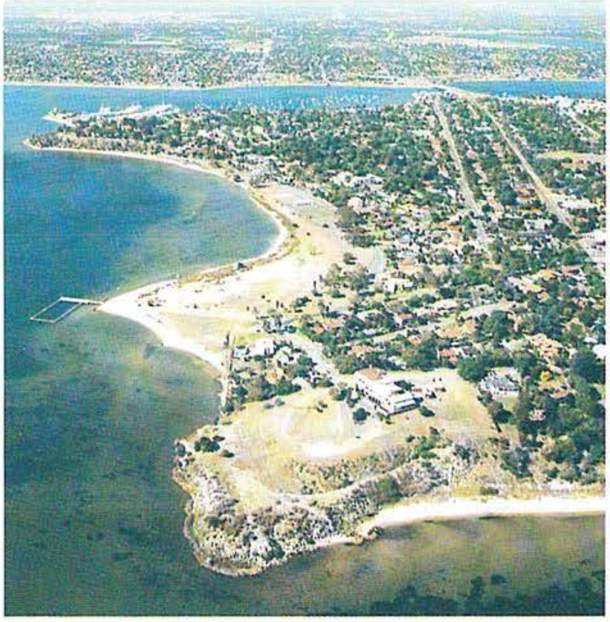
Figure 4

In future, the water balance model can be used to assess the effects on water levels of such things as changing bore density and abstraction rates for both public and private supplies, development of the urban area, variations in the climate, modifications to drainage systems, changes in vegetation type and density, the use of septic tanks and possible recharge with treated sewage effluent. The effectiveness of possible groundwater management strategies can be evaluated by comparing predicted with acceptable water level variations. The strategies can be applied either regionally or in specific areas and can be evaluated for the region as a whole or for specific areas using the water balance model.

INTENSIVE STUDIES

A number of intensive studies were carried out to supplement understanding of the water balance processes and to provide information to assist in the identification and development of viable managment strategies.

A detailed investigation of the water balance processes within the Applecross peninsula was carried out. Saltwater intrusion, urban hydrology, land use and groundwater use were studied in detail. A number of specific management options were evaluated to determine their effectiveness. This investigation can also be considered as a pilot study for similar investigations of other areas which may be at risk.



A comprehensive wetlands review was carried out to compile all available hydrogeological, biological and surrounding landuse information on about 100 major wetlands in the Perth region. In addition, the "natural" and "human use" attributes of 79 selected wetlands were assessed to identify management requirements of wetlands. The results of this review were used by the Environmental Protection Authority in developing their Draft Guidelines for Wetland Conservation in the Perth Metropolitan Area.

A detailed study of the macroinvertebrate fauna of five urban wetlands was conducted to evaluate the complexity and diversity of wetland ecosystems and how they are affected by human activity, climatic variation and changes in groundwater level. The study highlighted the value of biological monitoring techniques.

An understanding of the processes which affect groundwater quality was developed through research into the water quality variations along two selected groundwater flowlines. The impacts of various land use activities overlying the flow lines were examined in detail.

A survey of urban domestic and institutional bore use was undertaken to quantify the extent of private use of groundwater resources.

An investigation and monitoring program was carried out to identify the extent and landward movement of the saltwater wedge around the estuary and in coastal areas.

3

MANAGEMENT STRATEGIES

Having investigated and identified areas where the groundwater resource may be at risk, considerable effort was made to formulate and evaluate a number of management strategies which may be available to reduce the identified risks. Management strategies were evaluated by predicting their effects on groundwater levels, using the water balance model, with various combinations of climatic and urban development scenarios.

Assessment of strategies was limited to technical aspects, since the economic, social, legal and political aspects were beyond the scope of the Study. Studies covering these aspects are being undertaken by the Water Authority and the Western Australian Water Resources Council.

Management strategies involve the choice of actions which affect the regional water balance. These actions can be broadly divided into those which cause variations in rates of groundwater abstraction and those which modify recharge to the unconfined aquifer. Practical management strategies may require combinations of both of these types of actions.

The control of factors affecting the urban water balance is spread throughout many government departments and organisations. Management strategies must therefore be developed with communication and co-operation between those groups.

Direct management of groundwater resources may be achieved by any combination of legislative control, technical solutions and public education. The option also exists for indirect management through allowing use of the resource to self regulate.

There is a significant lead time involved in the implementation of management strategies. It is affected by the time needed to devise, assess and introduce the strategy and the time needed for the strategy to take effect. The time required for the strategy to take effect may be many years, as it depends on the sensitivity of the groundwater system to changes in recharge and extraction parameters.

Strategies should be implemented well in advance to be prepared for possible problems so that they may be avoided or satisfactorily managed and to allow management actions to be implemented in readily accepted stages. This is preferable to having to mount a rescue operation after problems have developed, a course which is usually socially and economically unpalatable. Effective planning allows handling of possible problems and through staged implementation of strategies allows the community to gradually become conscious of the need for management.

Groundwater management is a dynamic process. If components of the urban water balance change, or if our understanding is improved with additional information, management strategies may need to be amended. It is therefore essential that the groundwater system be monitored regularly to enable updating of predictions. Management strategies can then be modified to ensure that the optimum community benefit is achieved.

An understanding of the impact of man's activities on the groundwater resource was identified as a fundamental requirement for the development of effective management strategies. The information, techniques and expertise developed during the study provide a framework for the effective management of the groundwater resource.

CONCLUSIONS
OF THE PERTH URBAN WATER BALANCE STUDY

THE RESOURCE

CONCLUSION 1

Groundwater is vital to maintaining the lifestyle of the Perth region.

Groundwater meets about one third of the public water supply requirements of the region's one million inhabitants and provides about two thirds of all the water used in Perth.

About 77,000 or one in four households in Perth rely on private groundwater supplies for garden irrigation.

On the Swan Coastal Plain, virtually all irrigated public open space is irrigated with groundwater.

Groundwater supports much of the natural environment of the Swan Coastal Plain in the Perth region, including the 9000 hectares of major wetlands which were reviewed for this Study.

More than 2500 hectares of commercial agriculture, worth $40 million per annum, and some major industries, which contribute significantly to the economy of the region, depend upon readily available groundwater of suitable quality.

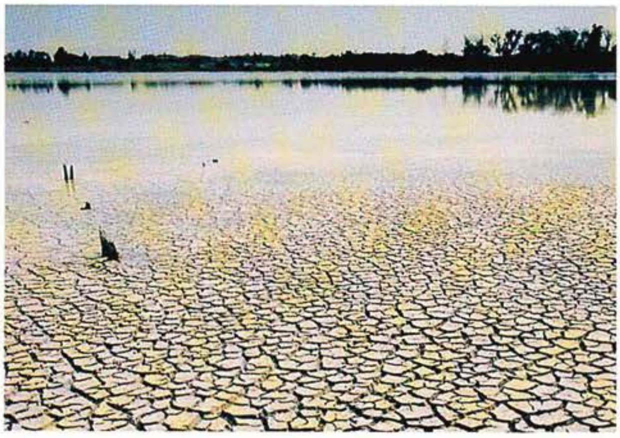
CONCLUSION 2

Without active management, the groundwater resource of the Perth region cannot meet the expanding public and private demands whilst continuing to sustain the region's environment.

Lowered water levels in some urban wetlands and increased salinity in some coastal and near-estuary bores since the mid-1970s are indications that the resource is locally under stress from current levels of development.

Uncontrolled expansion of groundwater use will lead to further problems of lowered water levels in wetlands and increased saltwater intrusion in coastal and near-estuary suburbs.

Management of factors affecting the water balance is necessary to ensure that groundwater continues to play its role in maintaining the lifestyle of the region.



CONCLUSION 3

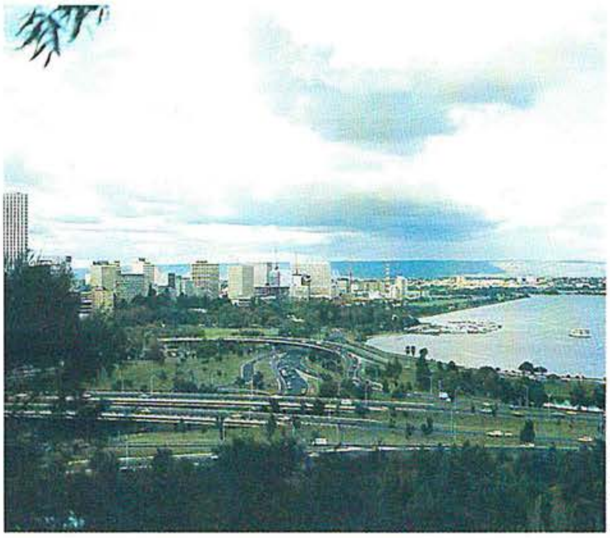
Water level variations within the groundwater system of the Perth region are dominated by climate.

Water levels rise and fall significantly each year as rainfall varies with the seasons, and successive years of above-average or below-average rainfall cause longer-term fluctuations in groundwater levels. Of the many influences that affect groundwater levels, climatic variations are the most significant.

Recharge to the groundwater resource during the extended period of below-average rainfall between 1975 and 1985 was about two thirds of that which would occur during periods of average rainfall and only about half of that which would occur during periods of above-average rainfall. Had average rainfall occurred in the period 1975 to 1985, water levels across the urban area would generally have been about 0.5 m higher than those recorded in 1985.

Evidence from lake bed sediments indicates that fluctuations in water levels have occurred over long periods of time. There is no doubt that some of the existing urban wetlands dried out occasionally due to variations in climate, prior to any land development by man. The eco-systems of many of the lakes in the region have adapted to this occasional drying out. This must be taken into account when developing management plans for wetlands. Wetlands which dry out almost annually sustain a diverse flora and fauna, reflecting their adaptation to the strongly seasonal climate.

Changes in groundwater levels induced by urbanisation and development of groundwater resources should be considered in the context of natural, long-term fluctuations in groundwater levels.



Jenni Bartle

CONCLUSION 4

Within the Perth region, land use has a significant influence on variations in both groundwater levels and groundwater quality.

Urban development can cause either a rise or a fall in water levels, depending on the local aquifer conditions and the nature of the development. There is evidence, including drowned fences across lakes and drowned trees within lakes, supporting the conclusion that long-term water level changes have occurred since European development of the region commenced in 1829. Urban development also affects groundwater quality through leaching of fertilisers and recharge of contaminated runoff and septic tank effluent.

Recreational developments, both passive and active, may have significant groundwater requirements. Passive recreation areas may require groundwater for the maintenance of natural or created environments while active recreation areas require groundwater for irrigation of playing fields and surrounds.

Large evapotranspirative losses of groundwater occur from wetlands and, in some areas, wetlands have a significant influence on the groundwater system.

Large scale modification of vegetation, such as pine plantations and regional open space, may have a considerable effect on evapotranspiration and recharge processes, and consequently on groundwater levels.

Industrial developments may place a significant demand on groundwater resources and are potential sources of pollution.

Irrigated agricultural development involves intense use of groundwater resources. On average, every hectare of land irrigated for market gardening requires an amount of water equivalent to the recharge occurring over ten hectares. Agricultural development also affects groundwater quality through the leaching of fertilisers and pesticides. Therefore, despite the potential economic returns, there is a finite limit to how much agricultural irrigation can be undertaken without conflict with other demands or activities.

Landuse planning should aim to develop urban forms that take account of impacts on groundwater resources so that demands remain compatible with availability of water.

CONCLUSION 5

Immediate implementation of an active regional groundwater management program, recognising all components of the water balance, is essential.

Management should be implemented to avoid problems. It is not satisfactory to wait until problems become evident before strategy development commences. With effective management, many of the problems associated with climatic variations, landuse development and uncontrolled use of the resource will be avoided.

Should appropriate strategies not be implemented in sufficient time to ensure that problems are avoided, the costs to the community to undertake rehabilitation activities would be considerable and may involve the expenditure of millions of dollars.

AREAS AT RISK

CONCLUSION 6

Urban wetlands are at risk due to hydrological changes associated with urban development.

Reduced water levels have been experienced in recent years in some urban wetlands, such as Shenton Park Lake and Perry Lakes.

The existence of dead trees within some urban lakes, such as Blue Gum Reserve and Lake Claremont, indicates elevated water levels resulting from urbanisation. Similar problems are likely to occur in Bibra, Yangebup and Thomsons Lakes following urban development in surrounding regions. These high water levels may require a regional drainage system to be established to protect environmentally significant wetlands from local flooding, although it must be recognised that artifically linking wetlands together with a drainage system may have undesirable ecological side effects.

Many lakes and wetlands form important discharge points in the urban drainage network. Much of the drainage water discharging to the wetlands contains contaminants from the surrounding urban area. The diversity of fauna and flora and the stability of lake ecosystems are at risk from degraded water quality from this contaminated drainage. This is already evident in Lakes Joondalup and Monger. Whilst the impact of these contaminants on the wetlands is not well understood, it may be possible to remove some of them using settling basins, for example, prior to discharging stormwater to the wetlands.

The maintenance of water levels in wetlands, which are important elements of the region's natural environment, is the most significant consideration in the regional development of the groundwater resource.

CONCLUSION 7

Saltwater intrusion is a significant risk in local areas adjacent to the coast and the Swan estuary.

Along the foreshore of the suburb of Applecross, saltwater intrusion has already occurred to the extent that the salinity of water drawn from the deeper bores in the unconfined aquifer has increased. In some cases, the salinity has increased to above levels considered tolerable for garden plants. Similar situations exist in other peninsulas, such as at South Perth, Maylands, Dalkeith and Rockingham/Safety Bay.

Management of the intrusion of salt water into bores in risk areas may be assisted by strategies which increase the flow of groundwater towards the ocean or estuary. Many problems experienced to date, however, are the result of inappropriate bore construction and high pumping rates. Users of groundwater in risk areas should be advised of the correct bore construction and pumping techniques to ensure that only good quality groundwater is pumped from above the saltwater wedge.

CONCLUSION 8

The peninsula containing the suburbs of Cottesloe, Claremont, Peppermint Grove, Mosman Park and North Fremantle is an area of high risk from saltwater intrusion.

This peninsula is completely underlain by salt water. The thickness of the lens of fresh water above the salt water is dependent on local recharge rather than on lateral inflow of groundwater from the Gnangara Mound.

The water table is less than 0.5 m above sea level throughout the peninsula and, as a result, saltwater occurs at a shallow depth below the water table, and there is a risk that it will be drawn into bores if appropriate bore construction and pumping techniques are not used.

CONCLUSION 9

The response of the groundwater system to above-average or below-average rainfall varies across the region according to aquifer permeability and thickness.

This is particularly significant in areas which overlie lower permeability or thinner parts of the aquifer, such as the suburbs between Bayswater and Marangaroo and parts of the Eastern Perth Area which are subject to wide variations in water level. The difference in water levels between above-average and below-average rainfall periods, with current urban development, could be up to 4.0 m, even allowing for the effect of the existing drainage system. Decreased bore yields may be experienced in below-average rainfall periods and flooding may occur in above-average rainfall periods.

Appropriate design and construction of bores are necessary to ensure yields are maintained at times of low water table elevation. An adequate drainage system is necessary to guard against flooding when water table elevations are high. Nevertheless, the system should be designed, where possible, to maximise groundwater recharge.

CONCLUSION 10

Regionally, water quality is not a cause for concern for current users of groundwater. However, elevated nutrient concentrations within parts of the urban area are a risk to wetlands and to the use of groundwater for drinking.

Groundwater contamination is closely associated with land use, particularly in market garden areas, industrial areas or in urban areas where septic tanks are in use or where large amounts of fertiliser are applied.

Land planning procedures are available which, if implemented, would ensure that land use remains compatible with maintaining good groundwater quality. Control measures are also available to prevent point-source discharge of polluting materials and non-point-source contamination of the groundwater resource.

Regional landuse planning and public water supply planning should include thorough consideration of the effects of urban development on groundwater quality. In areas where groundwater quality is adversely affecting the environment, Environmental Protection Policies should be considered to control non-point-source pollution of the groundwater resource in urban areas.

MANAGEMENT STRATEGIES

CONCLUSION 11

A number of management strategies can be applied to secure the groundwater resource and protect the environment of the Perth region, in general, and of specific risk areas, in particular.

About two hundred different combinations of management strategies and climatic and urban development scenarios were evaluated. The scenarios included above-average, average and below-average rainfall periods for both current and full urban development in accordance with the Corridor Plan for Perth.

To demonstrate the evaluation process and to indicate the sensitivity of the groundwater system to variations in climate and land use and to different management strategies, the results of nine possible management strategies are included in the Study report.

Effective management of the resource will include elements of many of the strategies presented in the Study report. On-going reviews of the effectiveness of management will enable the adopted strategies to be modified and additional strategies to be implemented, if necessary.

CONCLUSION 12

Assessment of social, political and economic factors, together with assessment of the technical factors considered in the Study, is essential in the selection of the optimum management strategy.

Although it is concluded that immediate implementation of an active regional management program is essential, based upon the outcome of the Study, it is recognised that strategies implemented immediately may need to be refined after assessment of social, political and economic factors. However, expertise and experience exist to enable the immediate implementation of acceptable management strategies.

CONCLUSION 13

Effective on-going management of the resource requires comprehensive groundwater monitoring, criteria for environment management and, because of the complexity of the groundwater system, a calibrated computer model.

To ensure that management strategies are effective and to provide better estimates of the use of groundwater and of the distribution of groundwater users, a comprehensive monitoring program is required. The program should provide regionally synoptic and locally detailed water level, water quality, abstraction and saltwater intrusion data which are relevant for assessing management strategies.

Because of the close link between groundwater and the environment of the Swan Coastal Plain, environment management criteria should be developed. In particular, a better understanding of wetland ecosystems is needed so that accurate predictions of the impacts of water level variations can be made and appropriate wetland management strategies can be formulated.

From these strategies, criteria for desirable water levels and water level variations and for desirable water quality can be determined so that appropriate groundwater management strategies may be developed.

During the Study, it was demonstrated that the computer model can be used effectively to predict regional water table movements for various climatic and landuse scenarios and with possible future management strategies. Furthermore, it is a valuable facility for the regular review and possible amendment of implemented strategies.

The model developed during the Study has already been used effectively by the Water Authority for detailed evaluations of the water balance of the Gnangara Mound, the Jandakot area and in the vicinity of wetlands in the Wanneroo area.

CONCLUSION 14

The fundamental aim of any adopted regional management strategy should be to achieve a balance between the availability of and the demand for groundwater, by:

- **ensuring that land use is compatible with the local availability of groundwater in developing areas;**
- **managing the per-capita growth in demand;**
- **ensuring that groundwater is used efficiently; and**
- **increasing recharge of surface drainage, where appropriate, particularly drainage from roads and roofs.**

Liaison between all government organisations and local government authorities involved in landuse development is essential to ensure that all developments are located in areas where the groundwater resource is adequate to meet local requirements, without risk to existing users or to the environment.

Direct control of major public and private users of groundwater would allow for the control of 60% of groundwater abstraction. Public education could be a cost-effective means of reducing the use of groundwater by domestic users. If not effective, public education could then be reinforced with more direct control measures, perhaps involving the licensing of all bores.

On-going education programs should be designed to advise people of methods of maintaining their gardens with minimum use of water and to encourage people to be concerned for the general welfare of the community and the environment.

Stormwater drainage systems provided by the Water Authority and local authorities should be designed, where appropriate, with an aim of maximising recharge to the aquifer. This aim should apply to all new systems and to existing systems as they are upgraded. In areas where there is a risk of detrimental lowering of groundwater levels, existing systems should be modified to maximise recharge.

CONCLUSION 15

In addition to regional management strategies, specific local management strategies are needed for risk areas.

The strategies appropriate for different areas may vary depending upon local hydrogeological, environmental and landuse factors, and should be flexible because of the dynamic nature of the groundwater system. Strategies may include any of the following components:

- groundwater recharge may be increased by modifying existing local drainage systems,
- abstraction may be controlled by increasing restrictions on major users of groundwater or by direct control of domestic users,
- treated sewage or drainage water may be transported and/or recharged, where the expense is warranted, to increase water levels or to limit saltwater intrusion,
- Recreation areas and public open space may be irrigated with treated sewage or by programmed pumping from stormwater drains as alternatives to using groundwater, and
- Intense local education programs may be used advise residents of the impact of their use of groundwater on their own local environment.

CONCLUSION 16

Specific management strategies are required for immediate implementation in the following areas which were identified during the Study as risk areas: .the peninsula where the suburbs between Cottesloe and North Fremantle are located;

- **the peninsula where the suburbs of Applecross, Mount Pleasant and Ardross are located;**
- **the inner western suburbs around Wembley and Floreat; and**
- **the locality of Kardinya.**

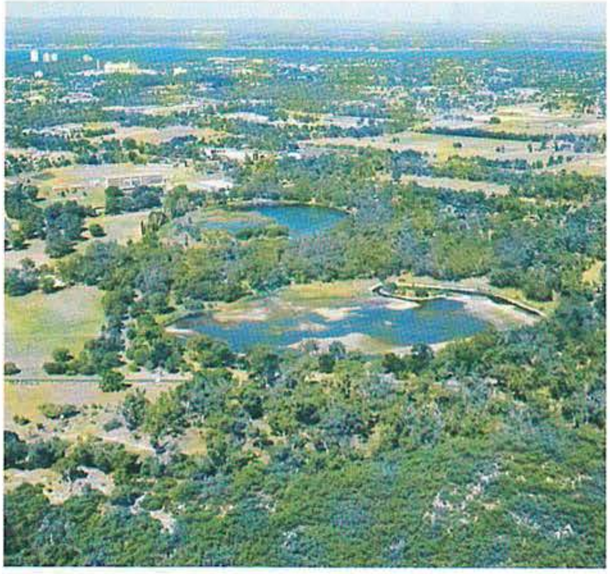
Specific management strategies may also be needed in other areas which have yet to be assessed in detail.

The thin layer of fresh water occurring within the peninsula extending from Cottesloe to North Fremantle is completely underlain by salt water. The fresh water is recharged directly from local rainfall with minimal contribution from lateral groundwater flow. Management strategies to reduce local abstraction and to maximise local recharge are essential.

Increasing intrusion of the saltwater wedge along the northern shore of Applecross has been detected. Strategies are required to reduce local abstraction of groundwater and to increase local recharge in the suburbs of Applecross, Mount Pleasant and Ardross to limit the extent of saltwater intrusion.

Reduced groundwater levels in the suburbs of Wembley and Floreat over the last few years have resulted in significant reductions in the water levels in Perry Lakes during summer months, reducing the recreational and natural amenity of the area. Strategies are required to increase local groundwater levels by reducing local abstraction and increasing local recharge. Some control in this area is necessary to even maintain 1986 levels during extended periods of below-average rainfall.

Following the clearing of vegetation for urban development at Kardinya and Winthrop, rising groundwater levels have placed some of the older homes at risk of flooding. Immediate steps are needed to protect those homes.



Although problems were only identified in some areas, there are likely to be many other areas with similar problems, for example, Maylands, Dalkeith and Fremantle may have similar problems to Applecross. It is therefore essential that the groundwater system in such areas be assessed as a matter of priority to enable appropriate management strategies to be developed. Locally intensive education programs may be all that are necessary initially, however if groundwater utility deteriorates or the environment is adversely affected in those areas, more stringent controls may then be needed.

CONCLUSION 17

The effects of using septic tanks in preference to reticulated sewerage, reducing the density of pine plantations and reducing Water Authority pumping were shown to yield insignificant benefits within urban areas.

The volume of water discharged from septic tanks is insignificant in the overall water balance of the region. Water level differences attributable to the use of septic tanks would be negligible.

Reducing Water Authority pumping and reducing the density of pine plantations would result in local rises in groundwater levels which would not have significant impact in urban areas. In non-urban areas, such as rural areas east of Wanneroo, the management of pine forests can result in significant increases in water availability.

CONCLUSION 18

It is imperative that adequate human, technical and financial resources be provided for the development, implementation and regular review of appropriate, on-going management strategies and for the regular monitoring of the groundwater resource of the Perth region.

Because of the community's dependence upon the groundwater resource and because the Water Authority relies on the continued use of groundwater within the community to reduce public demand for reticulated supplies, the careful management of the resource must be regarded as a high priority by the Water Authority. The facilities needed include people in the field and office, advanced computer systems and adequate instrumentation.

Additional staff and financial resources will be required to implement the recommendations of the Study. Experience gained within this Study and from other Water Authority groundwater management activities indicates that, in the initial stages, at least three professional people and two technical assistants will be required within the Water Authority with an additional annual operating budget of $250,000 for computing, investigation and monitoring activities. A hydrogeologist from the Geological Survey and an environmental scientist from the Environmental Protection Authority or the Department of Conservation and Land Management will also be required.

5

RECOMMENDATIONS
OF THE PERTH URBAN WATER BALANCE STUDY

The Steering Committee makes the following recommendations.

1. The Water Authority should immediately implement appropriate management strategies to maintain the valuable amenity of the Perth region's unconfined groundwater resource with an appropriate balance between public, private and environmental demands. The behaviour of the resource will need to be monitored and the management strategies will need to be reviewed and amended, as necessary, in the future.

2. The Water Authority should arrange for proclamation of the Perth metropolitan region of the Swan Coastal Plain as a Groundwater Area under the Rights in Water and Irrigation Act, and all non-domestic bores and wells should be licensed with groundwater allocations taking into account current activities and water availability.

3. A regional management strategy should be prepared by the Water Authority in consultation with the Geological Survey, the State Planning Commission, the Environmental Protection Authority, local government authorities and land development agencies. The strategy should aim to maximise recharge to the aquifer, where appropriate, and to reduce the total per-capita growth in demand for groundwater, consistent with the Western Australian Water Resources Council's Demand Management Strategy.

4. When planning for landuse development, the State Planning Commission and local government authorities should aim to develop urban forms to ensure that landuse development is compatible with groundwater availability. This planning should take account of impacts on all components of the water balance.

5. The Environmental Protection Authority should develop criteria for the water level and water quality tolerances of environmental features that rely upon groundwater for their viability. The Water Authority should then take these criteria into account as groundwater management strategies are refined.

6. The Environmental Protection Authority should prepare Environmental Protection Policies for areas where non-point-source pollution may degrade groundwater quality and adversely affect the environment.

7. The Water Authority should immediately develop and implement specific management strategies to reduce abstraction and increase recharge in the peninsula containing the suburbs of Cottesloe, Claremont, Peppermint Grove, Mosman Park and North Fremantle; the peninsula containing the suburbs of Applecross, Mount Pleasant and Ardross; and the inner western suburbs around Wembley and Floreat.

8. Further investigation should be undertaken by the Water Authority, in conjunction with the Geological Survey, the Department of Conservation and Land Management the Environmental Protection Authority and relevant local government authorities, to determine the need for loca management strategies in risk areas not specifically investigated during this Study.

9. The Water Authority should continue to support the Western Australian Water Resources Council's detailed assessment of social, political and economic factors relating to groundwater management. This will provide valuable information to the Water Authority to enable refinement of management strategies.

10. The Water Authority, the Geological Survey and the Environmental Protection Authority should ensure that adequate human, technical and financial resources are provided for the implementation of appropriate regional and local management strategies. These resources are, in the initial stages, at least three professional people and two technical assistants within the Water Authority with an additional annual operating budget of $250,000 for computing, investigation and monitoring activities, a hydrogeologist from the Geological Survey and an environmental scientist from the Environmental Protection Authority or the Department of Conservation and Land Management.