Water Authority
of Western Australia

Planning Future Sources for Perth's Water Supply (1989 Revision)

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STREAMLINE ABSTRACT

PLANNING FUTURE SOURCES FOR PERTH'S WATER SUPPLY (1989 REVISION)

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As part of the planning process to meet growing demands for water from the Perth Metropolitan Water Supply System, the Water Authority of Western Australia prepares a Source Development Plan (SDP) to identify new sources of water which are expected to be needed in the next 25 years. More detailed planning can then proceed for sources which the SDP has suggested are the best options for the near future. Also, the information which the SDP provides about the value of various water resources for public supply, is useful when planning other land uses or alternative uses of the water in the catchment areas of the water resources. This report explains the basis of the SDP, giving descriptions of the demand, the types and locations of water resources, the means of developing the resources for public supply, and the factors which affect the available yield of sources. The sources which feasibility studies have shown are preferred for development are identified and scheduled into three timetables: a 'most likely' timetable where best estimates are made of assumptions used in projections, and a 'maximum' and a 'minimum' timetable where extremes of the assumptions are used to find the fastest and slowest rates of development likely to be needed. The major appendix gives details of all the preferred schemes for developing sources, and of alternatives considered but assessed to be 'not preferred'. A map shows scheme locations, catchment areas and groundwater areas overlain on land-use. Another appendix tabulates the impacts that land use may have on water resources, and the impacts of source development on the environment and land-use. This report updates the version produced in January 1987.

Key words: Public water supply, water resources, source development, land-use planning, rivers, groundwater, dams, wells, water demand projection.

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FOREWORD

This report provides information on the planning being done by the Water Authority for sources of water which may be required for the Perth Metropolitan Water Supply System over the next 25 years. The report makes the information available to interested persons and organisations, and is intended to increase awareness of water problems and to help promote informed discussions on the issues facing the community in future water planning.

The Water Authority endeavours to update its planning on a regular basis, and respond to significant changes in the external factors which affect the plan. This report is an update of the original version which was published in January 1987. The main factors which have changed since are:

- the decision to take account of the expected impact of the Greenhouse Effect on the yields of sources.

- revision of projections of population and numbers of dwellings to be served.

- the inclusion of the targets of the Water Authority's Water Conservation Strategy in the demand projections.

There have been some other changes which particularly affect demand projections, but these have only been evaluated by the Water Authority to the extent that they affect sources planned for use in the next 7 or 8 years. In the next few years it is expected that the demand will lie between the 'maximum' and 'most likely' demand projections that are given in this report. If you require more information concerning such changes, you should contact the report's author at the John Tonkin Water Centre.

While the report concludes with a plan for development of new water sources, it should be recognised that the Water Authority will continue its efforts to limit demand growth through improved efficiency of water use, and thereby defer the need for new sources as much as possible.

Those sources which are presented but which have not yet been subject to the Environmental Impact Assessment process, may be modified, or even rejected as sources, if future investigations reveal some aspect of the development scheme which is socially or environmentally unacceptable. Conversely, continuing investigations of water resources may reveal new sources. The report and the associated development plan is thus a statement of current knowledge and will be modified to accommodate new information.

K. C. Webster
DIRECTOR OF WATER RESOURCES

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SUMMARY

The Metropolitan Water Supply System (MWS) is currently serving a population of 1.1 million. The MWS supplies water to Perth and nearby towns. The supply to the Goldfields and Agricultural Water Supply Scheme (G & AWS) from the Helena Reservoir is also included because the MWS and G & AWS are operated jointly. The growth in demand for water, about 3% per year, is mostly due to increasing population. The total annual demand of 223 million cubic metres in 1987/88 is approaching the total yield of 252 million cubic metres per year from the existing water supply sources. This yield is assessed on the basis that water restrictions may be applied in 10% of years when needed as a result of severe drought.

It is necessary to plan additional sources of water for the MWS to:

- ensure the security of supply in the medium term (up to 10 years).

- identify resources which could economically contribute to the yield of the system in the longer term if the growth of Perth continues as projected by the State Planning Commission.

- allow the value of the water resources as sources for the MWS to be appreciated by other land-use planners so that unnecessary degradation of water quality by other land uses can be avoided and decisions on alternative uses of the water can be better evaluated.

Planning for Perth's future water supply must satisfy the Water Authority's objectives of providing water at minimum long term cost to a standard acceptable to the community, and of efficiently managing the State's water resources. The Water Authority has prepared a Source Development Plan (SDP) for the MWS. The SDP identifies possible future water sources and recommends the type of development and scheduling of the schemes to meet projected demands for the next 25 years. It is guided by water resources policy and general studies relating to allocation of water resources. The SDP is a long-term regional strategy in the planning and decision-making processes of the Water Authority and is the basis of more detailed planning of sources required in the near future. If detailed planning modifies the scheme proposals, the information is fed back for inclusion in future reviews of the SDP. Comments from the public are also considered in reviews of the SDP. The Water Authority tries to fully review the SDP every two years.

The two main types of water resources near Perth which have potential for development within 25 years are rivers and groundwater. Rivers may be developed by building large dams to create storage reservoirs. Alternatively, small dams may be built to divert winter streamflow into existing storage reservoirs (pump-back schemes), or directly into the distribution system for immediate use (pipehead schemes).

Groundwater resources are of three types, found one below the other: shallow groundwater, which has the water-table as its top surface; and shallow and deep artesian resources. The shallow groundwater and shallow artesian water are usually developed together in a wellfield which pumps water from wells to a treatment plant. After treatment, the water is pumped to service reservoirs for distribution. The deep artesian water requires only disinfection, but it is usually warm and brackish. Thus it is fed in relatively small quantities to a service reservoir where it is cooled and the salinity reduced by mixing with water from other sources.

The need for additional sources, and the value of resources which are near Perth, are affected by a variety of factors:

- The Water Authority aims to minimise demand (the 'need' for water) through its Water Conservation Strategy. Reducing the growth in demand has the effect of deferring the time when new sources are needed, with consequent environmental and economic benefits.

- It appears likely that climate changes over the next few decades due to the Greenhouse Effect will lead to less streamflow in the south-west of the State. If this happens, new sources will be needed to replace yield lost from existing sources. Allowance has been made in the SDP for this possibility. This will be reviewed as predictions of the impacts of the Greenhouse Effect become more confident.

- Some water needs, for example irrigation, can be satisfied with a lesser quality of water than the drinking water supplied by the MWS. At present, groundwater from private wells is the most attractive alternative to the MWS to supply such needs. As local groundwater resources become fully allocated, re-use of wastewater could become increasingly important as a source of second-class water which can reduce demands on the MWS.

- The Water Authority places an extremely high priority on preserving native vegetation or timber plantations on Crown land overlying major recharge areas for shallow groundwater resources. Such areas have the best potential as secure sources of water for the future. Other land uses, especially urban, have the potential to pollute the shallow groundwater and make it expensive to treat, or even to make the resource unuseable in the long term. Suitable management of land use to reduce risks of pollution can enable resources under urban or rural land to be economically developed. However, some doubt remains about the ability to maintain the quality of the resource in the long term.

- Reducing the density of trees in appropriate locations on the catchment areas of rivers and groundwater resources, has been shown to be effective in increasing available water. However, further hydrological and environmental studies by the Water Authority and the Department of Conservation and Land Management are required before it can be considered in source development planning as a strategy for increasing yield.

- Water supply sources which cost more per kilolitre than seawater desalination are not considered to be economically feasible. Seawater desalination is a very expensive option by today's standards, but with seawater easily available to Perth, it is likely to be the major source of additional water for the MWS in the very long term.

The SDP is summarised in three Source Development Timetables. The 'most likely' timetable is based on best estimates of assumptions relating to demand projections and yields of sources. The 'maximum' and 'minimum' timetables use extreme values of assumptions to give an indication of the earliest dates at which future projects will be required and the longest construction schedule. In each case, the sequence and timing of sources are designed to give the best economic efficiency subject to social and environmental constraints. Sources identified as being required in the near future, and which are currently the subject of more detailed planning, are:

SOURCE	(Dates in development timetables) MAXIMUM	MOST LIKELY	MINIMUM
Remainder of Pinjar Groundwater Scheme Stage I	1989/90	1989/90	1989/90
Conjurunup Pipehead	1991/92	1994/95	2001/02
Victoria-Bickley Redevelopment	1991/92	1991/92	1991/92
Jandakot Groundwater Scheme Stage II	1992/93	1995/96	2001/02
North Dandalup Dam	1993/94	1996/97	2002/03

1. INTRODUCTION

Continued availability of good quality water supplies is essential for the future of Perth. A constant supply of drinking water is vital for human life. The use of water for other purposes, such as toilet flushing, bathing and washing, firefighting, and in primary production and manufacturing processes, is essential to maintain the economic and social structure of Perth. To maintain our lifestyle and attractive urban environment, water is also required for such uses as irrigating sporting and recreation areas, and maintaining gardens and private swimming pools.

As demands for water rise, the financial and environmental costs of providing a city water supply increase. In the future, the community will need to address the broad issues of whether water use can continue to increase as at present, and the price that users are prepared to pay for different uses of water. In the meantime, planning for new sources of water must proceed to enable the Water Authority to continue to provide a satisfactory public water supply.

Due to engineering advances in desalination, there is no technical limit to the quantity of water available to a city like Perth which has access to the ocean. However, production of drinking water from sea water is at present a very expensive water resource option.

Water resources which can provide water supplies at less cost than desalination of seawater are limited. The cheapest sources close to the city are subject to most pressure for use by competing demands such as development for public and private water supplies and irrigation schemes, and recreation. At the same time, there is increasing recognition of the importance of water resources for maintaining the quality of the natural environment.

The Water Authority has the responsibility for managing the water resources of Western Australia in the best interests of the community and for providing satisfactory public water supplies. To ensure that sufficient sources of water are available for Perth's public water supply in the future, the Water Authority has prepared a Source Development Plan (SDP). The SDP is a long-term plan to meet future water demands by developing sources which are most cost-effective within known environmental and social constraints. The sequence of development of these sources (Source Development Timetable) is designed to give the lowest cost long-term programme, allowing for some technical constraints on the timing of certain sources.

The Source Development Plan is the basis for current planning of future water sources for Perth's public supply. However, all aspects should still be regarded as flexible. The proposals or timing can be modified, if required, to satisfy other environmental or social priorities for use of the water resources if these are indicated by public or environmental review of the plan, or if warranted by the continuing technical studies conducted by the Water Authority.

The purpose of this report is to present the current Source Development Plan to the public. The report discusses the planning process, demands which must be satisfied by the Metropolitan Water Supply Scheme (MWS), the available water resources, the alternatives for developing public supplies, the basis for selecting the preferred water supply schemes and development timetables in the SDP. The present report is a revision of the report published in January 1987 (Mauger,1987).

Comments are invited which will enable the Water Authority to assess the community's view of the SDP, so that immediate decisions and long-term plans for developing Perth's future water supply will reflect, as far as possible, the community's expectations and values.

2. THE PLANNING PROCESS

OBJECTIVES

The Water Authority's primary objectives are:

". Provision of Services
To provide water, sewerage, irrigation and drainage services at minimum long-term cost and to a standard acceptable to the community.

. Management of Water Resources
To conserve, assess and efficiently manage the State's water resources for the continuing benefit of the community." (Quoted from Water Authority, 1987c)

Planning for Perth's future water supply must serve each of these objectives. However, the process of planning to satisfy public demands for water supply within the wider context of comprehensive water resources management is becoming increasingly complex. The most economic sources available for future expansion of Perth's water services are individually small when compared to the rate of growth in demand. Planning must provide for developing a steady succession of such sources whilst simultaneously satisfying widening community interest in environmental management and allocation of water resources.

PLANNING PROCEDURES

Planning procedures for Perth's water supply are not fixed but are progressively reviewed and adapted with the aim of improving their effectiveness within a changing planning environment. It is a tiered process, progressing down from the broad-based and long-term guiding frameworks to specific implementation planning.

The flow diagram in Figure 1 is an example of the process for the decisions leading to the construction of new major metropolitan sources. It highlights the formal involvement of the Environmental Protection Authority (EPA) in such decisions, but it should be noted that there is a strong interaction between the Water Authority and all government agencies which have responsibilities for planning or managing land use in areas where the Water Authority has water resource development proposals. This interaction is carried on in all phases of planning, with the objective of maintaining awareness of constraints which may apply to each others planning proposals due to the activities or proposals of the Water Authority and other agencies. The agencies most commonly involved are the State Planning Commission, the Department of Conservation and Land Management and the Environmental Protection Authority.

STRATEGIC PLANNING

Strategic planning involves research and development of long-term framework plans or policies for the allocation, conservation and management of water resources on a regional or state-wide basis. Long-term strategies are developed for meeting specific regional water needs.

This planning is non-statutory and presents a guiding framework to:

- project demands and issues in a long-term regional context;
- provide an orderly basis for timing the work of planning specific projects, and developing such plans in a regional context;
- identify specific planning priorities;
- contribute to specific decisions on water resource allocation, taking into account the needs of the public, private users and the environment;
- use in specific planning for water resource conservation and pollution control;
- assist other planning authorities which need to give consideration to water resource matters.

A comprehensive approach to water resource planning has evolved during the past 15 years, as a result of planning studies initiated and carried out by the former Metropolitan Water Board and Public Works Department, notably the South West Regional Planning Study (Sadler and Field, 1976), the Source Development Plans for the Metropolitan system (Caldwell, 1981; MWA, 1975-83; Water Authority, 1986b), development of regional salinity strategies (Sadler and Williams, 1981), the Perth Urban Water Balance Study (Cargeeg et al., 1987), the Domestic Water Use Study (MWA, 1985) and various research projects concerning the management of surface catchments, recharge of

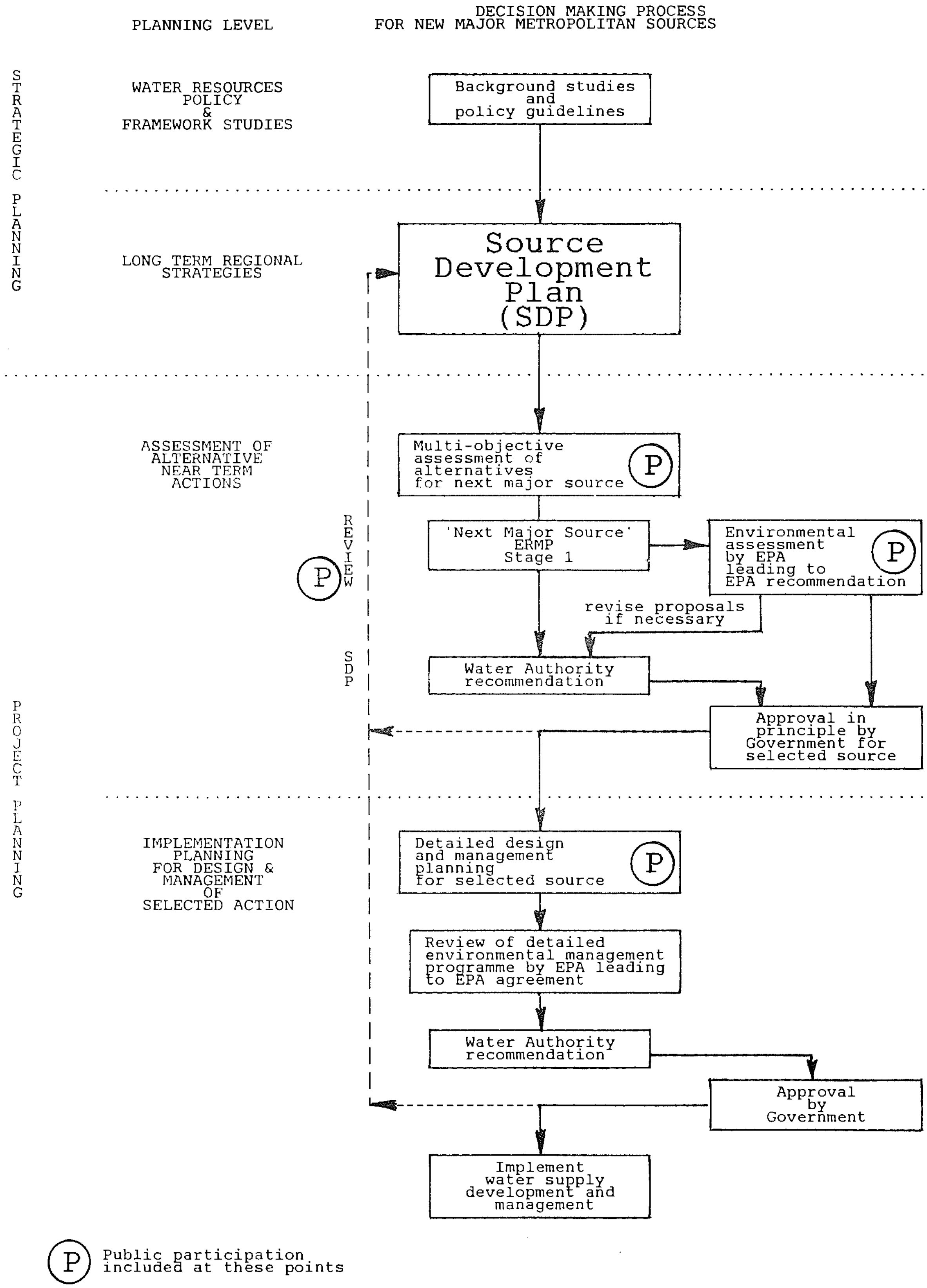


Fig 1. The planning and decision-making processes.

groundwater resources, re-use of treated sewerage effluent and desalination of brackish waters.

Some more recent initiatives introduced by the Western Australian Water Resources Council with the support of the Water Authority (which have their origins in the earlier studies), are the Perth/Bunbury Regional Planning Study (WAWRC, 1987), Water for the 21st Century' (WAWRC, 1988), and the Water Conservation Plan 1987/89 (Water Authority, 1987a).

The Perth/Bunbury Regional Planning Study is investigating water demands, issues, allocation options and development/management options on a multi-purpose basis for the region. As this study progresses, it will provide information and broad value assessments to help guide more specific planning in the region and to guide other planning agencies. The regional information base for water planning is currently somewhat fragmentary and is strongest in relation to public water supply and public irrigation. Some early initiatives in this study therefore have been directed towards recreational, environmental and private horticultural use.

'Water for the 21st Century' was a study to investigate the long-term options for water supply to Perth and the south of the State. The report gives the public an appreciation of the options available when local resources can no longer supply all of Perth's needs, and provides useful direction to strategic planning.

The Water Conservation Plan outlines programmes for encouraging more efficient use of water as a means of reducing pressures on the environment and capital costs.

The development of the Metropolitan Source Development Plan (SDP), has been the most significant specific-purpose strategic planning initiative in the region. It was first produced by the Metropolitan Water Board in 1975 and is continuing to be updated and employed in the planning processes of the Water Authority. The SDP can be viewed as a considered bid for water resource allocation on behalf of present and future members of the community requiring a public water supply. This bid provides a realistic basis for projecting long-term water planning priorities and issues and presents the most favourable supply options for further, more detailed, assessment and implementation planning.

PROJECT PLANNING

Project planning involves the preparation of specific purpose plans to deal with short-term demands or issues.

The demand projections of the SDP indicate the years at which new source developments will need to be commissioned and the plan indicates the most economically favourable source. Project planning commences as the anticipated commissioning date approaches, typically a minimum of 6 to 10 years ahead.

All other potential sources that could realistically meet the same requirements as the most economically favourable source are identified. A broad-based (multi-objective) assessment of these alternatives for the next major source is undertaken to determine the most beneficial source. This evaluation involves environmental and social as well as economic and engineering considerations, and may involve active public participation.

The selected project then proceeds to detailed design, including preparation of implementation and management plans.

ENVIRONMENTAL ASSESSMENT

The environmental impact assessment process is an integral part of project planning which:

- provides environmental input to the multi-objective evaluation and detailed design phases;

- involves documentation of the project planning process to facilitate EPA and public review of the project;

- provides a procedure for seeking formal environmental approval.

Before any scheme for development of a source for public water supply can be constructed, the proposal must be submitted to the EPA for review of its environmental impacts and environmental management plans. At the commencement of project planning, the Water Authority refers details of its proposals to the EPA. The EPA may then approve the environmental aspects of the proposal if they are obviously minor, or may request a higher level of Environmental Impact Assessment (EIA) through a Notice of Intent (NOI), Public Environmental Report (PER) or an Environmental Review and Management Program (ERMP).

For larger projects requiring an ERMP, a two-stage approach may be favoured. Stage 1 documents the multi-objective evaluation process and seeks environmental approval in principle for the selected source. Stage 2 documents the final project design, detailed environmental investigations and proposed management measures and seeks environmental approval to allow the project to proceed to implementation. The EPA seeks public comments on the ERMP and provides advice to Government, based on assessment of the ERMP and of the public submissions.

The Minister for Environment sets environmental conditions on the proposal before it can be implemented. These are based on the recommendations of the EPA and additional material brought before the Minister by the public, the proponent or the EPA.

3. THE DEMAND FOR WATER

WATER USERS

The principal demand for water from the MWS comes from users within the Perth metropolitan area. The MWS has expanded to meet the water needs of Perth's increasing population and the needs of nearby towns which have come within a distance that makes connection desirable. Map 1 shows the areas currently served by the MWS and generally how water is distributed from source works to the area of demand. The water is mainly used for domestic supplies and industrial and commercial applications.

The MWS has also been used to improve the security of supply to the Goldfields and Agricultural Water Supply Scheme (G&AWS). The water for the G&AWS can only be drawn from the Helena Reservoir, but the demand is now slightly in excess of the yield that can be relied upon (safe yield) from the Helena Reservoir operating by itself. Pipelines have been installed to transfer water to Helena Reservoir from other MWS sources to maintain security of supply.

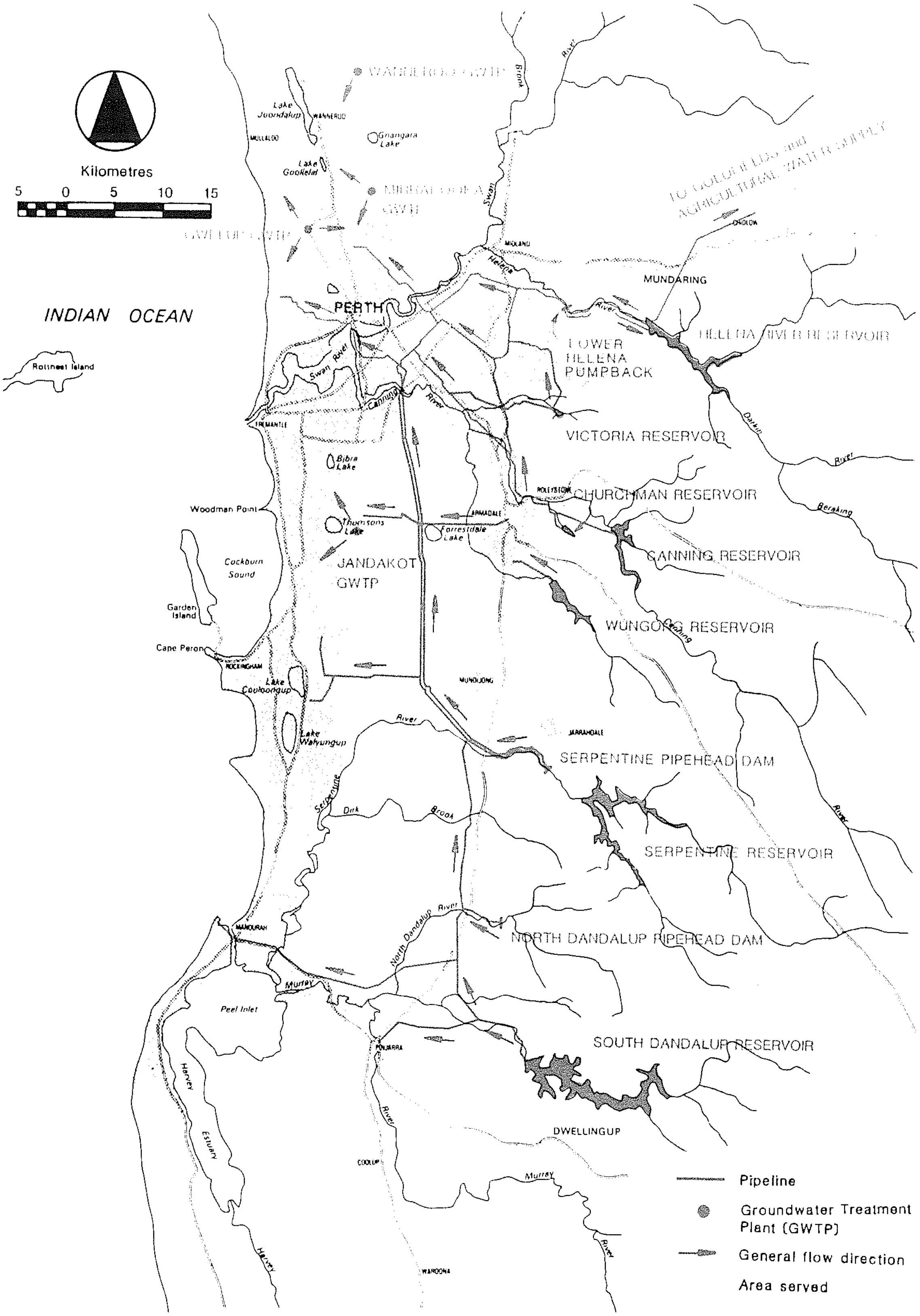
DEMAND HISTORY

Water use from the MWS increased through the 1960s and early 1970s (Figure 2) and the rate of increase was considerably in excess of the growth rate of the population served, i.e. water used per person was increasing.

Rainfall in 1975 and 1976 was well below average and it became evident that restrictions on water use would be required if trends in the demand continued and there were more dry years. A public education campaign was mounted in the summer of 1976/77 and water use for that year was 10% less than in the previous year. The drought continued and restrictions on the use of garden sprinklers were needed for nearly two years. The construction of additional groundwater schemes and the Wungong Dam allowed restrictions to be lifted in May 1979. There have been no general restrictions on water use since that time, although in 1987/88 restrictions were averted only through the success of a publicity campaign encouraging water conservation.

An unexpected effect after the lifting of restrictions in 1979 was that water use in the following years did not immediately return to the pre-restriction levels. It is likely that further restrictions would have been necessary if it had done so.

A Domestic Water Use Study (MWA, 1985), conducted over 12 months in 1981/82, found that there was about a 50% increase in the number of private wells in the metropolitan area during the restriction period from 1977 to 1979. As most private wells are used for garden irrigation, the effect of a well on demand for water from the MWS is similar to water restrictions in that



Map 1 Existing MWS Sources, Distribution and Areas Served

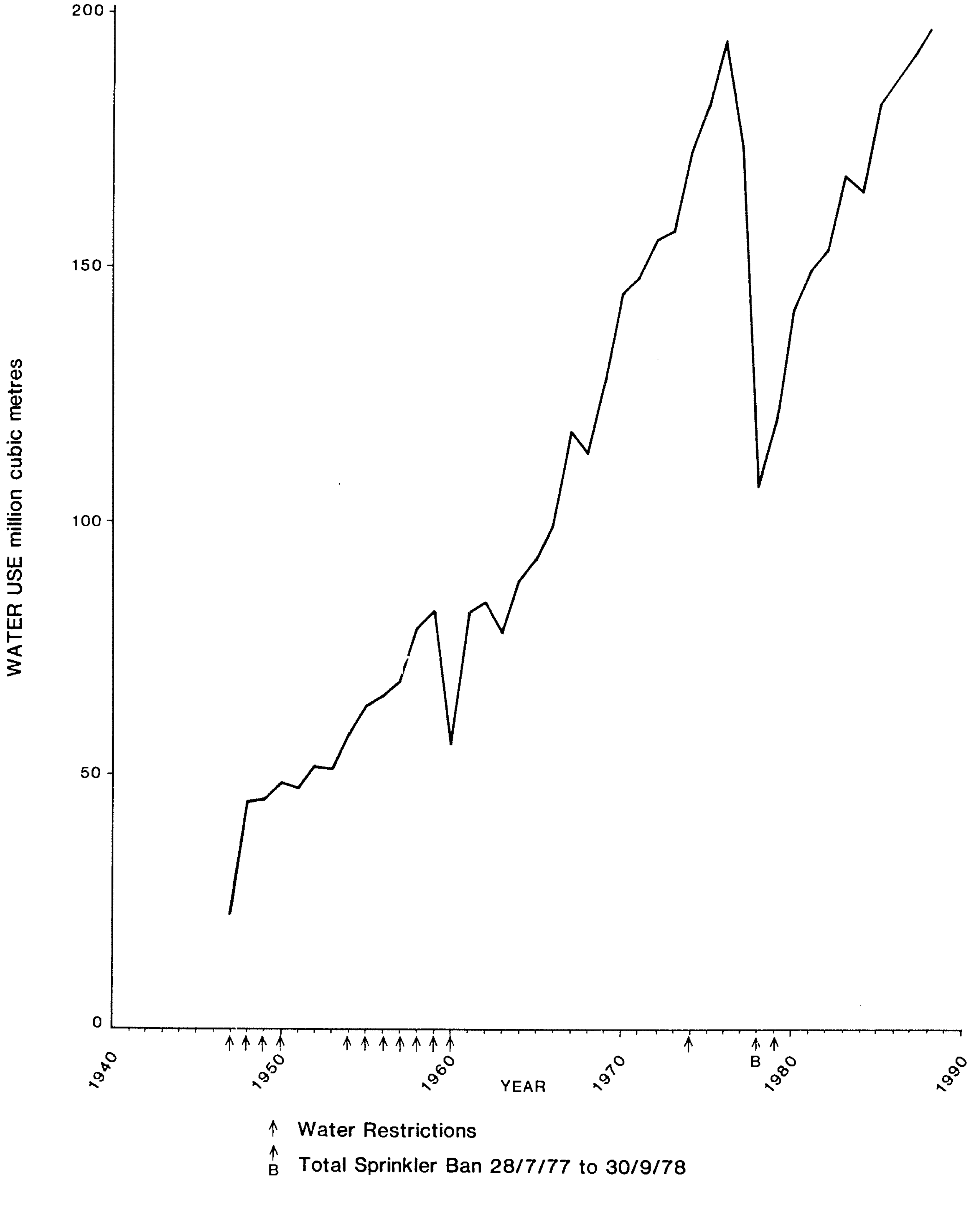


Figure 2 ANNUAL WATER USE FROM PERTH'S PUBLIC WATER SUPPLY

it reduces use of MWS water by single residences. The difference is that the effect of a well is permanent.

The total amount of water drawn from private wells in the metropolitan area can only be approximately estimated because most wells are not metered and records of the number of wells installed are incomplete. However, on the basis of estimated well-water usage, it would appear that overall water use per person (from the MWS and private wells) returned to pre-restriction levels two years after restrictions were lifted (Figure 3) but with a reduced demand per person on the MWS.

There are other factors which are likely to have reduced demand since 1979 from what it would otherwise have been:

- a continuation by individuals of water conservation habits acquired during the restriction period. e.g. maintenance of native gardens;

- introduction in 1978 of 'pay-for-use' for services to residences, which included setting the basic water allowance at 150 kilolitres per service, instead of basing it on the rateable value of the land (a reduction in free allowance for most services);

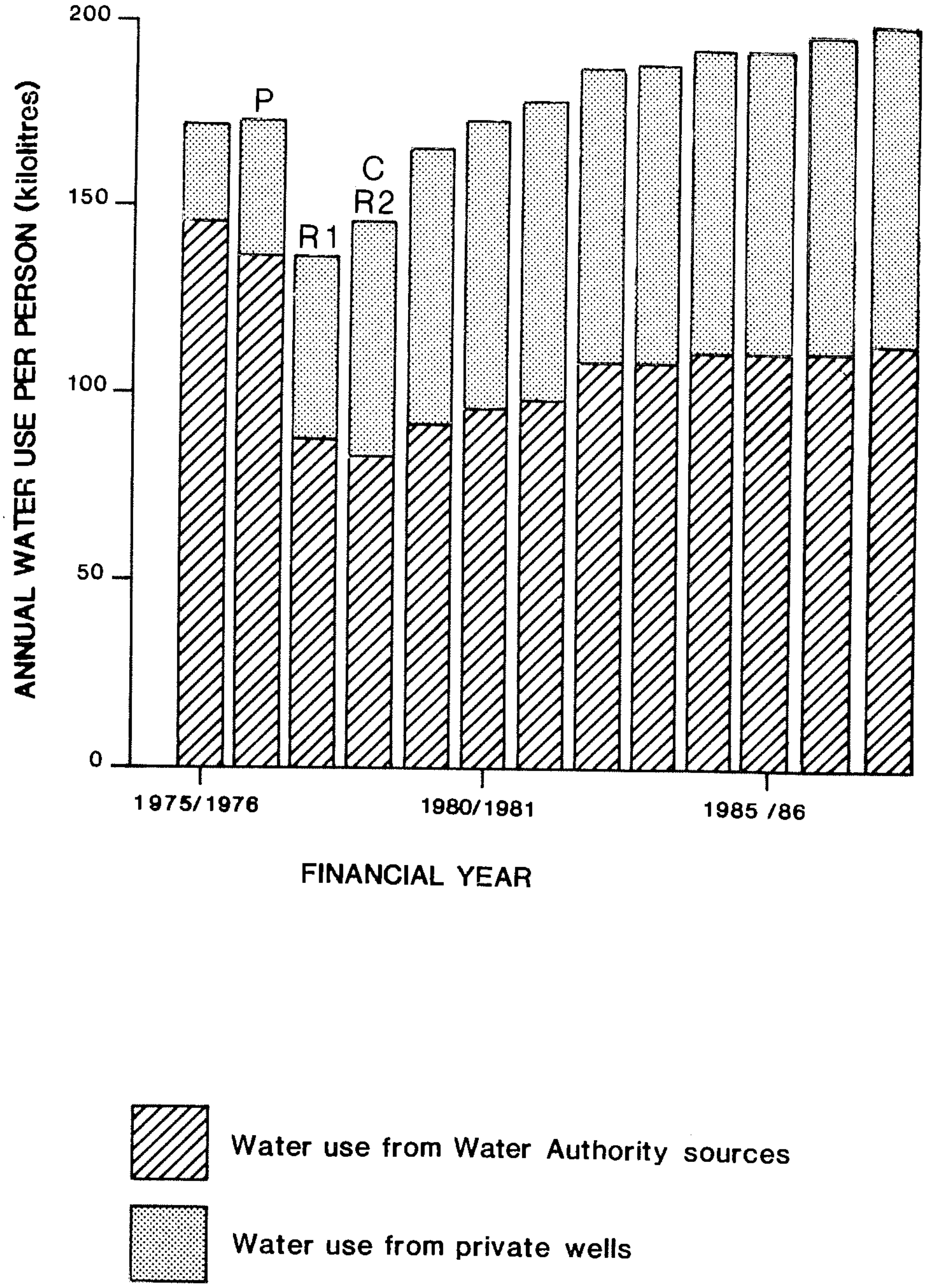
- increases in the charge per cubic metre for excess water use by residences (the Domestic Water Use Study estimated that a 10% rise in the cost per cubic metre would result in a 3% reduction in use of water outside the house);

- introduction in 1982 of a new tariff policy for industrial and commercial users, including gradual achievement of 100% metering and a 'pay-for-use' scheme.

PREDICTING FUTURE DEMANDS FOR WATER

The Water Authority needs to estimate future demands on the MWS so that sufficient supply capacity will always be available. Scheduling of construction works for new sources is based on a short-term projection of demand which is basically an extrapolation for the next five years of recent trends in water use. Determining priorities for development of potential water sources and identifying the next source to be developed require a longer view into the future.

The current curves of projected water use for the next 25 years are shown in Figure 4. These projections are based on many assumptions (Appendix C). However, the principal factor is the population projection produced by the Treasury (W.A. Treasury, 1986) and the State Planning Commission (SPC, 1987). The influence of these assumptions on the demand projection is shown by using extreme assumption values which lead to higher demands (a 'maximum' projection) and to lower demands (a 'minimum' projection).



P = Promotion campaign urging water conservation

R1 = Total sprinkler ban 28/7/77 to 30/9/78

R2 = Sprinklers only 6am to 7am and 6pm to 9pm
Alternate days 1/10/78 to 20/12/78
Sprinklers only 6pm to 7pm from 21/12/78 to 21/5/79

C = Pay for use introduced on 1/7/78

Figure 3 ANNUAL DOMESTIC WATER USE PER PERSON PERTH METROPOLITAN AREA

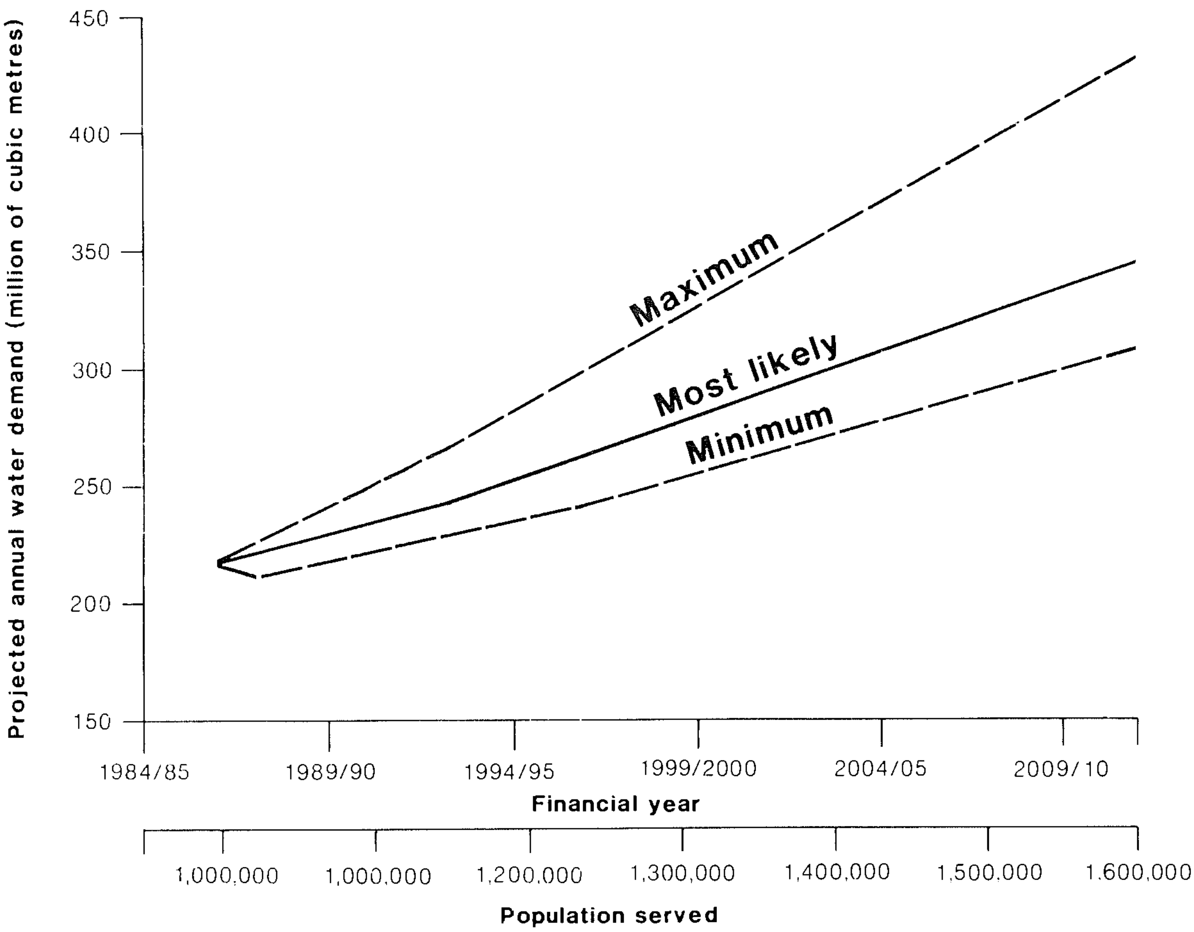


Figure 4 Projected Annual Demand for Public Water Supply for the Perth Metropolitan Area (as at 1986)

WATER CONSERVATION

The Water Authority is formulating a water conservation strategy as part of its programme for managing water resources efficiently. Water conservation is a programme which is adopted to achieve effective management of the use of water resources in order to meet the general objectives of economic effectiveness, environmental conservation and community and consumer satisfaction (AWRC and WAWRC, 1986).

Generally, water conservation involves working towards these objectives by implementing strategies in the following areas:

Education: e.g. information can be broadcast to teach people how to water their lawns efficiently.

Design: Dual-flush toilets are an example of a design change which can result in significant savings of water.

Regulation: Restrictions are one example of 'regulation', and another example is that certain plumbing fixtures or appliances that are attached to the public water supply must conform to design standards specified by the Water Authority.

Pricing: People tend to be more careful in using water when they know that the more they use, the more they pay.

The Western Australian Water Resources Council has published a book which presents practical ideas to help planners, landscape architects, architects, and engineers to incorporate water conservation in their designs for urban areas in Western Australia (WAWRC, 1986).

Water conservation reduces overall water use, but costs can also be reduced by shifting some water use away from the time of peak demand. For example, pipes and pumps must be large enough to satisfy peak demands. They need not to be so large if enough demand can be moved to other periods of the day. Strategies to achieve such management of demand are part of the activities of water conservation.

The Water Authority has established a policy on Urban Water Conservation and has prepared a Water Conservation Plan (Water Authority, 1987a) to guide the implementation of the policy in the immediate future. The initial actions are aimed mainly at increasing public awareness and improving public education on the principles of water conservation. The target is to hold the total consumption for the Perth Metropolitan area at the 1986/87 level of 190 kilolitres per person per year by 1991/92. Current trends of increasing consumption per person will need to be halted to meet this target. The 'most likely' demand projection (Fig. 4) assumes that the target will be achieved.

WATER RESTRICTIONS

General water restrictions are a form of water conservation which are already effective in keeping down the cost of the water supply system. If restrictions were allowed only as an emergency action in an extreme drought, the maximum demand which could be sustained by the existing system would be about 12% less and new sources would need to be built sooner and more frequently.

The current restriction policy allows for some level of general restriction in 10% of years, with the most severe form of restriction occurring in 5% of years. Table 1 shows the three levels of restrictions currently available, and the percentage saving in demand expected in a year in which they are applied.

During extended periods of low rainfall, restrictions may be needed for two or more consecutive years. In most cases, however, it is expected that restrictions would only be needed for one or two years.

Table 1 Classes of General Water Restrictions for the MWS

Restriction class	Assumed method of application	Maximum probability of this class or worse	Reduction in annual demand
Class 1	Sprinklers banned 7 am to 8 pm	10%	14%
Class 2	Sprinklers banned except 2 hours/day	7%	29%
Class 3	Total sprinkler ban	5%	46%

4. WATER RESOURCES

SOURCES OF WATER

The types of water resources currently used by the MWS, and of most interest for development of further supplies in the near future, are river (surface) resources, shallow (unconfined) groundwater and artesian (confined) groundwater.

There are other resources which could be used for water supply. These include surface (stormwater) drainage, wastewater re-use and desalination of seawater or brackish water sources. At present only desalination could provide another practical source of drinking water, although surface drainage and wastewater re-use are increasingly useful for industry, irrigation and maintaining the environment.

Perth faces particular water supply problems because, unlike many Australian cities, there is no single large fresh water source which could supply water needs for many years to come. As the demand for water increases, it will be necessary to continue to develop the relatively small sources which are available.

Cost is a major factor in determining which potential water sources are considered for development for the MWS. Table 2 gives an indication of the cost of producing water from various types of sources with costs of existing sources and the cost of distributing the water shown for comparison. Water supplies are currently drawn from groundwater resources within the Perth Metropolitan Area and rivers to the east in the Darling Range. Increasing water requirements will generate pressure to develop water sources further afield. When considering potential resources at greater distance from the centre of demand, the cost of transporting the water to Perth becomes more and more

Table 2 Approximate Costs of Water from Various Sources

(Including costs of delivery to the metropolitan area but excluding distribution costs which amount to 39 cents/kl on average)

	WATER SOURCE	COST (Dec. '87 Prices) cents/kilolitre
1.	Currently developed sources (averages)	
	i) Hills sources (pipeheads and dams)	11
	ii) Treated groundwater	22
	iii) Artesian groundwater (untreated)	9
2.	Future treated groundwater sources	17 - 44
3.	Future major metropolitan hills sources north of Pinjarra	19 - 40
4.	Rivers south of Pinjarra	46 - 74
5.	Desalination of	
	i) Brackish surface water (including pre-treatment)	100
	ii) Sea water	180
6.	Rainwater tank (tank purchase only)	300
7.	Water from the Kimberleys	535
8.	Icebergs from Antarctica	very expensive with present technology
9.	Solar distillation	not yet proven on a commercial scale

critical in determining the feasibility of a proposal. A distance of 700 kilometres has been estimated as the maximum from which a good source of water (not requiring desalination or other treatment beyond chlorination) could be transported at a cost less than the cost of desalination of seawater. The geographical significance of this distance is shown in Map 2. The maximum distance to brackish sources which require desalination, or sources which require other treatment, is considerably less. Consequently, sources estimated to cost considerably more than seawater desalination, such as water from the Pilbara or the Kimberley, or icebergs from Antarctica, have not been considered further in this report as potential water sources for Perth.

The study on 'Water for the 21st Century' (WAWRC, 1988) has shown that there are sufficient water resources in the south of the State to meet foreseeable demands, at least until the middle of next century. No details are given here on sources more distant from Perth than Harvey because nearer sources which are cheaper should be able to meet demands for the next 25 years. The more expensive sources close to Perth are identified so that the importance of preserving the water quality of streams and groundwater in their catchments is recognised.

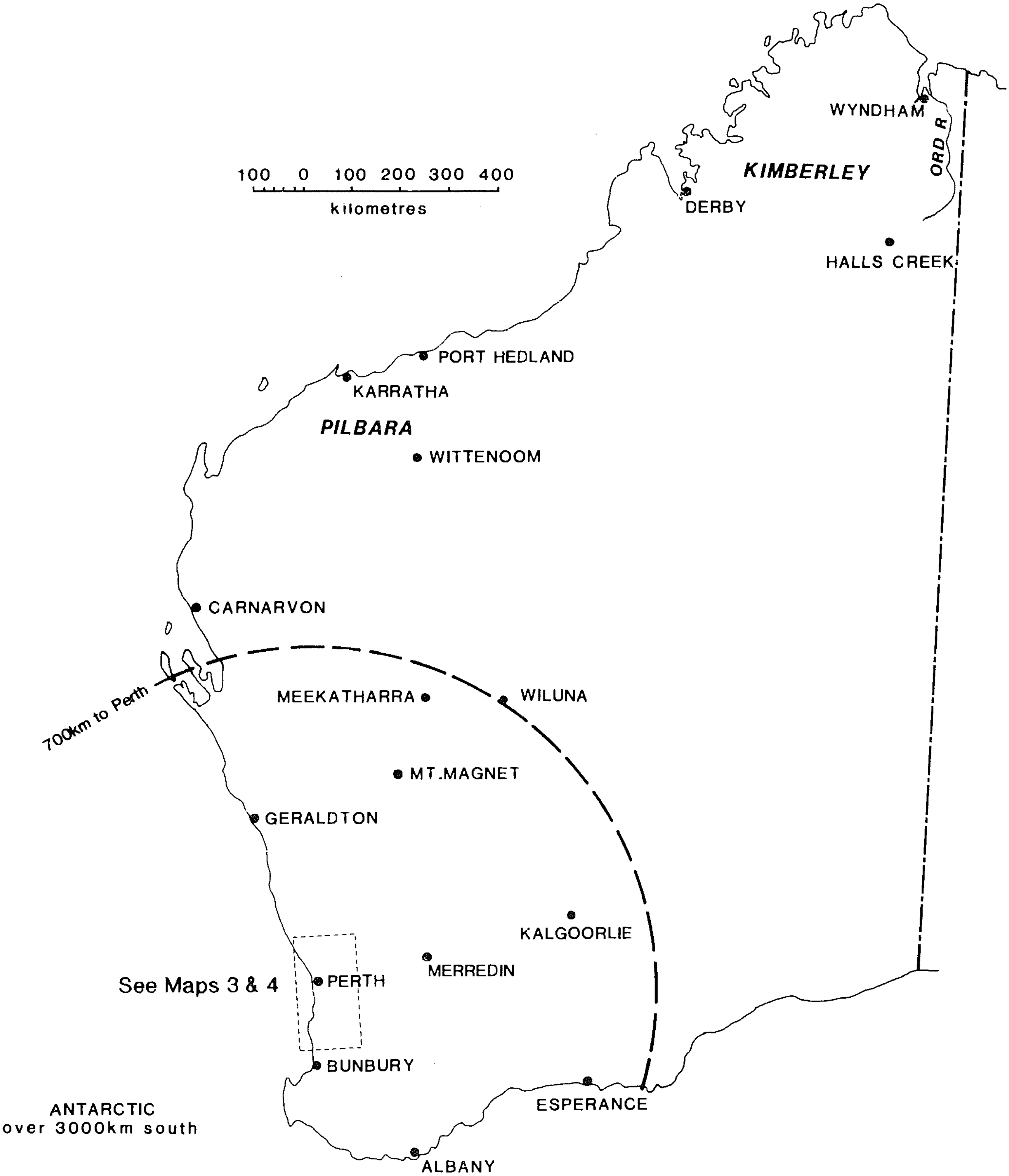
The following sections discuss resources which currently supply water to the MWS and those which have been being given more detailed consideration as future sources. The location of the resources is shown in Map 3 and information on schemes to develop them is given in Map 4, Chapter 7 and Appendix A.

RIVER (SURFACE) RESOURCES

River sources currently supply about 70% of Perth's water. At present, the only treatment required before supplying the water to consumers is disinfection by chlorination.

The catchments of rivers currently supplying the MWS are all east of the Darling Scarp between Mundaring in the north and Dwellingup in the south. The catchments are almost totally covered by native forest, with small areas of pine plantations, orchards and pastoral land. The main commercial activities in the forest are timber production and bauxite mining, although there are many smaller industries which make use of the forest resources. The forest is also renowned for its conservation and recreation values. The rivers are currently generally fresh, but permanent clearing of forest in the drier parts of the catchment would certainly increase salinity.

Several smaller catchments along the western edge of the developed catchments have potential as river resources because they are in relatively high rainfall areas and can be harnessed quite cheaply by pipehead or pumpback schemes, i.e. without a large reservoir on the stream. (Water supply schemes are described in Chapter 5). Some of these catchments contain orchards which make a significant contribution to the State's



Showing the geographical significance of the 700km radius from Perth (the estimated maximum distance from which a good source of water could be transported at a cost less than desalination of sea water)

Map 2 Location Map

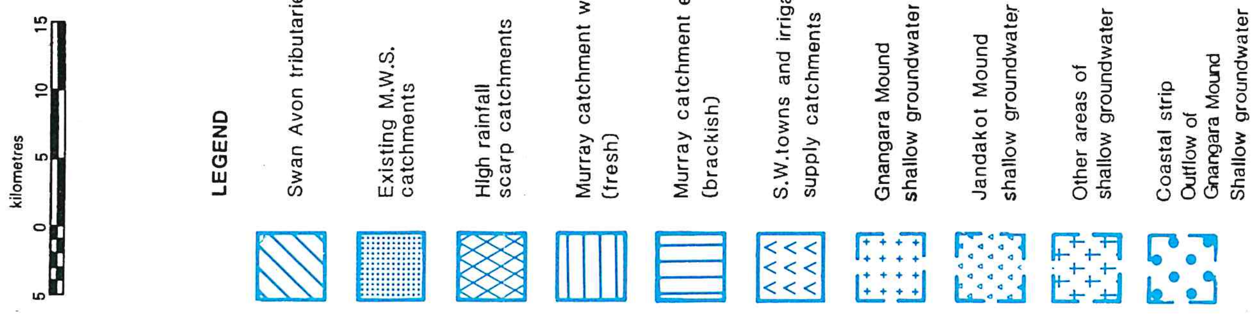
agricultural production. The areas are also becoming attractive for special rural (smallholding) subdivision and development due to their proximity to Perth. However, these catchments are still mostly forested, with enclaves of privately-owned rural land. Salinity is not a problem here because if any salt is flushed from the soil after clearing, it is diluted by the increased streamflow caused by clearing. Generally, river water from catchments containing significant areas of agricultural or residential land is not of sufficiently good quality to allow direct supply to consumers after disinfection alone. Schemes for developing such rivers must provide for extra treatment, storage or selective use by taking water only when the quality is satisfactory.

To the south of Dwellingup lies the Murray River catchment. The eastern portion of this catchment has been cleared for agriculture and the river flows are now brackish. The western portion of the catchment is still forested and streamflows from tributaries in this area are fresh or only slightly brackish. Although identified as a potential future water resource, through declaration of a Water Reserve over the area, the western area has gained a reputation for wilderness recreation, especially along the main river valley. Areas suitable for conservation reserves have also been located nearby, and the Lane-Poole Reserve encompasses the area of conservation and recreation priority. There is no provision made for water supply development in the vesting and purpose of the Lane-Poole Reserve.

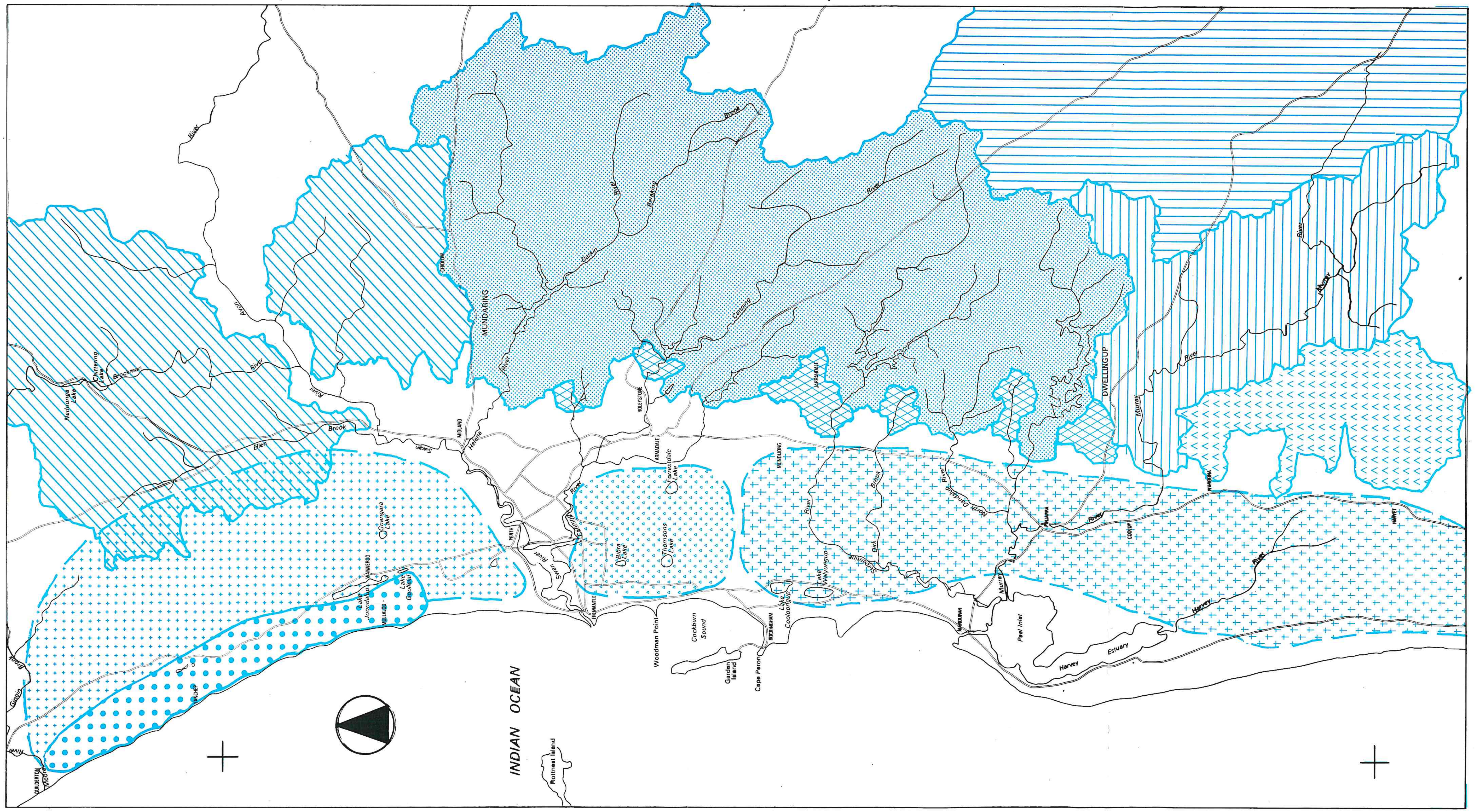
South-west of the Murray catchment are more forested catchments which have been dammed to provide supplies of irrigation water to farmers in the Harvey-Waroona Irrigation district, and for local supplies to towns. Of these catchments, the Harvey River has been identified as having the potential for greater utilisation for Perth's water supply if the Harvey River Dam was increased in size, without detriment to existing uses of the resource.

To the north of Mundaring are catchments of tributaries of the Swan and Avon Rivers. These catchments are predominantly privately-owned rural land which has been substantially cleared, leaving remnants of native forest. An exception is the Julimar State Forest and adjoining Bindoon Army Training Ground. These forest areas occupy a large proportion of the Brockman and Julimar River catchments. All the catchments are affected by increases in stream salinity due to the agricultural clearing. The Brockman and Wooroloo Rivers are brackish and would require desalination to provide potable water supplies. The other rivers have salinities near the upper limit of 'fresh'; the water could be used for water supply after normal treatment if mixed with fresher water. The water from these catchments also requires more treatment for water supply than simply disinfection due to the high level of human activity.

Land use in river catchments has a strong influence on the quantity and quality of the water, and the availability of



Map 3 Water Resources near Perth (excluding Artesian Water)



sites for the development of the resource for public water supply. Reduction of water quality, for example by pollution or increasing salinity levels, and constraints on development sites for dams and other works lead to increased costs of water from the source and consequently higher costs of water to the metropolitan consumer. In its role of conserving and managing the State's water resources, the Water Authority must be aware of plans or land use changes in catchments, to protect both the quality of the existing water supply and of the water resources which have potential as future sources. The potential impacts of land use on river resources are summarized in Tables B2 and B4 in Appendix B.

SHALLOW GROUNDWATER RESOURCES

Shallow (unconfined) groundwater is found if a hole is dug to below the water-table in the sand which forms the surface layer over large areas of the coastal plain north and south of the Swan River. The sand can be 20 to 100 metres thick in places. Lakes (e.g. Gnangara Lake, Bibra Lake) occur on the coastal plain where the water-table lies above the natural depressions in the ground surface. Figure 5 illustrates shallow groundwater occurrence and movement.

The source of the groundwater is rain which drains through the sand to the water-table. The availability of groundwater is ultimately limited by the amount of rain received. Much of the rain does not reach the water-table because it evaporates from the wet ground, vegetation and ponded water, or is drawn from the soil by plant roots and returned to the atmosphere by transpiration.

In deciding how much shallow groundwater can be drawn from wells for public or private use, consideration must be given to the environmental importance of the groundwater. Pumping from wells lowers the level of the water-table, more so very close to a well. Wetlands and lakes which are formed where the water-table is at the ground surface may become shallower or dry up if the water-table lowers. If the wetland or lake has significant conservation or recreation value which could be damaged if the water level was lowered, then pumping in its vicinity may have to be limited or avoided. The EPA, when reviewing EIA's for new groundwater schemes, has expressed particular concern that the environmental values of specific lakes and wetlands are not jeopardised by the projects. The EPA has set criteria specifying the minimum water levels which must be maintained in some lakes (EPA, 1987).

Shallow groundwater is often coloured by peaty deposits, contains iron, is turbid and has an odour. Consequently, schemes to develop these sources for public water supply routinely involve treatment of the water in a treatment plant. Groundwater schemes are described in general in Chapter 5.

The shallow groundwater resources to the immediate north and south of Perth are referred to as 'groundwater mounds' because

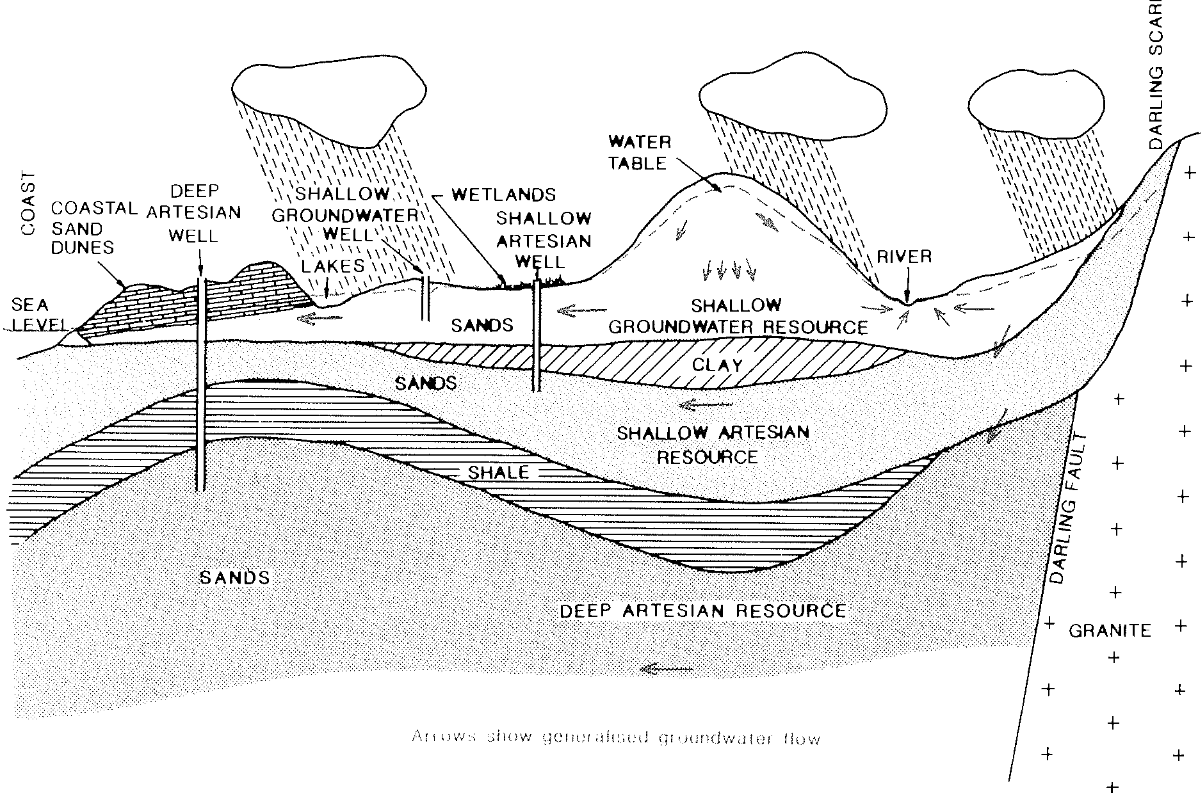


Figure 5 Occurrence and Movement of Groundwater

the water-table would have the general appearance of a mound if it could be seen over fairly large areas. To the north of the Swan River, the Gnangara Mound rises to about 70 metres above sea level. To the south, the Jandakot Mound rises to about 25 metres above sea level.

Groundwater schemes on both the Gnangara and Jandakot Mounds are supplying about 25% of the water in the MWS, and proposed schemes listed in Chapter 7 could greatly increase the quantity of groundwater presently used for public supply.

Large areas of State Forest on the Gnangara Mound have been progressively cleared of native vegetation to grow pines for timber. An equal area is owned by the Australian Government for defence purposes and is generally covered by native vegetation. Around Wanneroo, and nearer to Perth, market gardening is an important activity, and development of special rural zones and suburban areas is increasing.

The area marked as 'Coastal strip outflow of Gnangara Mound' on Map 3 is gaining greater significance as a water resource since the quantity which can be drawn from the Gnangara Mound further inland is becoming increasingly limited by environmental constraints and competition for the resource. Because the groundwater is in limestone along this part of the coast, fairly large volumes of water can be drawn without affecting inland wetlands or local environmental values (with

Yanchep National Park being a notable exception). State Planning Commission plans (SPC, 1987), indicate that most of the strip is intended to become urban land. Great care must be taken during design of urban development to prevent pollution of the groundwater.

On the Jandakot Mound, the land is predominantly privately owned rural land with about a quarter uncleared. Substantial areas are subject to winter flooding, and drains have been installed in the southern and eastern flanks of the mound. As with the Gnangara Mound, there are some areas of market gardening and special rural land use. Jandakot Airport is located at the northern end of the mound. Proposals to urbanise land east of Thomsons Lake have the potential to increase the water useable for public supply because the amount of vegetation which uses the groundwater is reduced. However, risks of pollution of groundwater must be minimised by recognising during engineering design of the subdivisions that the area will be used as a water supply source.

Shallow groundwater resources also exist north of the Moore River and south of the Serpentine River. Agriculture is an important land use in both regions, and extensive drainage works have been constructed to improve the viability of farming. The Water Authority and the Geological Survey are continuing to investigate these regions to assess their potential as sources for future public water supply.

As with river resources, land use in areas where there is a shallow groundwater resource can significantly affect the water quality and its availability for development for public water supply. Table B6 in Appendix B gives a guide to the potential impacts of land uses on shallow groundwater resources. Groundwater Areas (and similarly Groundwater Reserves, Underground Pollution Control Areas and Public Water Supply Areas) have been declared for specific areas in response to problems arising from competition for the resources and the effects of land uses with potential for pollution. These areas give the Water Authority a basis for effective management and conservation of the shallow groundwater resources. The means for administering these areas include representation of local interests through advisory committees, as well as the application of by-laws and regulations.

ARTESIAN WATER RESOURCES

Artesian water is located in sandy material between layers of almost watertight (impermeable) material such as clay, usually at considerable depth below the ground surface. The water is under pressure and when a well is drilled into it, the water in the well rises and may even flow to the surface.

In most areas around Perth there are two principal sources of artesian water located one beneath the other with an almost impermeable layer of shale between them. The upper source is generally separated from the shallow groundwater above it by clay. The occurrence and movements of artesian groundwater are shown in Figure 5.

The total volume of artesian water below Perth is enormous, but the rate of replenishment from the recharge areas is quite low, with the water taking several thousand years to move from where it fell as rain to an artesian well in Perth.

In the interests of conservation and good management of the resource, the rate at which water is removed from the resource should not exceed the rate at which it can be recharged. This means that there will be a limit on the development of the resource. Long-term monitoring of artesian water pressures will enable assessment of these limits. All artesian wells must be licensed by the Water Authority so that, if necessary, the total quantity being drawn can be controlled.

A recent review of the monitoring data from the deep artesian resource suggests that the limit of development for this resource may be much lower than was previously estimated. The revised limit is 15 million cubic metres per year on average, compared to a current useage of 12 million cubic metres per year and a potential useage of 37 million cubic metres per year if all previously planned schemes were developed. The reduced limit has been used as a basis for planning in this revision of the SDP.

Land use in the immediate vicinity of an artesian well has no impact on the resource, but land use on recharge areas could be significant if it causes persistent pollutants to enter the artesian water. However, if reasonable care is taken of the shallow groundwater in the recharge areas, special precautions should not be necessary.

Generally, the water from the shallower artesian source has a relatively high iron content and needs treatment to make the water quality satisfactory for public water supply. Consequently, wells in this source are usually developed in conjunction with shallow groundwater schemes which also require treatment (see Chapter 5).

Water from the deeper source usually does not need treatment but is quite warm (about 40°C) and may have a salinity too high to be suitable for drinking. Both these problems can be overcome by feeding the water into a service reservoir where it mixes with cooler, lower salinity water from other sources.

DESALINATION

Desalination is the treatment process of removing salts from brackish or saline water. It is a common technique for producing potable water when sources of fresh water are insufficient or non-existant. Some of the resources described so far are brackish and would require desalination if they are to be developed for water supply. When the cost of developing fresh water sources at further distances from Perth becomes great enough, desalination of nearby brackish sources will become economically preferable. More brackish sources, particularly groundwater, are likely to be identified near Perth by future investigations, but the total resource will still be fundamentally limited by the quantity of rainfall available annually to replenish the sources, and additional sources will have to be sought from further afield. Eventually, if Perth's population continues to grow, desalination of seawater will be the economically preferred source of additional water.

Because brackish water often needs pretreatment before it is actually desalinated, the plant size is generally similar to a conventional treatment plant of similar capacity, such as a groundwater treatment plant. A particular environmental problem of such plants is disposal of the waste-water in which all the salt has been concentrated by the process.

The size of a seawater desalination plant depends on the size of the demand it is to serve, with the largest plants being comparable in size with a major power station. Economies possible with large plants make them attractive for large demands, as opposed to using many small plants, but environmental impacts at the site of a large plant could be more severe than for smaller plants. However, if there is a power station planned for a suitable location, there would be very little additional environmental impact in incorporating a desalination process.

The greatest disadvantage of desalination is the cost, which includes the requirement for an abundant source of energy. Costs per cubic metre for seawater desalination would be approximately four times the current charges for water, and power requirements would be approximately 7 kilowatt hours (units) per cubic metre. Costs of desalination of brackish water are generally about half those of seawater desalination and energy requirements are less, depending on how saline the water source is.

RE-USE OF WASTEWATER

There is no immediate prospect that treated sewerage effluent could be economically purified sufficiently to allow its re-use in the public water supply system.

Treated wastewater is used in many Western Australian country towns for irrigating sports fields, providing facilities for the community and effectively contributing to the public supply by reducing the demand for irrigation water. Re-use of wastewater is subject to Health Department regulations and care must be taken that the 'second class' supply cannot be inadvertently used for drinking water.

In the metropolitan area, sports fields are usually irrigated with groundwater. Until positive plans are made for re-use of wastewater in a way which reduces existing or projected demand on the MWS, no allowance will be made for it in demand projections.

It has been suggested that recharge of treated wastewater to groundwater could increase the available groundwater resource. An experimental recharge scheme was operating for a number of years to assess the practicality of such recharge. It used some of the effluent from the Canning Vale Waste Water Treatment Plant. It showed that the effluent should be further treated to remove nutrients before recharge, to avoid environmental problems when the water reaches wetlands. This makes the process very costly, in addition to the problems of finding suitable areas for recharge and the environmental impacts of the large infiltration ponds required. These results suggest that other options for re-using wastewater would be economically and environmentally preferable to using it for groundwater recharge.

DEVELOPMENT OF PRIVATE RESOURCES

People who could draw water from the public supply but choose to obtain part of their supply from other sources effectively reduce the demand on the MWS.

Private wells, which are usually installed for irrigation purposes, can be economically attractive and in many cases make use of water not readily accessible to, or of a quality suitable for, public supplies. However, private wells cannot be recommended as a complete substitute for a service from the public water supply because of the health risk associated with drinking untreated water. Efficient private use of groundwater resources can contribute to overall efficiency of water supply, but if many private wells compete for the same resource (for example the shallow groundwater in urban areas) issues of over-exploitation, pressures on wetland areas, or fair allocation of the resource may arise. These issues must be addressed by a management policy.

Currently, about 28% of residential lots in Perth have a private well. Increases in the number of such wells will be limited in the future by the availability of the water resource (Cargeeg et al., 1987). When well water is not available then residences will still want some water for irrigation, but usually not as much as when there is access to a well. The amount that is required becomes additional demand on the public supply system. Demand projections for this SDP have considered variations in percentage of well ownership and the absolute limit to the number of wells. In the 'most likely' demand projection, the maximum number of wells would be reached in the year 2004 if the amount of water pumped from each well continues as at present.

Rainwater tanks are often suggested as a means of reducing demand on public supplies. In Perth, however, a house roof can rarely supply a household's complete water requirements, and the cost of the tank makes the water many times more expensive than the public supply. There may also be significant health risks if tanks are used as a source of drinking water without sterilization.

5. WATER SUPPLY SCHEMES

The quantity of water which can be drawn from a water resource depends on the size of the resource, the nature of environmental or social constraints on use of the water, and the mechanics of the works used to withdraw the water. The quality of the water available will also influence the method of developing the resource so that quality criteria (Appendix D) for water delivered to consumers are achieved. If the constraints are known, engineering studies can determine the most efficient way to develop the available resource.

RIVER RESOURCES

MWS schemes for development of river resources for water supply can be generally classified as 'main dams', 'upper dams', 'pipeheads' and 'pumpbacks'.

- Main dams create a major reservoir in a valley. Water is delivered, after disinfection by chlorination, directly to consumers or to service reservoirs in the city.

- An upper dam creates a major reservoir on a river upstream of a main dam. Water is released from an upper dam to flow down the river into the main dam in order to maintain desirable water levels in the reservoir of the main dam.

- A pipehead is a small dam only large enough to allow the water flowing in the river to be diverted into a pipe. The diverted water is supplied to consumers in the same way as water from a main dam.

- A pumpback uses the same type of small dam on a river to divert the streamflow, but instead of delivering the water for immediate use, the water is pumped through a pipeline into one of the major reservoirs.

These scheme types are shown diagramatically in Figure 6, and information on size and other characteristics is presented in Table 3. Appendix B broadly indicates the effects of river resource development in forest land (Table B3) and in rural and urban land (Table B5).

Table 3 Characteristics of Schemes for Development of River Sources

	MAIN DAM	UPPER DAM	PIPEHEAD	PUMPBACK
TOLERANCE OF CATCHMENT AREA TO POLLUTING ACTIVITIES	Low	High	Low	High
DAM TYPE	Storage	Storage	Pipehead	Pipehead
DAM HEIGHT	15 - 70 m	30 - 70 m	3 - 10 m	3 - 10 m
RESERVOIR: AREA VOLUME	10 - 200 ha 1 - 200 mill.cu.m	300 - 2000 ha 50 - 200 mill.cu.m	1 - 10 ha 20 - 100 thou.cu.m	1 - 10 ha 20 - 100 thou.cu.m
PIPELINES/TUNNELS AWAY FROM DAMSITE	To consumer	None	To consumer	To storage reservoir
WITHDRAWALS	Supply all year round.	Release water to replenish lower reservoir.	Supply June - November.	Pump to reservoir June - November unless reservoir too full.
DOWNSTREAM FLOWS	Downstream flow only from riparian release or occasional winter overflow.	Flow downstream controlled by release policy, plus occasional winter overflows.	Downstream receives flows in excess of pipe capacity in June - Nov., and total stream flow in other months.	Downstream as for pipehead.

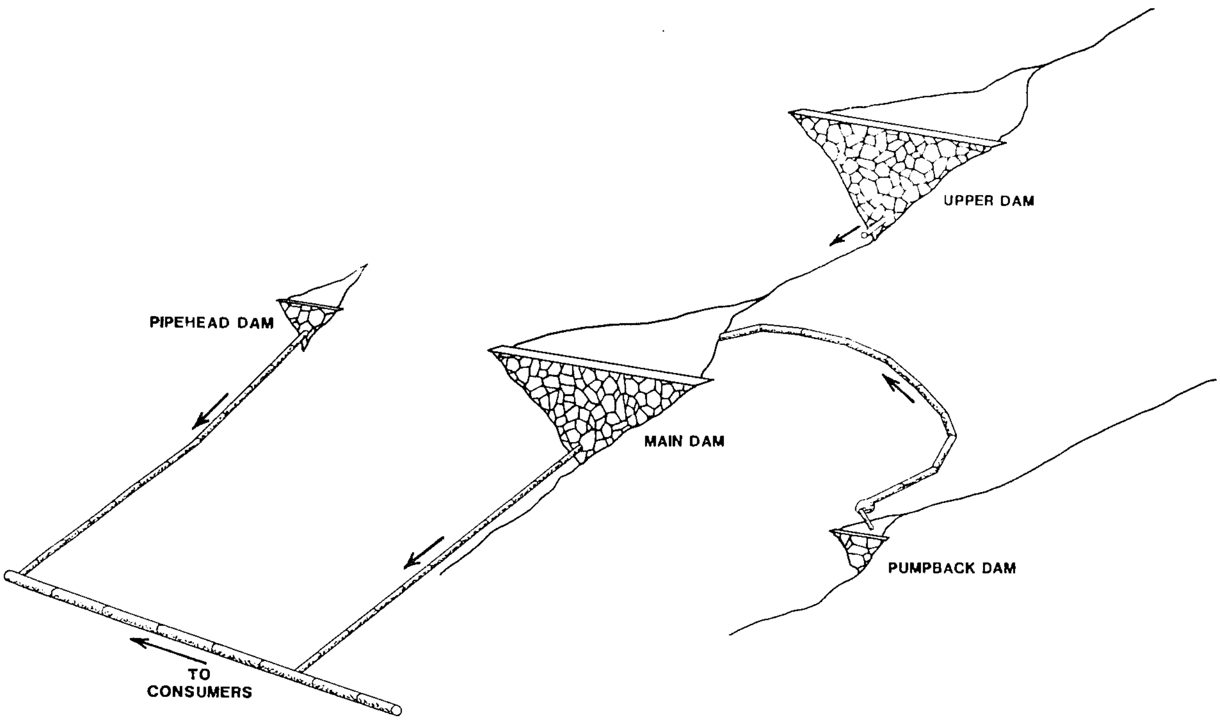


Figure 6 Schematic Description of Types of Development of River Sources

GROUNDWATER RESOURCES

Shallow groundwater and shallow artesian resources require full treatment of their water to be suitable for public water supply. A 'wellfield' consists of wells which are spaced over the resource and linked by pipelines called 'collector mains'. Pumps on each well send the water through the collector mains to a groundwater treatment plant before it is delivered to service reservoirs.

Deep artesian wells, which only require disinfection, cooling and dilution of their water, may also be installed near service reservoirs without being directly associated with a groundwater treatment plant.

The main components and typical dimensions of groundwater schemes are shown in Figure 7.

The impacts of shallow groundwater schemes on land use are summarized in Table B7 in Appendix B. Artesian wells have very little impact on land uses in their vicinity because they occupy a very small area of land and are not affected by, nor do they affect, nearby surface uses of the land. However, an operating well creates a local area of low pressure in the artesian groundwater. Any other artesian well within this area of low pressure will experience reduced pumping efficiency.

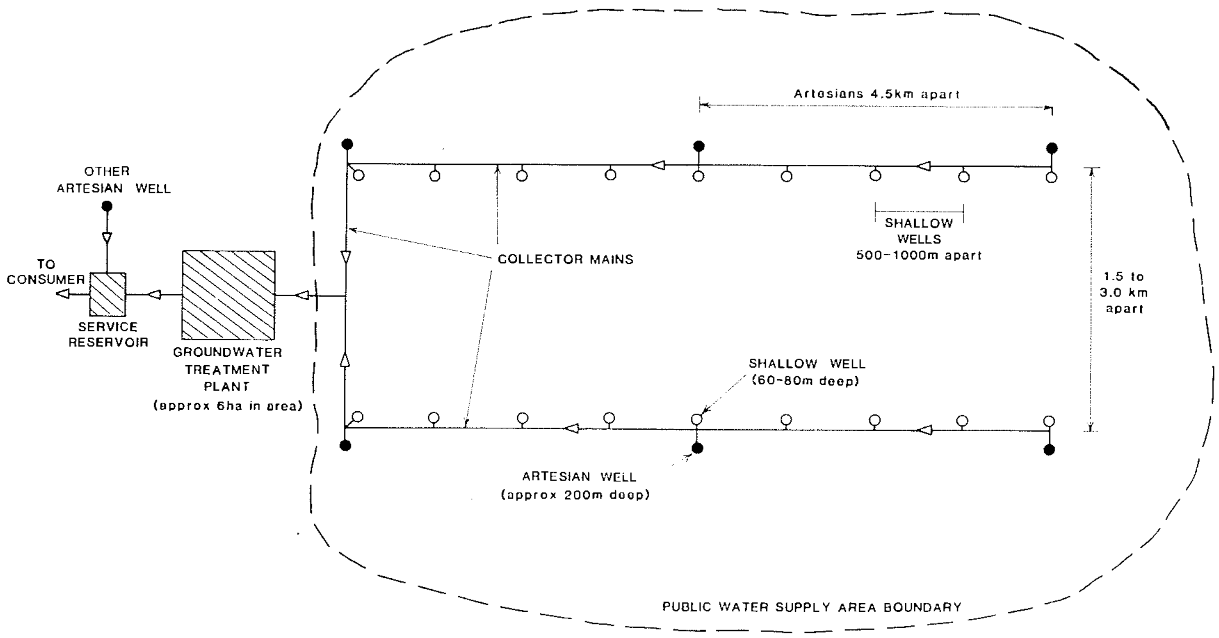


Figure 7 Schematic Description of Groundwater Scheme Development

THE WATER SUPPLY SYSTEM

The individual schemes currently supplying the MWS operate together as a system. Computer analysis is used to determine the maximum demand that the system can sustain. This is called the 'system yield'. Adding a new source to the system will increase the system yield. The increase is called the 'system yield benefit' of the proposed scheme. The yield may be greater than the water produced from the new source if its inclusion results in greater overall efficiency of the system.

6. CHANGING YIELD OF RESOURCES ALREADY DEVELOPED

GREENHOUSE EFFECT

The Greenhouse Effect may result in reduced rainfall in the south west of Australia (Pearman, 1988). The degree and timing of the effect are uncertain. The current SDP recognises the possible consequences of the Greenhouse Effect for water yields in the future. Future reviews of the SDP will reflect more confident predictions. In this SDP, estimates of yields from surface water resources are based on the following assumptions about the extent of the effects:

(i) When estimating the present system yield, only stream flow records after 1947 are used because the consistently higher rainfall years of the 1930s and early 1940s are not likely to recur in the foreseeable future. This reduces the estimated yield of river resources by about 13%, but has no effect on groundwater sources whose management is based only on recent data.

(ii) When estimating yields of sources at times in the future, it is assumed that mean rainfall is steadily decreasing. For the 'most likely' case, it is assumed that the mean rainfall in the year 2040 will be 10% less than in 1986, while for 'minimum' and 'maximum' cases, the reduction is assumed to be 5% and 15% respectively. These assumptions are illustrated in Figure 8.

For rivers used as sources for the MWS, it has been estimated that a percentage reduction in rainfall generally causes a reduction in yield of river sources of twice that percentage (Pearman, 1988). Consequently, the 'most likely' percentage reduction in yield of river sources by 2040 is 20%. The 'minimum' case results in a 10% reduction in yield, and the 'maximum' gives a 30% reduction.

The possible impact of reduced rainfall on groundwater resources has only been assessed in terms of its effect on public supply schemes for the Metropolitan Area. Shallow wells

PERTH RAINFALL

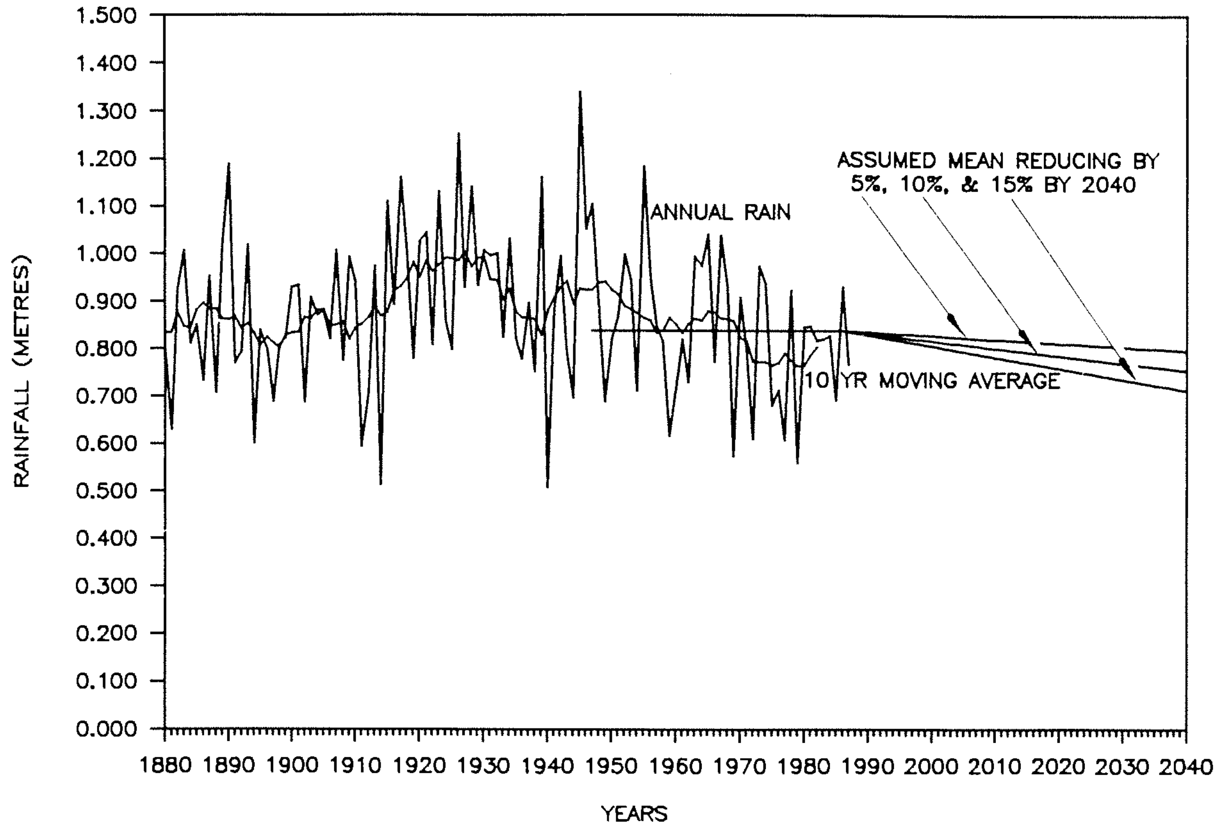


Figure 8 Perth Rainfall Showing Assumed Reducing Mean to 2040

nearest to wetlands may have to be shut down when reducing rainfall makes it impossible to maintain water levels in the lakes. Groundwater production could be reduced by up to 20% if all such wells, existing and planned, ceased production. The reduction in rainfall which would cause all these wells to be closed is not known. A 20% reduction in groundwater yield has been assumed for 2040 in the 'maximum' and 'most likely' timetables. Only 10% reduction in yield is assumed in the 'minimum' timetable which is based on a small reduction in rainfall.

MANAGEMENT OF NATIVE FOREST

The streamflow from forested catchments in the Darling Range is only a small fraction of the volume of water which falls on the catchments as rain. Streamflow is, on average, 9% of rainfall on catchments for the existing MWS, although in the higher rainfall areas the streamflow is up to 20% of rainfall. The remainder of the rainfall is passed directly back into the atmosphere by evaporation from wet surfaces or transpiration through vegetation. Preliminary analysis by the Water Authority and CALM (Water Authority, 1987b) indicates that the system yield could be increased by 37 million cubic metres per year by thinning suitable forest in the high rainfall zone of existing catchments.

Assessment of the benefits of forest thinning needs to consider the following:

- The natural density of the forest is the maximum which can be sustained by the available rainfall. If the forest density is artificially reduced, vegetation growth rapidly responds to re-establish the maximum density. Government agencies must make a commitment to a long-term programme of forest management activities associated with thinning, such as controlling regrowth, as well as actually thinning periodically, if increased yield is to be achieved and maintained.

- Some economic benefits are expected to accrue from improving the quantity of timber produced, but these are not sufficient to cover costs. Economic justification of the proposal depends on the long-term benefits in reducing the cost of future water supplies.

- Environmental impacts of the thinning operation require investigation and assessment. There are impacts associated with the operation itself, for example the possible spread of jarrah dieback disease to new sites. There could also be impacts from the consequences of thinning, for example changes in forest ecology could alter habitats for rare species.

- The first effect of reduced transpiration is to allow groundwater to build up, which subsequently leads to increased streamflow. Rising groundwater levels in lower rainfall areas increase the chance of developing the salinity problems usually associated with agricultural clearing.

The Water Authority is involved in studies which are exploring the potential of forest thinning for increasing the yield from the existing catchments. The next step planned is an operational-scale experiment to thin within a 1700 hectare section of the South Dandalup Catchment in the high rainfall zone (Water Authority, 1987b). As positive proposals for increasing yield depend on the outcome of these studies, forest thinning is not included at present in long-term planning for future sources and it is unlikely that it will be possible to include this technique within the next ten years.

MANAGEMENT OF PINE PLANTATIONS

Pine plantations on the coastal plain have a significant affect on the availability of shallow groundwater, mainly by reducing the proportion of rainwater which reaches the water-table. This happens because a lot of rain is held on the trees' foliage, from which it evaporates, or is drawn from the soil by the tree roots before it reaches the water-table.

The pine plantations can be considered as a use of the groundwater resource for the purpose of producing timber. However, when there are other potential demands on the groundwater, it is possible that the plantation should be thinned more than would be the case if the objective was only to maximise timber production.

Studies to assess the increase in the groundwater yield due to thinning of pines on the Gnangara Mound are being progressed by the Water Authority in conjunction with the Department of Conservation and Land Management. The results can only be incorporated in estimates of yield from the resource when appropriate forest management procedures are operational. At this stage it appears that pines and water production can co-exist as long as the pines are kept at a low density by thinning.

REDEVELOPMENT OF EXISTING SCHEMES

Sometimes a water resource is developed with a relatively low percentage of use of the available water because the demand at the time does not warrant a larger scheme. In such cases, redevelopment of the resource is possible at a later date. A pipehead could be replaced with a dam, a dam could be raised, or an upper dam or a pumpback could be added (see Chapter 5). Unless the original scheme is at the end of its life, the increased yield will be that part of the total yield of the new scheme which is greater than the yield of the original scheme. Provided the cost per cubic metre of this increase in yield does not exceed the cost of seawater desalination, there will come a time when such schemes are economically viable. Several of the current proposals in the SDP could be considered as 're-development' schemes, e.g. North Dandalup Dam (replaces pipehead), raising Mundaring Weir, and the scheme for re-developing the Victoria/Bickley catchments. (Details of these proposals are given in Appendix A.)

INCREASING PIPELINE CAPACITY

The yield of a source is sometimes limited if the pipes taking water from the source have a relatively low capacity. In such cases, provision of an additional pipe will result in an increase in system yield. Pipes are sometimes added because they are needed to enable peak rates of demand to be satisfied and they are planned for installation when demands exceed existing capacity. Increasing the capacity of the outlet main from Wungong Dam is in this category (Wungong outlet main amplification).

If the only benefit to be gained by a new pipe is a yield increase, then consideration must be given to the cost of the pipe in comparison to the cost of increasing yield by, say, developing another new source, when deciding if and when the additional pipe is required. An example of this case is the duplication of part of the pipeline from North Dandalup River (North Dandalup Main Amplification). (Details of these proposals are given in Appendix A.)

7. THE SOURCE DEVELOPMENT PLAN

EXISTING AND PROPOSED SCHEMES

The names and types of existing MWS schemes, and of all proposed schemes which are currently the Water Authority's preferred alternatives for future development of each resource, are listed in Tables 4 (river resources) and 5 (groundwater

Table 4 Existing and Possible Future River Schemes for the MWS

	MAP REF	SCHEME No.	MAIN DAMS	MAP REF	SCHEME No.	UPPER DAMS	MAP REF	SCHEME No.	PIPEHEADS
EXISTING	Fl	R1	Canning				Eh	R8	Nth Dandalup
	Fl	R2	Churchmans				Fi	R9	Serpentine
	Gn	R3	Helena						
	Fi	R4	Serpentine						
	Ff	R5	Sth Dandalup						
	Fm	R6	Victoria						
	Fk	R7	Wungong						
POSSIBLE FUTURE	Ea	R12	Harvey				Eg	R18	Conjurunup
	Gn	R13	Helena Res. Raised				Ep	R19	Ellen
							Fo	R25	Jane
	Eh	R14	Nth Dandalup				Fo	R32	Susannah
	Fm	R15	Victoria						
	Fp	R16	Wooroloo						

The map reference enables location of schemes by their scheme number on Map 4.

Note: Possible future sources listed here are currently the Water Authority's preferred alternative for development of each source.
Other proposals are listed in Table A1 in Appendix A.

resources). Schemes which are simply additional pipelines to increase the capacity for moving water in the system are also listed in Table 4.

The tables include a map reference which allows the schemes to be located by their Scheme Number on Map 4. Map 4 also shows the resource boundaries: catchment areas for river sources, and declared Groundwater Areas, Water Reserves or Public Water Supply Areas for groundwater schemes.

Table 4 (continued)

MAP REF	SCHEME No.	PUMPBACKS	MAP REF	SCHEME No.	ADDITIONAL PIPELINES
Gl	R10	Kangaroo Gully			
Fn	R11	Lower Helena			
Fl	R20	Araluen	Fn	R33	Mundaring Integration
Fm	R21	Bickley	Eh	R34	North Dandalup Mains Amplification
Fq	R22	Brockman	Ek	R35	Wungong Outlet Amplification
Ei	R23	Dirk			
Fj	R24	Gooralong			
Ei	R27	Lower Serpentine Stage II			
Eg	R28	Lower South Dandalup			
Ef	R29	Marrinup (Site 1)			
Gd	R30	Murray Tributaries			

Details of the proposed schemes, and also of other alternatives considered for developing each resource, can be found in Appendix A. The Appendix includes a map showing land use within the resource boundaries.

SELECTING SCHEMES FOR THE SOURCE DEVELOPMENT PLAN

The SDP is based on engineering feasibility studies and on

Table 5 Existing and Possible Future Groundwater Schemes for the MWS

	MAP REF	SCHEME No.	GROUNDWATER SCHEMES	No. OF WELLS	
				Shallow G'water	Artesian (Treated)
EXISTING	Co	G1	Gwelup	12	5
	Dl	G2	Jandakot	15	2
	Do	G3	Mirrabooka	34	5
	Dq	G4	Wanneroo	24	8
POSSIBLE FUTURE	Bt	G10	Barragoon Stage I	12	2
	Bt	G11	Barragoon Stage II	11	2
	Dh	G13	Dandalup	20	25
	Ep	G14	East Mirrabooka Stage III	4	-
	Dl	G15	Jandakot Stage II	15	2
	Dk	G16	Jandakot South Stage I	7	5
	Dk	G17	Jandakot South Stage II	7	1
	Di	G18	Karnup	20	15
	Ep	G19	Lexia	15	-
	Cq	G20	Pinjar Stage I	9	5
	Cq	G21	Pinjar Stage II	9	3
	Cq	G22	Pinjar Stage III	10	2
	Cs	G23	Yeal Stage I	12	2
	Cs	G24	Yeal Stage II	12	2

The map reference enables location of schemes by their scheme number on Map 4.

Note: Possible future sources listed here are currently the Water Authority's preferred alternative for development of each source. Other proposals are listed in Table A2 in Appendix A.

projections of demand for public water supply in the Perth metropolitan area. When developing the plan, the Water Authority identifies constraints so that a realistic allowance is made for other claims for use of the water resources, and environmental effects of the source development projects are limited. The preferred alternative for developing each resource will be the most economically efficient proposal, within the known environmental and social constraints. This preference could change in the future if public review or

Table 5 (continued)

MAP REF	SCHEME No.	OTHER ARTESIAN WELLS (Untreated)	No. OF WELLS
Cn	G5	Bold Park	2
Cm	G6	Melville	1
Do	G7	Mirrabooka	1
Dn	G8	Mt Eliza	6
Do	G9	Yokine	4
Cp	G29	Wanneroo	1

further studies show that environmental or social impacts which are currently assumed to be acceptable, are in fact not acceptable, or that costs of environmental management make the proposal less cost-effective than an alternative development of that resource.

THE SOURCE DEVELOPMENT TIMETABLE

A Source Development Timetable is prepared by scheduling the construction of these preferred schemes to meet projected increases in the demand for water supply. Schemes are generally sequenced in order of increasing cost per cubic metre of water supplied. For each scheme, this cost can be found in Appendix A. This ensures that the cost of producing water from the system is the minimum that can be achieved at all times. In some cases, however, there are constraints arising from the geographical distribution of the system or from operational requirements, which result in alterations to the sequence. These constraints on sources in the Source Development Timetable are described in Appendix E.

Three Source Development Timetables have been produced to meet maximum, most likely and minimum demand projections, as explained in Chapter 3. The timetables indicate when sources need to be operational if the assumptions of the demand projections are realised, but commitment to construction dates will be deferred until absolutely necessary.

The 'Maximum', 'Most Likely' and 'Minimum' Source Development Timetables are listed in Tables 6, 7 and 8, and shown graphically in Figures 9, 10 and 11.

- The 'Maximum' timetable shows the earliest dates at which future projects will be required as a basis for planning (assuming that there will be no more constraints on development than have been assumed in selecting and scheduling the sources).

- The 'Most Likely' timetable represents the expected construction programme.

- 'Minimum' represents a possible lowest limit on the construction schedule necessary to meet future demands. It is useful to indicate how significant reductions in demand arising from demand management could defer the need to develop new sources, and the associated cost savings.

ALTERNATIVE TIMETABLES

The Source Development Timetable represents the most cost-efficient programme for meeting water supply needs within known environmental and social constraints on developing sources.

If new environmental constraints arise, for example a community decision that loss of forest due to construction of reservoirs is unacceptable, or that more streams must remain undeveloped in order to preserve native aquatic fauna, resources may be excluded or limited in the way they can be developed.

Re-scheduling the sources results in increased development costs. This represents the cost to the community of imposing the added constraint. The community will need to address these issues of social, environmental and recreational values of water resources.

8. CURRENT PLANNING FOR NEAR FUTURE SOURCES

NEW SOURCES IN 1988/89

Wanneroo Deep Artesian Well and part of the Pinjar Stage 1 Groundwater Scheme have been commissioned in time to be available for summer 1988/89.

REMAINDER OF PINJAR GROUNDWATER SCHEME

The Minister for Environment, in the conditions set on implementing the next phase in the development of the Gnangara Mound Groundwater Resources, stated that Stage 1 of the Pinjar Scheme was environmentally acceptable. Also, while accepting in principle that Stages 2 and 3 of the Pinjar Scheme were environmentally acceptable, the EPA recommended that the Water Authority review these stages in the light of the outcome of the ERMP and refer them again to EPA for further consideration (EPA, 1987). This is the procedure being adopted by the Water Authority.

NEXT MAJOR PUBLIC WATER SUPPLY SOURCE FOR PERTH

The EPA has made recommendations to the Government on the ERMP for the next major public water supply source for Perth (Water Authority, 1988). The EPA recommended that the proposal to build a dam on the North Dandalup River was environmentally acceptable, and that the Water Authority should prepare an Environmental Management Programme for the project (EPA, 1988). This Management Programme will be subject to review and acceptance by the EPA.

The EPA also concluded that the options of raising Mundaring Weir and raising Canning Dam were both environmentally acceptable in principle, but recommended that detailed proposals on the options should be referred to the EPA for assessment before any final decisions were made.

The EPA was advised by the Water Authority that the option of an upper dam at South Canning should no longer be considered due to uncertainty about estimated yield benefits and possible salinity problems. These problems are associated with the assumption that mean rainfall will tend to be lower in the foreseeable future because of the Greenhouse Effect.

CONJURUNUP PIPEHEAD

The Water Authority submitted a Notice of Intent for the Conjurunup Pipehead dam to the EPA in 1983. The Notice of Intent described the project and its anticipated environmental impacts and management proposals. The EPA responded by agreeing in principle to a pipehead dam development subject to final approval of detailed designs for the pipe route in the valley of Conjurunup Creek. The Water Authority will shortly submit the requested pipeline design and associated information to the EPA for its assessment. Detailed design for the complete project is in progress.

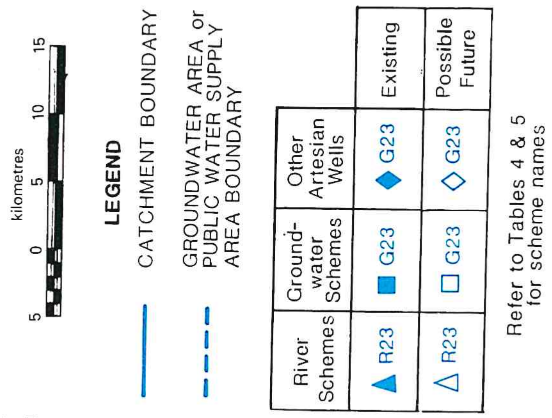
VICTORIA-BICKLEY REDEVELOPMENT

The Water Authority has decided that, for dam safety reasons, the existing Victoria Dam must be replaced within 10 years. The proposed redevelopment scheme includes a larger reservoir at about the same site as the existing reservoir, and a pumpback which collects water flowing from Bickley catchment and delivers it into the new reservoir (refer Scheme R15). The project has been referred to the EPA which has determined that a Notice of Intent should be prepared. Preparation of the NOI is in progress.

JANDAKOT STAGE II GROUNDWATER SCHEME

The Water Authority has referred this project to the EPA. A PER is being prepared to address the environmental management implications and requirements of the project.

Map 4 Water Supply Scheme Locations



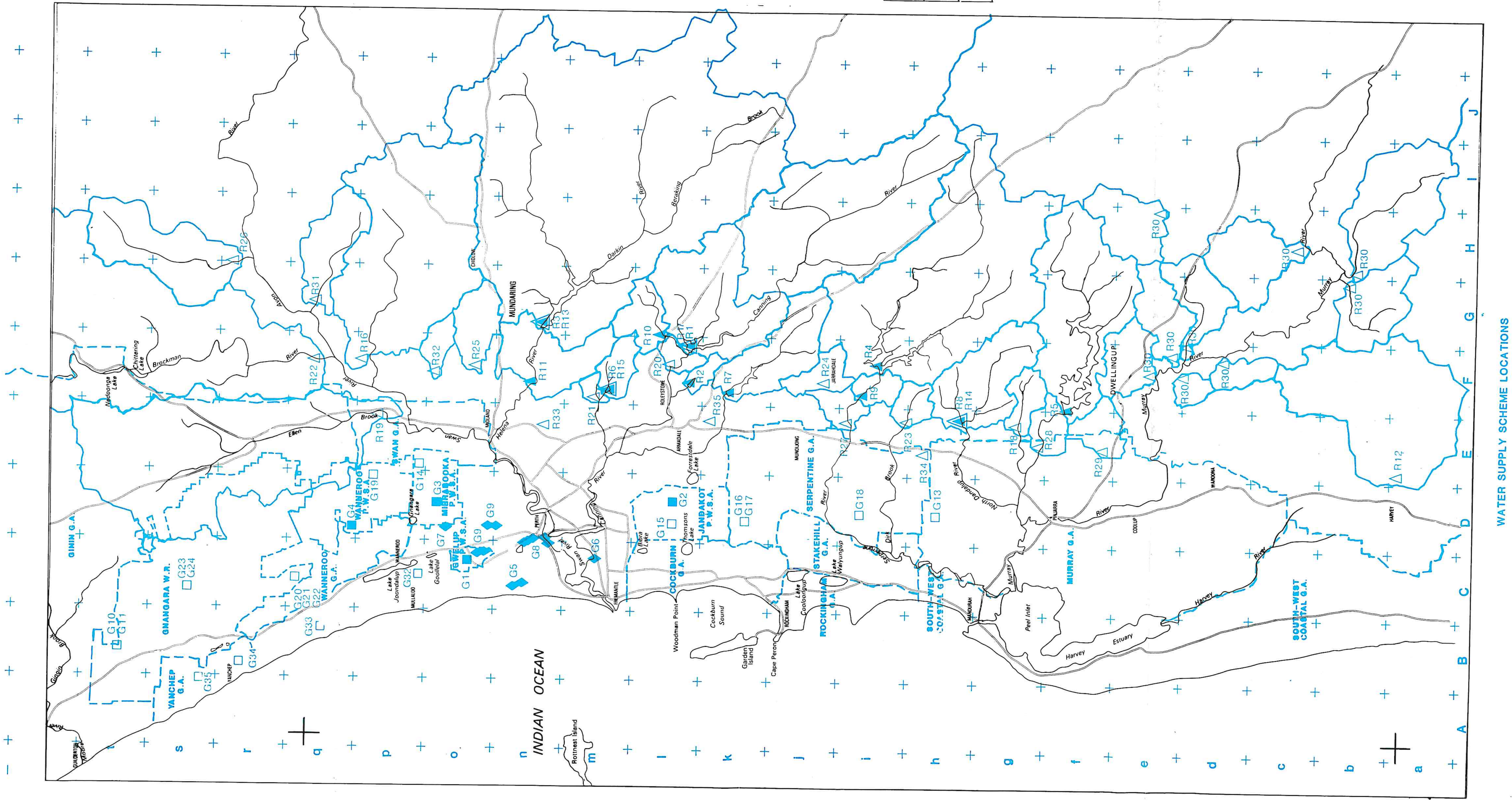


Table 6. Maximum Source Development Timetable (includes G & AWS System)

All units Millions of Cubic Metres per Annum

D.A.W.=Deep Artesian Well G.W.=Groundwater Scheme P.H.=Pipehead P.B.=Pumpback ST=Stage

Year	Forecast Unrestricted Demand	Sources Commissioned (Operational)	Groundwater Interim Quota Scheme	Groundwater Interim Quota Total	System Yield Benefit	Reduced Yield Benefit (1)	System Yield	Surplus Yield
1986/87	218.7	Storage Reservoirs:						
		Canning, Serpentine,						
		South Dandalup, Wungong (Restricted Outlet) (2),						
		Churchmans, Victoria,						
		Mundaring.						
		Pipeheads/Pumpbacks:						
		North Dandalup P.H.						
		Lower Helena P.B.						
		Groundwater Schemes:						
		Gwelup	12.0					
		Mirrabooka	22.0					
		Wanneroo	21.2					
		Jandakot ST 1.	5.3					
		Deep Artesian	12.0	72.5			252.6	33.9
1987/88	223.0						251.3	28.3
1988/89	230.2	Wanneroo D.A.W.	1.5		2.0	2.0		
		Pinjar ST 1 G.W. Pt 1	6.3	80.3	7.0	6.9	259.0	28.8
1989/90	238.4	Pinjar ST 1 G.W. Pt 2	6.4		7.1	7.0		
		Delete 2 G.W.	-2.0	84.7	-2.0	-2.0	262.7	24.3
1990/91	246.6	Mundaring Integration			0.0	0.0		
		Delete Victoria Dam			-3.1	-3.0	258.4	11.8
1991/92	254.8	Victoria/Bickley Dam Redev			6.0	5.8		
		Deletion of North Dandalup P.H.			-10.6	-10.3		
		Conjurunup Creek P.H.			4.5	4.4	257.0	2.2
1992/93	263.0	Dirk Brook P.B.			3.5	3.4		
		Jandakot ST 2 G.W.	4.0	88.7	4.7	4.6	263.7	0.7
1993/94	271.2	Wungong Outlet Main Amp			0.9	0.9		
		North Dandalup Dam (Part)			8.0	7.7		
		Araluen P.B.			1.2	1.2	272.0	0.8
1994/95	279.4	North Dandalup Dam (add)			6.0	5.7		
		Lexia G.W.	6.5	95.2	6.9	6.7	283.1	3.7
1995/96	288.6	North Dandalup Dam (add)			3.0	2.9		
		Pinjar ST 2 G.W.	7.2	102.4	8.0	7.7	292.2	3.6
1996/97	297.8	North Dandalup Dam (add)			1.9	1.8		
		Pinjar ST 3 G.W.	5.6	108.0	6.0	5.8	298.3	0.5
1997/98	307.0	Marrinup Brook P.B.			6.1	5.7		
		Gooralong P.B.			4.4	4.1		
		Raise Mundaring			0.0	0.0		
		North Dandalup Main Amp			2.9	2.7	309.3	2.3
1998/99	316.2	Jandakot South ST 1 G.W.	3.1		3.3	3.2		
		Lower Serpentine P.B.			4.6	4.3		
		Raise Mundaring (part)		111.1	3.0	2.8	317.9	1.7
1999/2000	324.4	Yeal ST 1 G.W.	6.1		6.7	6.4		
		Jandakot South ST 2 G.W.	3.1		3.3	3.1		
		Raise Mundaring (add)		120.3	1.0	0.9	326.7	2.3
2000/01	333.6	Yeal ST 2 G.W.	6.1		6.4	6.1		
		Barragoon ST 1 G.W.	4.8	131.2	6.0	5.7	336.8	3.2
2001/02	341.8	Barragoon ST 2 G.W.	4.8		6.0	5.7		
		Lower South Dandalup P.B.		136.0	2.3	2.1	342.8	1.0
2002/03	351.0	Jane Brook P.B.			9.4	8.6		
		East Mirrabooka ST 3 G.W.	2.0		1.5	1.4		
		Raise Mundaring (add)		138.0	3.0	2.7	353.7	2.7
2003/04	360.2	Susannah Brook P.H.			3.4	3.1		
		Ellen Brook P.H.			7.1	6.4	361.4	1.2
2004/05	368.4	Harvey Dam (Part)			20.0	18.0	377.4	9.0
2005/06	378.6	Harvey Dam (Add)			20.0	17.9	393.3	14.7
2006/07	386.8	Raise Mundaring (add)			3.0	2.7	393.8	7.0
2007/08	396.0	Karnup G.W.	7.5	145.5	7.4	6.8	398.5	2.5
2008/09	404.2	Dandalup G.W.	10.6	156.1	10.6	9.7	406.0	1.8
2009/10	414.4	Harvey Basin Sources			15.0	13.2	416.9	2.5
2010/11	422.6	Harvey Basin Sources			10.0	8.6	423.3	0.7
2011/12	432.8	Harvey Basin Sources			15.0	12.9	433.8	1.0

(1) Assumed yield reduction by 2040 due to climate change.
- Surfacewater Sources 30%.
- Groundwater Sources 20%.

(2) Assumes Wungong Tunnel and Outlet Pipes Completed to South West Highway.

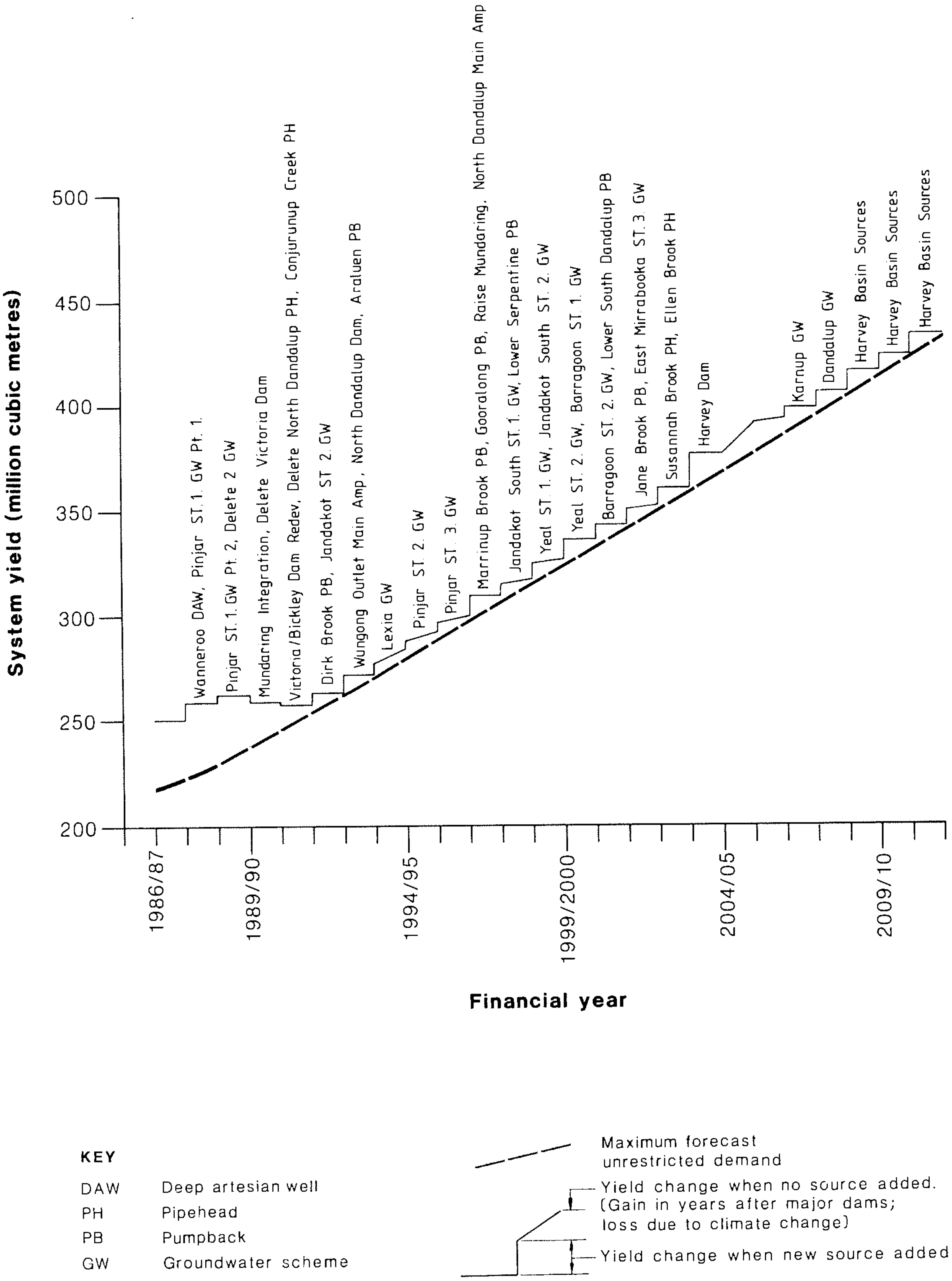


Figure 9 'Maximum' Source Development Timetable

Table 7. Most Likely Source Development Timetable (includes G & AWS System)

All units Millions of Cubic Metres per Annum
D.A.W.=Deep Artesian Well G.W.=Groundwater Scheme P.H.=Pipehead P.B.=Pumpback ST=Stage

Year	Forecast Unrestricted Demand	Sources Commissioned (Operational)	Groundwater Interim Quota Scheme	Groundwater Interim Quota Total	System Yield Benefit	Reduced Yield Benefit [(1)]	System Yield	Surplus Yield
1986/87	218.7	Storage Reservoirs:						
		Canning, Serpentine,						
		South Dandalup, Wungong (Restricted Outlet)[(2)],						
		Churchmans, Victoria,						
		Mundaring.						
		Pipeheads/Pumpbacks:						
		North Dandalup P.H.						
		Lower Helena P.B.						
		Groundwater Schemes:						
		Gwelup	12.0					
		Mirrabooka	22.0					
		Wanneroo	21.2					
		Jandakot ST 1.	5.3					
		Deep Artesian	12.0	72.5			252.6	33.9
1987/88	219.0						251.7	32.7
1988/89	224.2	Wanneroo D.A.W.	1.5		2.0	2.0		
		Pinjar ST 1 G.W. Pt 1	6.3	80.3	7.0	6.9	259.6	35.4
1989/90	227.4	Pinjar ST 1 G.W. Pt 2	6.4		7.1	7.0		
		Delete 2 D.A.W.	-2.0	84.7	-2.0	-2.0	263.6	36.2
1990/91	231.6	Mundaring Integration			0.0	0.0		
		Delete Victoria Dam			-3.1	-3.0	259.6	28.0
1991/92	235.1	Victoria/Bickley Dam Redev			6.0	5.8	264.5	29.4
1992/93	240.1						263.5	23.4
1993/94	245.2	Wungong Outlet Main Amp			0.9	0.9		
		Deletion of North Dandalup P.H.			-10.6	-10.2	253.3	8.1
1994/95	250.4	Conjurunup Creek P.H.			4.5	4.4	256.7	6.3
1995/96	255.7	Jandakot ST 2 G.W.	4.0	88.7	4.7	4.5	260.2	4.5
1996/97	260.8	North Dandalup Dam (part)			8.0	7.7	266.9	6.1
1997/98	266.5	North Dandalup Dam (add)			6.0	5.8	271.7	5.2
1998/99	271.9	North Dandalup Dam (add)			3.0	2.9	273.6	1.7
1999/2000	276.7	North Dandalup Dam (add)			1.9	1.8		
		Gooralong P.B.			4.4	4.2	278.5	1.8
2000/01	281.5	Araluen P.B.			1.2	1.1		
		Pinjar ST 2 G.W. Pt 1	3.6		4.0	3.8		
		Raise Mundaring		92.3	0.0	0.0	282.4	0.9
2001/02	286.4	Lower Serpentine P.B.			4.6	4.3		
		Raise Mundaring (part)			3.0	2.8	288.4	2.0
2002/03	291.1	Lexia G.W.	6.5		6.9	6.5		
		Raise Mundaring (add)		98.8	1.0	0.9	294.7	3.6
2003/04	296.2	Marrinup Brook P.B.			6.1	5.7	299.3	3.1
2004/05	301.5	Pinjar ST 2 G.W. Pt 2	3.6	102.4	4.0	3.7	301.9	0.4
2005/06	306.8	Pinjar ST 3 G.W.	5.6		6.0	5.6		
		Raise Mundaring (add)		108.0	3.0	2.8	309.1	2.3
2006/07	311.3	North Dandalup Main Amp			2.9	2.9		
		Dirk Brook P.B.			3.5	3.2	314.1	2.8
2007/08	316.6	Jandakot South ST 1 G.W.	3.1		3.3	3.0		
		Jandakot South ST 2 G.W.	3.1	114.2	3.3	3.0	318.9	2.3
2008/09	321.1	Yeal ST 1 G.W.	6.1	120.3	6.7	6.2	323.9	2.8
2009/10	326.6	Yeal ST 2 G.W.	6.1		6.4	5.9		
		Raise Mundaring (add)		126.4	3.0	2.7	331.2	4.6
2010/11	331.6	Lower South Dandalup P.B.			2.3	2.1	332.1	0.5
2011/12	336.7	Barragoon ST 1 G.W.	4.8		6.0	5.4		
		East Mirrabooka ST 3 G.W.	2.0	133.2	1.5	1.4	337.7	1.0

(1) Assumed yield reduction by 2040 due to climate change.
- Surfacewater Sources 20 %.
- Groundwater Sources 20 %.

(2) Assumes Wungong Tunnel and Outlet Pipes Completed to South West Highway.

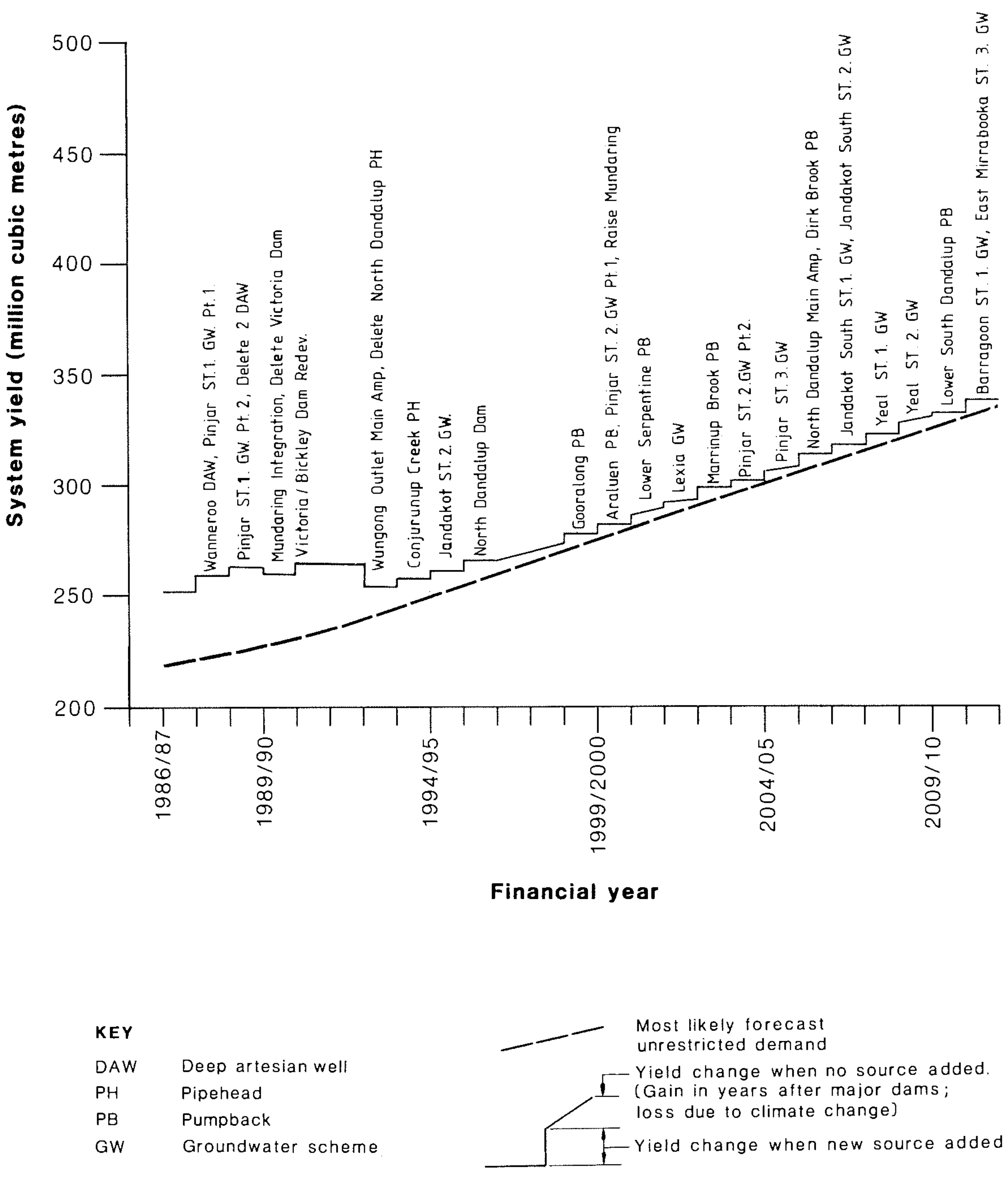


Figure 10 'Most Likely' Source Development Timetable

Table 8. Minimum Source Development Timetable (includes G & AWS System)

All units Millions of Cubic Metres per Annum
D.A.W.=Deep Artesian Well G.W.=Groundwater Scheme P.H.=Pipehead P.B.=Pumpback ST=Stage

Year	Forecast Unrestricted Demand	Sources Commissioned (Operational)	Groundwater Interim Quota Scheme	Groundwater Interim Quota Total	System Yield Benefit	Reduced Yield Benefit (1)	System Yield	Surplus Yield
1986/87	218.7	Storage Reservoirs:						
		Canning, Serpentine,						
		South Dandalup, Wungong (2) (Restricted Outlet),						
		Churchmans, Victoria,						
		Mundaring.						
		Pipeheads/Pumpbacks:						
		North Dandalup P.H.						
		Lower Helena P.B.						
		Groundwater Schemes:						
		Gwelup	12.0					
		Mirrabooka	22.0					
		Wanneroo	21.2					
		Jandakot ST 1.	5.3					
		Deep Artesian	12.0	72.5			252.6	33.9
1987/88	210.9						252.1	41.2
1988/89	213.5	Wanneroo D.A.W.	1.5	74.0	2.0	2.0		
		Pinjar ST 1 G.W. Pt 1	6.4	80.4	7.0	7.0	260.6	47.1
1989/90	216.3	Pinjar ST 1 G.W. Pt 2	6.3	86.7	7.1	7.1		
		Delete 2 D.A.W.	-2.0	84.7	-2.0	-2.0	265.2	48.9
1990/91	219.2	Mundaring Integration			0.0	0.0		
		Delete Victoria Dam			-3.1	-3.1	261.7	42.5
1991/92	222.2	Victoria/Bickley Dam Redev			6.0	5.9	267.1	44.9
1992/93	225.5						266.6	41.1
1993/94	228.9	Wungong Outlet Main Amp			0.9	0.9	267.0	38.1
1994/95	232.3						266.5	34.2
1995/96	235.7						266.0	30.3
1996/97	239.3						265.5	26.2
1997/98	242.8						265.0	22.2
1998/99	246.2						264.5	18.3
1999/2000	250.6	Deletion of North Dandalup P.H.			-10.6	-10.4	253.6	3.0
2000/01	255.2	Conjurunup Creek P.H.			4.5	4.4	257.6	2.4
2001/02	259.3	Jandakot ST 2 G.W.	4.0	88.7	4.7	4.6	261.7	2.4
2002/03	263.7	North dandalup Dam (Part)			8.0	7.8	269.0	5.3
2003/04	268.1	North Dandalup Dam (add)			6.0	5.8	274.3	6.2
2004/05	272.4	North Dandalup Dam (add)			3.0	2.9	276.6	4.2
2005/06	276.8	North Dandalup Dam (add)			1.9	1.8	277.9	1.1
2006/07	281.1	Gooralong P.B.			4.4	4.2	281.6	0.5
2007/08	285.6	Lower Serpentine P.B.			4.6	4.4		
		Raise Mundaring			0.0	0.0	285.5	-0.1
2008/09	289.9	Pinjar ST 2 G.W. Pt 1	3.6	92.3	4.0	3.8		
		Raise Mundaring (part)			3.0	2.9	291.6	1.7
2009/10	294.5	Pinjar ST 2 G.W. Pt 2	3.6	95.9	4.0	3.8		
		Raise Mundaring (add)			1.0	1.0	295.9	1.4
2010/11	298.0	Lexia G.W.	6.5	102.4	6.9	6.6	301.9	3.9
2011/12	301.7						301.4	-0.3

(1) Assumed yield reduction by 2040 due to climate change.
- Surfacewater Sources 10 %.
- Groundwater Sources 10 %.

(2) Assumes Wungong Tunnel and Outlet Pipes Completed to South West Highway.

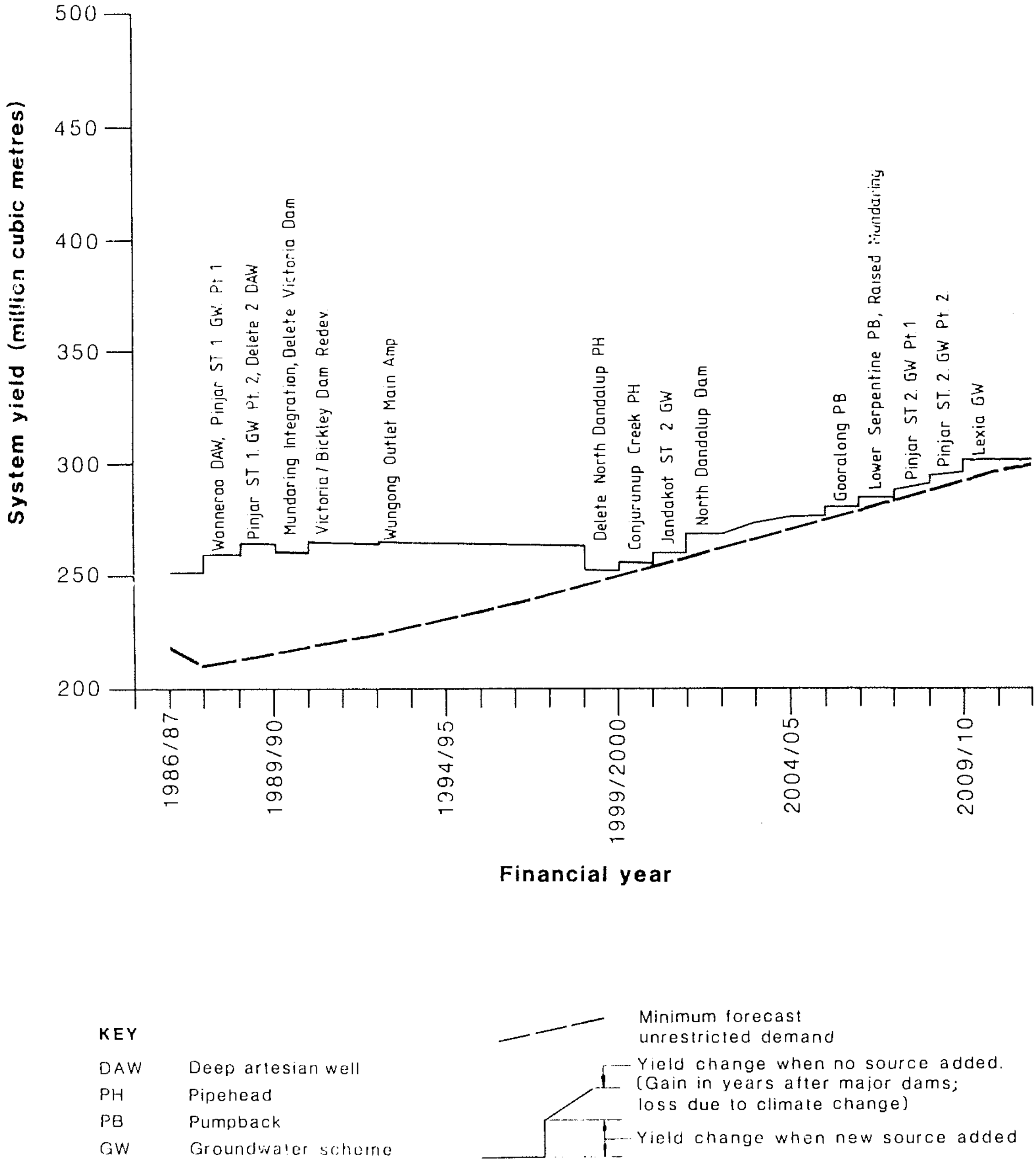


Figure 11 'Minimum' Source Development Timetable

ACKNOWLEDGEMENTS

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REFERENCES

Australian Water Resources Council and Western Australian Water Resources Council (1986)
Working Papers for the National Workshop on Urban Water Demand.

Australian Water Resources Council and Western Australian Water Resources Council (1987)
Proceedings of the National Workshop on Urban Water Demand Management AWRC Conference Series No. 14, Perth, March 1987. ISBN 0 7244 67599.

Caldwell M.(1981)
Perth Water Supply. The Role of Groundwater Resources. Proc. of Symposium Groundwater Resources of the Swan Coastal Plain (1981). CSIRO Division of Land Resources Management and Western Australian State Committee of the Water Research Foundation of Australia. ISBN 0 643 02863 3 pp 1-28.

Cargeeg G.C., Boughton G.N., Townley L.R., Smith G.R., Appleyard S.J. and Smith R.A. (1987)
Perth Urban Water Balance Study. Water Authority of Western Australia , May 1987. ISBN 0 7244 67878 1

Environmental Protection Authority (1987)
Gnangara Mound Groundwater Resources: Report and Recommendations of the Environmental Protection Authority EPA, Perth, Western Australia, Bulletin 295, August 1987.

Environmental Protection Authority (1988)
Next Major Water Supply Source for Perth (Post 1992): Report and Recommendations of the Environmental Protection Authority EPA, Perth, Western Australia, Bulletin 343 August 1988.

Department of Conservation and Environment (1980)
Atlas of Natural Resources, Darling System, Western Australia. University of Western Australia Press, Nedlands, W.A. 6009 ISBN 0 7244 80420.

Mauger G. (1987)
Planning Future Sources for Perth's Water Supply. Water Authority of Western Australia, January 1987. ISBN 0 7244 6743 2

Metropolitan Water Authority (1975-83)
Master Plan for Perth Water Supply - Phase 1 Development Programme 1975-1985. Forward Planning and Computing Section, December 1975.

Master Plan for Perth Water Supply - Update and Review of Development Programme. Forward Planning and Computing Section, September 1977.

Sources Development Plan - 1979 Review. Forward Planning and Computing Section, December 1979.

Source Development Plan - 1983 Review. Water Resources Section, September 1983.

Metropolitan Water Authority (1985)
Domestic Water Use in Perth, Western Australia. John Tonkin Water Centre, 629 Newcastle St, Leederville, W.A. 6007. ISBN 0 7244 6766 1

Pearman G.I. (1988)
Greenhouse: Planning for Climate Change. CSIRO Division of Atmospheric Research. EJ Brill Publishing Company ISBN 0 643 04863 4.

Sadler B.S. and Field C.A.R. (1976)
Water Supply and Alternate Sources. Proc. of Symposium Groundwater Resources of the Swan Coastal Plain. EPA and CSIRO Division of Land Resources Management, Western Australia. ISBN 0 643 02044 6. pp 37-60.

Sadler B.S. and Williams P.J. (1981)
The Evolution of a Regional Approach to Salinity Management in Western Australia. Land and Stream Salinity Seminar and Workshop. Elsevier Scientific Publishing Company. ISBN 0 444 41999 3. pp 353-382.

State Planning Commission (1987)
Planning for the Future of the Perth Metropolitan Region. State Planning Commission, November 1987

Water Authority of Western Australia (1986a)
Gnangara Mound Groundwater Resources Environmental Review and Management Programme. Dames and Moore, Water Resources Management Branch, Report No. WM4, November 1986 ISBN 0 7244 6870 6.

Water Authority of Western Australia (1986b)
Sources Development Plan 1986 Review. Water Resources Planning Branch, Report No. WP14, May 1986.

Water Authority of Western Australia (1987a)
Water Conservation Plan 1987/89. Water Resources Directorate December 1987.

Water Authority of Western Australia (1987b)
Forest Management to Increase Water Yield from the Northern Jarrah Forest. Steering Committee for Research on Land use and Water Supply, Water Authority of Western Australia, Report No. WS3, August 1987. ISBN 0 7244 6847 1

Water Authority of Western Australia (1987c)
Corporate Plan 1987-1992. July 1987. ISBN 0 7244 6791 2.

Water Authority of Western Australia (1988)
Next Major Public Water Supply Source for Perth (post 1992). Environmental Review and Management Programme Stage 1. Evaluation of Alternatives. Water Resources Planning Branch, Report No. WP74, January 1988. ISBN 0 7309 1725 8

Western Australian Treasury (1986)
Projected Population of Western Australia and the Perth Statistical Division 1986-2025. W.A. Treasury, March 1986.

Western Australian Water Resources Council (1986)
Water Conservation Through Good Design. Western Australian Water Resources Council. ISBN 0 7244 6830 7

Western Australian Water Resources Council (1987)
A Strategy for Water Allocation in the Perth-Bunbury Region - Discussion Paper. WAWRC Publication No. WRC 3/87 December 1987. ISBN 07244 6879 X

Western Australian Water Resources Council (1988)
Water for the 21st Century: Supply Options for the Long-term Water Requirements of Southern Western Australia. WAWRC Publication No. WRC 4/88 November 1988. ISBN 07309 1756 8

Service reservoir:	a reservoir built near consumers to receive bulk supplies of water from major sources prior to final distribution to services
Sewage:	domestic wastewater
Storage dam:	see main dam
Stormwater:	rain water which has run off roads etc., and is usually disposed of by drains
System yield:	the maximum demand that the water supply system can sustain under specified expectation of restrictions (currently restrictions are expected in 10% of years).
Transpiration:	the process by which plants take up water from the soil and release water vapour through the leaves.
Treatment:	application of techniques such as settlement, filtration, chlorination, to render water suitable for drinking purposes
Turbidity:	clouding of water due to suspended material in the water causing a reduction in the transmission of light
Underground Water Pollution Control Areas:	see Groundwater Area
Upper dam:	a major reservoir on a river upstream of a main dam (see Chapter 5: Water Supply Schemes).
Wastewater:	water which has been used for some purpose and would normally be discarded. Wastewater usually contains significant quantities of pollutant (see Pollution)
Water-table:	the surface of the groundwater
Well:	a hole drilled from the ground surface into an aquifer to withdraw water
Yield benefit:	the increase in system yield which occurs when a new source is added to the system.

LIST OF ABBREVIATIONS

MAIN TEXT

AWRC	Australian Water Resources Council
CALM	Department of Conservation and Land Management
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
ERMP	Environmental Review and Management Programme
G & AWS	Goldfields and Agricultural Water Supply Scheme
MWA	Metropolitan Water Authority
MWS	Metropolitan Water Supply Scheme
PER	Public Environmental Report
SDP	Source Development Plan
WAWRC	Western Australian Water Resources Council

TABLES AND APPENDICES

GA	Groundwater area
g/w	groundwater
GWTP	Groundwater Treatment Plant
ha	hectares
km	kilometres
m	metres
cu.m	cubic metres
mg/L	milligrams per litre
mill.cu.m	million cubic metres
mill.cu.m/yr	million cubic metres per year
N/A	not applicable
Nat. veg.	Native vegetation
PWSA	Public Water Supply Area
Res.	reservoir
Spec. rural	Special rural
sq. km	square kilometres
thou. cu.m.	thousand cubic metres
TSS	Total Soluble Salts
WR	Water reserve

Appendix A

SOURCES ASSESSED FOR INCLUSION IN THE SOURCE DEVELOPMENT PLAN

Appendix A

SOURCES ASSESSED FOR INCLUSION IN THE SOURCE DEVELOPMENT PLAN

Existing schemes supplying water to the MWS and schemes for development of water resources for public water supply which have been given consideration by the Water Authority are identified in Tables A1 (river sources) and A2 (groundwater sources). The location of the schemes is shown on Map A1 which also shows the resource area associated with each scheme (catchment areas for rivers, and Groundwater Areas, Public Water Supply Areas or Groundwater Reserves for groundwater). Details of each scheme are presented in Table A3 in scheme number sequence.

The base map used for Map A1 is taken from Atlas of Natural Resources, Darling System, Western Australia (DCE, 1980). It shows the nature and distribution of land use within the resource areas. The significance of this land use in terms of its potential impact on the water resources, and the potential impacts of water supply schemes on the land use, are summarised in table form in Appendix B.

The following notes explain the data presented in the panels (Table A3) for each scheme:

1. Scheme No. (upper left of panel):

2. Title (at right of scheme no.):

   Name of scheme as shown in Tables A1 and A2.

   Identifies scheme in Tables A1 and A2 and on Map A1. The G prefix on a number denotes a groundwater scheme, and the R prefix denotes a river scheme. Schemes which are not preferred alternatives for development of a resource have the same number as the preferred alternative, with a lower case letter added.

3. Map reference:

   To locate a scheme from its map reference, find the upper case letter on the south boundary of Map A1, find the lower case letter on the west boundary, then find the box where lines drawn across the map from the two letters would intersect. The symbol marking the position of the scheme will be found within that box, and its scheme number will be printed close by.

4. Map (upper left of panel):

Shows the major components of the scheme. Existing scheme components are shown with solid symbols and solid lines. Proposed scheme components are shown with open symbols and dashed lines. The base map is a selection of features from the 1:250 000 Topographic Survey map series produced by Department of Lands and Surveys, W.A. presented at a scale of 1:200 000.

5. Scheme:

Brief description of the function of the scheme.

6. Special Notes:

Significant features of the scheme, and in particular, any specific environmental concerns associated with the scheme.

7. Status of Option:

'Existing' - scheme is part of the existing MWS.

'Preferred alternative' - scheme is the option currently preferred by the Water Authority for future development of the particular water resource. Note that for all future proposals the alternative of 'do-nothing' is available for consideration.

'Further investigation is required' - the option has been proposed after a preliminary assessment, but more efficient schemes may be devised with more detailed study.

Where an option is not the preferred alternative, a brief reason is given.

8. Land Use:

Categories of land use are compatible with titles in Tables in Appendix B. The land uses listed are those which occupy major areas within the catchment or resource area, or which may be significant in relation to the proposed scheme.

% Area:

Area of land use is given as percentage of catchment or resource area, to nearest 5%. Asterisk (*) marks significant land uses which occupy only a small area.

9. Catchment Area:

Area of catchment to site of development, not including areas of previous development upstream.

10. Streamflow:

Average annual streamflow at development site. The average is calculated for the period of years shown in parentheses.

11. Reservoir area and Capacity:

Sizes for pipehead or pumpback schemes are only approximate and tend to be overestimated.

12. Resource Area:

Area of Public Water Supply Area (PWSA), Water Reserve (WR) or Groundwater Area (GA) associated with the groundwater scheme. The name of the relevant resource area is shown in parenthesis. Note that, with the exception of Gwelup PWSA, there is more than one scheme proposed for each resource area.

13. Quota:

Volume of water that, according to current estimates could be safely drawn from the resource each year, allowing for environmental constraints.

14. No. of Wells - Shallow and artesian groundwater:

The number of wells indicated are spaced along the collector mains shown for the scheme.

15. Yield Benefit:

Quoted for proposed schemes. The figure is the increase in System Yield which would result from adding the scheme to the system. For some groundwater schemes the yield benefit is greater than the quota because more efficient use is made of river schemes when such groundwater schemes are added to the system.

Water Used:

Quoted for existing schemes. The figure is the average annual usage of water the source would supply if the MWS was supplying the System Yield, i.e. was at its capacity.

16. Cost:

The cost per cubic metre of yield is the cost of delivering water from the scheme into the distribution system, assuming the MWS is supplying the System Yield. The cost is quoted in December 1987 dollars and includes capital costs converted to an annual charge at 6% interest rate, plus operating costs directly associated with the source.

17. Treatment:

A brief statement of the type of treatment that the development proposal has allowed for, based on the expected quality of the raw water.

18. Most likely date:

When the scheme has been included in the 'Most Likely' Source Development Timetable, its date of commissioning (coming into operation) is shown for easy reference. When a scheme is the preferred alternative for development of a resource but it is not expected to be required in the next 25 years, the date is shown as 'post 2012'.

Table A1 Existing and Possible Future River Schemes for the MWS

	MAP REF	SCHEME No.	MAIN DAMS	MAP REF	SCHEME No.	UPPER DAMS	MAP REF	SCHEME No.	PIPEHEADS
EXISTING	Fl	R1	Canning				Eh	R8	Nth Dandalup
	Fl	R2	Churchmans				Fi	R9	Serpentine
	Gn	R3	Helena						
	Fi	R4	Serpentine						
	Ff	R5	Sth Dandalup						
	Fm	R6	Victoria						
	Fk	R7	Wungong						
POSSIBLE FUTURE	Ea	R12	Harvey	Hn	R13b	Helena Upper Dam (Helena R.)	Eg	R18	Conjurunup
	Gn	R13	Helena Res. Raised				Ep	R19	Ellen
	Fn	R13a	Helena Lower Dam	Hm	R13c	Helena Upper Dam (Darkin R.)	Fo	R25	Jane
							Fo	R32	Susannah
	Eh	R14	Nth Dandalup	Gk	R17	Sth Canning			
	Fm	R15	Victoria						
	Fp	R16	Wooroloo						
	Fl	R17a	Canning Dam Raised						
	Eg	R18a	Conjurunup Dam						
	Ef	R29b	Marrinup Dam						
	Ee, Hc	R30a	Murray Dam outside Lane-Poole Reserve						
	Ee, Hc	R30b	Murray Two Dams						
	Ee	R30c	Murray Single Dam						

Table A1 (continued)

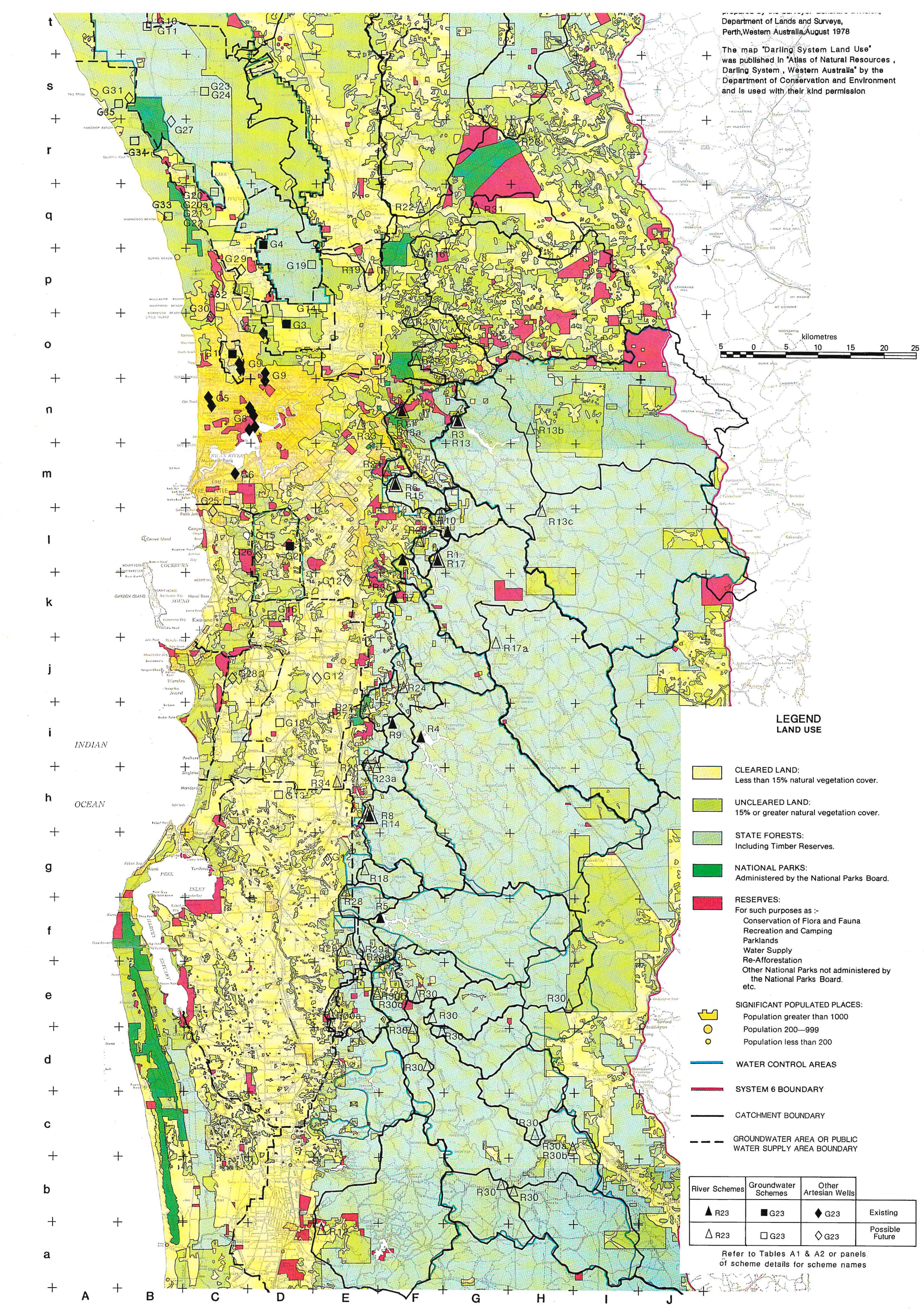
MAP REF	SCHEME No.	PUMPBACKS	MAP REF	SCHEME No.	ADDITIONAL PIPELINES
Gl	R10	Kangaroo Gully			
Fn	R11	Lower Helena			
Fl	R20	Araluen	Fn	R33	Mundaring Integration
Fm	R21	Bickley	Eh	R34	North Dandalup Mains Amplification
Fq	R22	Brockman			
Ei	R23	Dirk	Ek	R35	Wungong Outlet Amplification
Ei	R23a	Dirk Pumpback to Serpentine Pipehead			
Fj	R24	Gooralong			
Hr	R26	Julimar			
Ei	R27	Lower Serpentine Stage II			
Ei	R27a	Lower Serpentine Single P/B			
Eg	R28	Lower South Dandalup			
Ef	R29	Marrinup (Site 1)			
Ef	R29a	Marrinup (Site 2)			
Gd	R30	Murray Tributaries			
Gq	R31	Red Swamp			

Table A2 Existing and Possible Future Groundwater Schemes for the MWS

	MAP REF	SCHEME No.	GROUNDWATER SCHEMES	No. OF WELLS	
				Shallow G'water	Artesian (Treated)
EXISTING	Co	G1	Gwelup	12	5
	D1	G2	Jandakot	15	2
	Do	G3	Mirrabooka	34	5
	Dq	G4	Wanneroo	24	8
POSSIBLE FUTURE	Bt	G10	Barragoon Stage I	12	2
	Bt	G11	Barragoon Stage II	11	2
	Ek,Ej,Eg	G12	Cockleshell Gully Artesian	-	3
	Dh	G13	Dandalup	20	25
	Ep	G14	East Mirrabooka Stage III	4	-
	Br	G34	Eglinton	14	2
	D1	G15	Jandakot Stage II	15	2
	Dk	G16	Jandakot South Stage I	7	2
	Dk	G17	Jandakot South Stage II	7	1
	Di	G18	Karnup	20	15
	Ep	G19	Lexia	15	-
	Cq	G20	Pinjar Stage I	9	5
	Cq	G21	Pinjar Stage II	9	3
	Cq	G22	Pinjar Stage III	10	2
	Bq	G33	Quinns	14	-
	As	G35	Two Rocks/Yanchep	14	2
	Cp	G32	Whitfords	12	-
	Cs	G23	Yeal Stage I	12	2
	Cs	G24	Yeal Stage II	12	2

Table A2 (continued)

MAP REF	SCHEME No.	OTHER ARTESIAN WELLS (Untreated)	No. OF WELLS
Cn	G5	Bold Park	2
Cm	G6	Melville	1
Do	G7	Mirrabooka	1
Dn	G8	Mt Eliza	6
Do	G9	Yokine	4
Cl	G25	Hamilton Hill	1
Dl	G26	Lake Thomson	1
Br	G27	McNess East	1
Cj	G28	Tamworth	1
Cp	G29	Wanneroo	1
Co	G30	Whitfords	1
Bs	G31	Yanchep	1

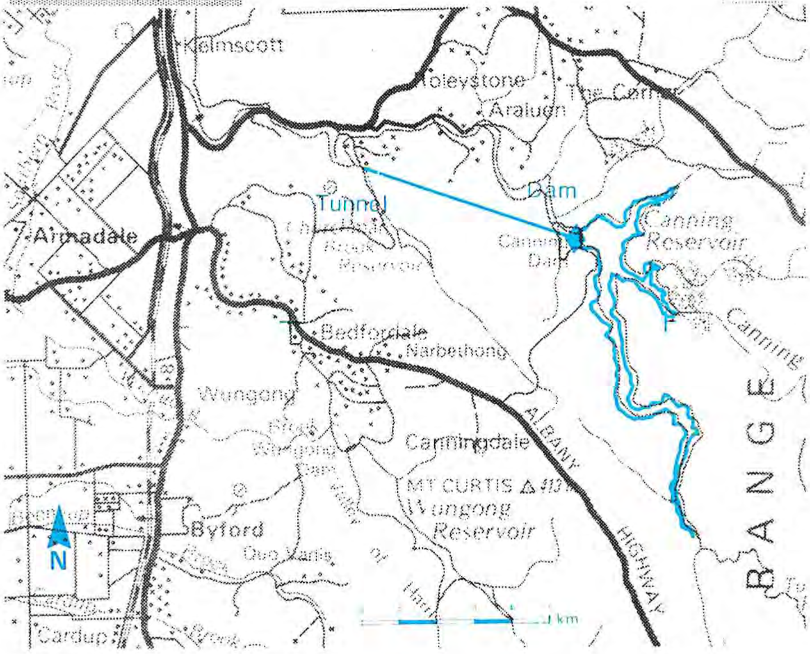


WATER SUPPLY SCHEME LOCATIONS and LAND USE

MAP A1

Table A3 Details of Existing and Proposed Water Supply Schemes

R1 CANNING DAM



Map reference F1

Catchment Area
727 sq.km

Streamflow (1947-86)
52.0 mill.cu.m/yr

Reservoir
Area
501 ha
Capacity
90.5 mill.cu.m

Water used
36.4 mill.cu.m/yr

Cost
11.0 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

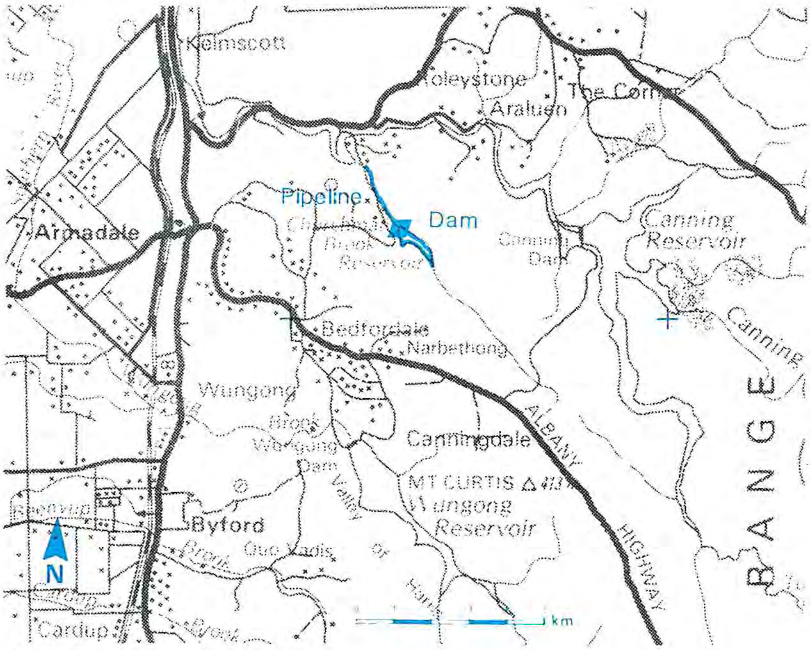
Land use	% of area
Forest	100

SCHEME: CANNING DAM.
Kangaroo Gully Diversion (R10), which channels part of Kangaroo Gully flows into Canning Reservoir, is included in costs. A temporary pumpback also takes water from the Canning River near Araluen in winter.

SPECIAL NOTES: Scheme R20 is proposed to replace the temporary pumpback. Scheme R17a is a proposal to raise Canning Dam.

STATUS OF OPTION: Existing.

R2 CHURCHMAN'S BROOK DAM



Map reference F1

Catchment Area
17 sq.km

Streamflow (1911-80)
4.5 mill.cu.m/yr

Reservoir
Area
23 ha
Capacity
2.2 mill.cu.m

Water used
3.75 mill.cu.m/yr

Cost
11.8 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

Land use	% of area
Forest	100

SCHEME: CHURCHMAN'S DAM.

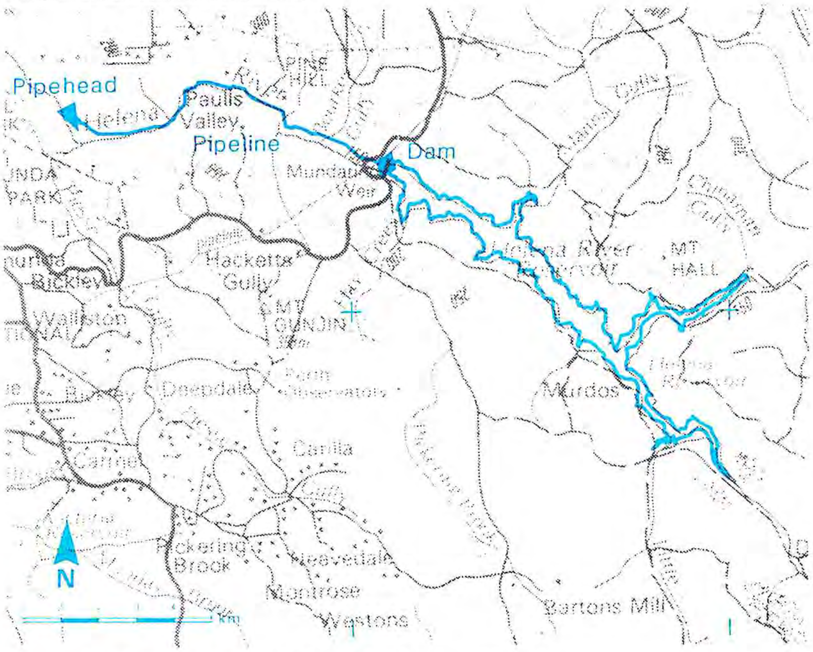
SPECIAL NOTES: Outlet main enlarged in 1987 resulting in increased yield.

STATUS OF OPTION: Existing.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R3 HELENA RESERVOIR



Map reference Gn

Catchment Area
1482 sq.km

Streamflow (1947-86)
38.3 mill.cu.m/yr

Reservoir
Area
761 ha
Capacity
77.1 mill.cu.m

Water used
22.3 mill.cu.m/yr

Cost
6.6 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

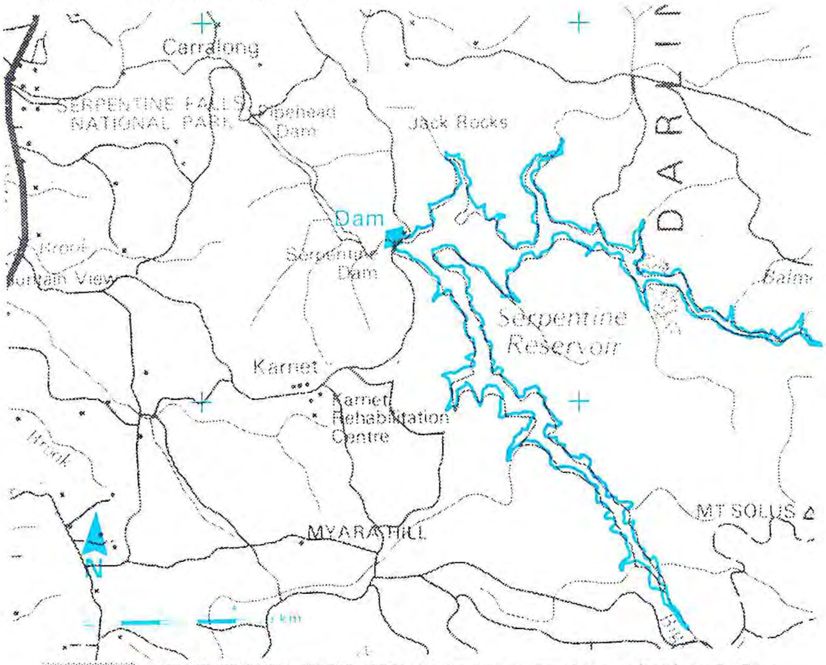
Land use	**% of area**
Forest	95
Pasture	5

SCHEME: HELENA RESERVOIR (Mundaring Weir). Principally supplies water for the G&AWS System but also contributes to the MWS. Receives water from L. Helena Pumpback (R11).

SPECIAL NOTES: Famous for being originally constructed by C.Y. O'connor to supply the Goldfields. A museum is established in the old pumping station. Scheme R13 proposes to raise Mundaring Weir.

STATUS OF OPTION: Existing.

R4 SERPENTINE DAM



Map reference Fi

Catchment Area
660 sq.km

Streamflow (1911-80)
72.4 mill.cu.m/yr

Reservoir
Area
1280 ha
Capacity
194.5 mill.cu.m

Water used
63.6 mill.cu.m/yr

Cost
6.8 cents/cu.m

Treatment
Nil

Most likely date
Existing

Land use	**% of area**
Forest	95
Pasture	*

SCHEME: SERPENTINE MAIN DAM releases to the pipehead dam downstream (R9) for entry to the distribution system. (Cost includes Serpentine Pipehead)

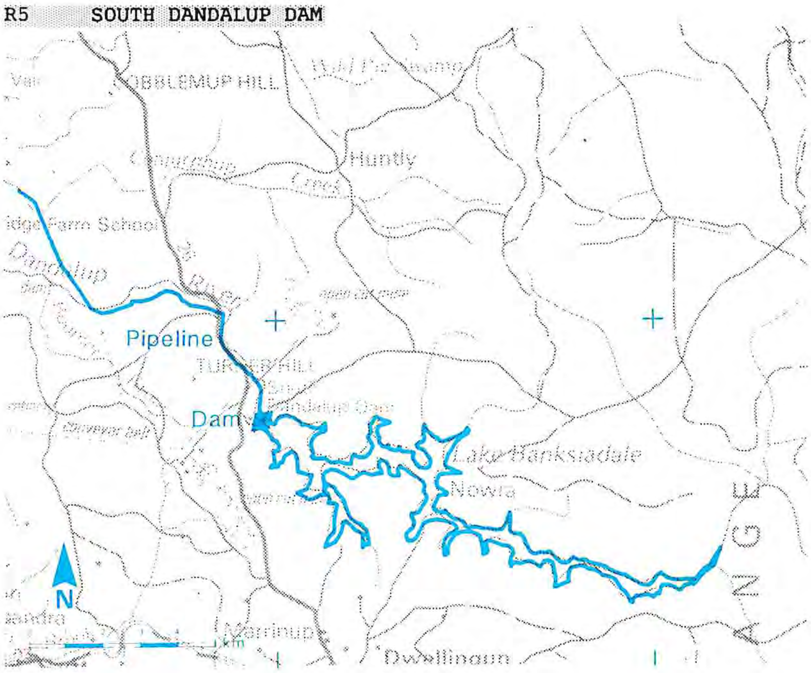
SPECIAL NOTES: Bauxite mining in the catchment is planned within 25 years. Schemes R23, R24, R27 and R27a are proposals to pumpback to Serpentine Reservoir.

STATUS OF OPTION: Existing.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R5 SOUTH DANDALUP DAM



Map reference Ff

Catchment Area
315 sq.km

Streamflow (1947-86)
30.7 mill.cu.m/yr

Reservoir
Area
2100 ha
Capacity
208.2 mill.cu.m

Water used
17.9 mill.cu.m/yr

Cost
9.6 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

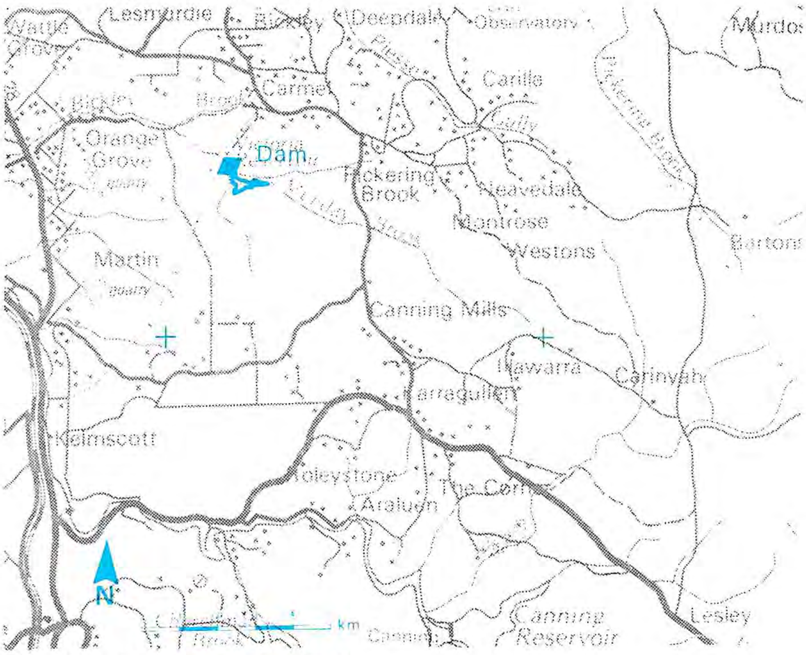
SCHEME: SOUTH DANDALUP DAM.
Pinjarra Pipehead (referred to in R28), located downstream supplies Pinjarra and is supplemented from the South Dandalup pipeline when streamflows are inadequate for the pipehead or turbidity in pipehead water is severe.

Land use	% of area
Forest	100

SPECIAL NOTES: Bauxite mining has occurred in the catchment. Schemes R28, R29, R29a and R30 are proposals to pumpback to South Dandalup Reservoir.

STATUS OF OPTION: Existing.

R6 VICTORIA RESERVOIR



Map reference Fm

Catchment Area
37 sq.km

Streamflow (1911-80)
5 mill.cu.m/yr

Reservoir
Area
18 ha
Capacity
0.9 mill.cu.m

Water used
4.3 mill.cu.m/yr

Cost
12.7 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

SCHEME: VICTORIA RESERVOIR.

Land use	% of area
Forest	95
Horticulture	*

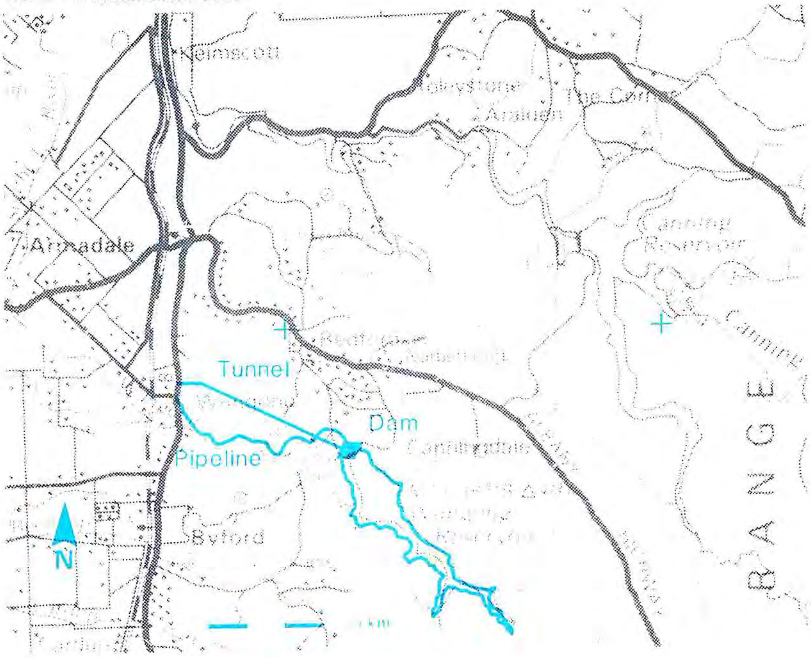
SPECIAL NOTES: R15 is a scheme for replacing the dam to increase yield. The spillway crest was lowered 2 m in 1988 to ensure capacity for the Maximum Probable Flood. The dam is scheduled for early replacement so that standards of earthquake resistance can be raised.

STATUS OF OPTION: Existing.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R7 WUNGONG DAM



Map reference Fk

Catchment Area
130 sq.km

Streamflow (1947-86)
25.6 mill.cu.m/yr

Reservoir
Area
330 ha
Capacity
60 mill.cu.m

Water used
20.9 mill.cu.m/yr

Cost
17.8 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

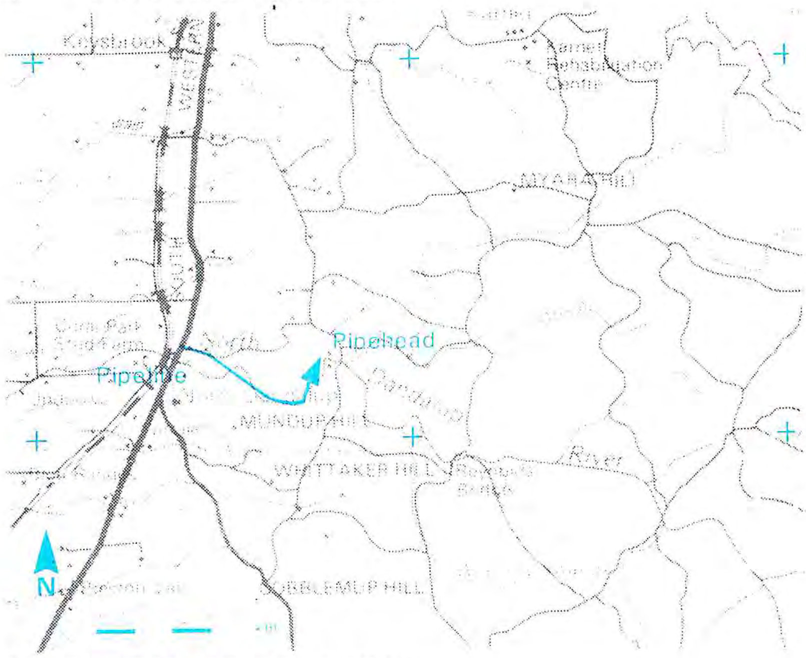
Land use	% of area
Forest	100

SCHEME: WUNGONG DAM.

SPECIAL NOTES: Bauxite mining has occurred in the catchment. Scheme R35 is proposed to increase the outlet capacity of Wungong Dam.

STATUS OF OPTION: Existing.

R8 NORTH DANDALUP PIPEHEAD



Map reference Eh

Catchment Area
153 sq.km

Streamflow (1947-86)
28.0 mill.cu.m/yr

Reservoir
Area
1 ha
Capacity
0.02 mill.cu.m

Water used
11.3 mill.cu.m/yr

Cost
2.2 cents/cu.m

Treatment
Disinfection

Most likely date
Existing

Land use	% of area
Forest	100

SCHEME: NORTH DANDALUP PIPEHEAD.

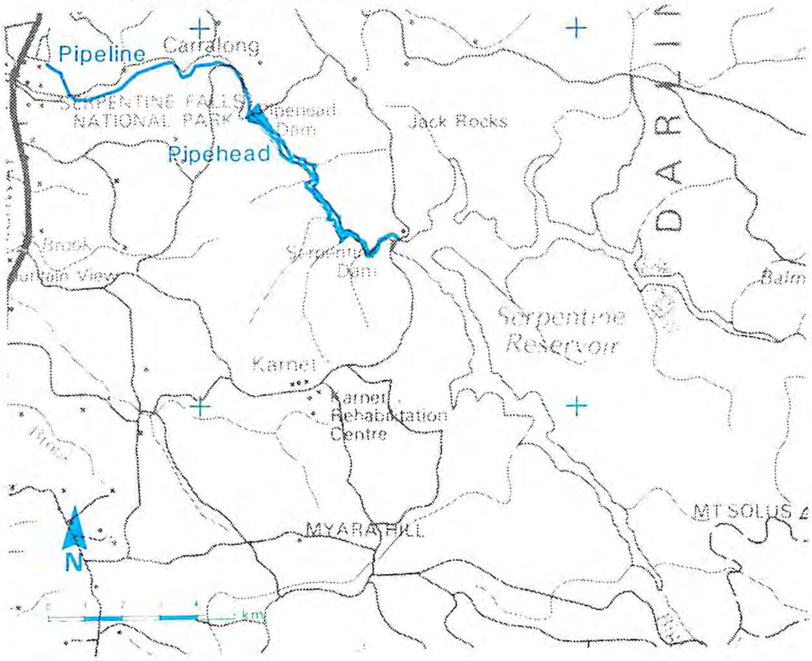
SPECIAL NOTES: Scheme R14 is a proposal to to replace this pipehead with a main dam.

STATUS OF OPTION: Existing.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R9 SERPENTINE PIPEHEAD



Map reference Fi 0

Catchment Area
29 sq.km

Streamflow (1911-80)
4.8 mill.cu.m/yr

Reservoir
Area
61 ha
Capacity
3.1 mill.cu.m

Water used
2.8 mill.cu.m/yr

Cost
see Scheme R4

Treatment
Disinfection

Most likely date
Existing

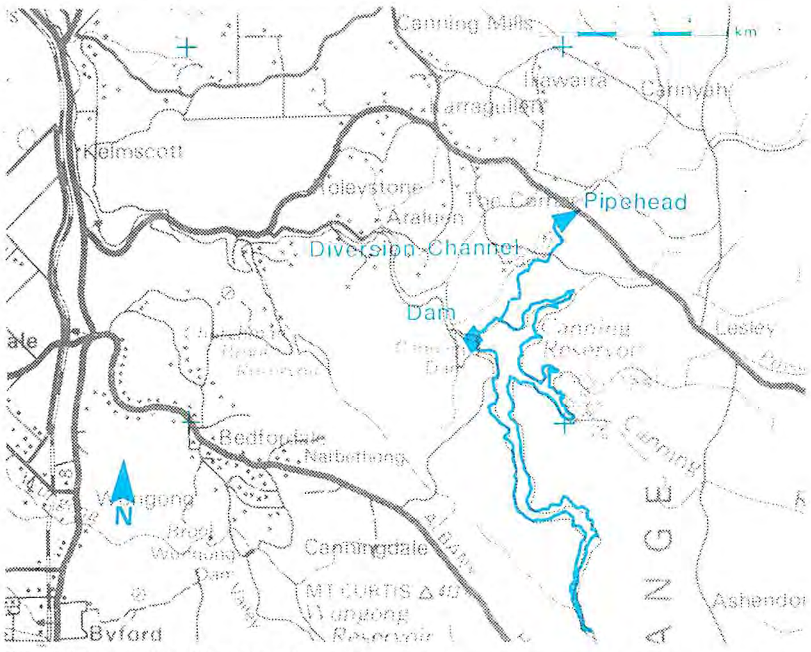
Land use	% of area
Forest	100

SCHEME: SERPENTINE PIPEHEAD.
Functions with Serpentine Dam (R4).

SPECIAL NOTES: The reservoir is surrounded by System 6 reserves M86 and M87.

STATUS OF OPTION: Existing.

R10 KANGAROO GULLY DIVERSION



Map reference G1

Catchment Area
54 sq.km

Streamflow (1911-80)
5.3 mill.cu.m/yr

Reservoir
Area
1 ha
Capacity
0.02 mill.cu.m

Water used
3.5 mill.cu.m/yr

Cost
Scheme R1

Treatment
Retention in Canning Reservoir

Most likely date
Existing

Land use	% of area
Forest	95
Horticulture	*

SCHEME: KANGAROO GULLY DIVERSION to Canning Dam (R1) operates in a similar manner to a pumpback.

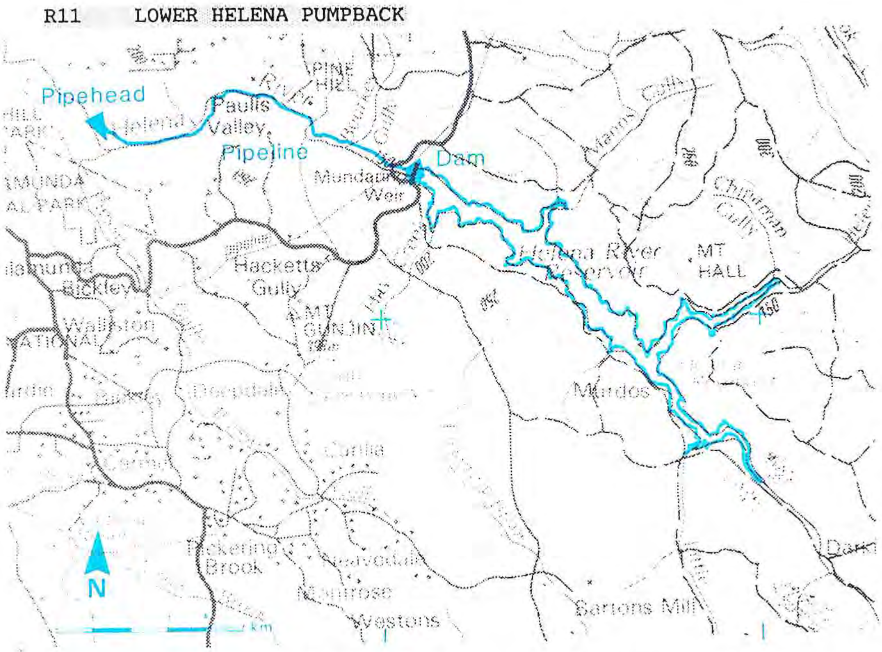
SPECIAL NOTES:

STATUS OF OPTION: Existing.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R11 LOWER HELENA PUMPBACK



Map reference Fn

Catchment Area
118 sq.km

Streamflow (1947-86)
18.0 mill.cu.m/yr

Reservoir
Area
4 ha
Capacity
0.13 mill.cu.m

Water used
9.1 mill.cu.m/yr

Cost
18.7 cents/cu.m

Treatment
Retention in Helena Reservoir

Most likely date
Existing

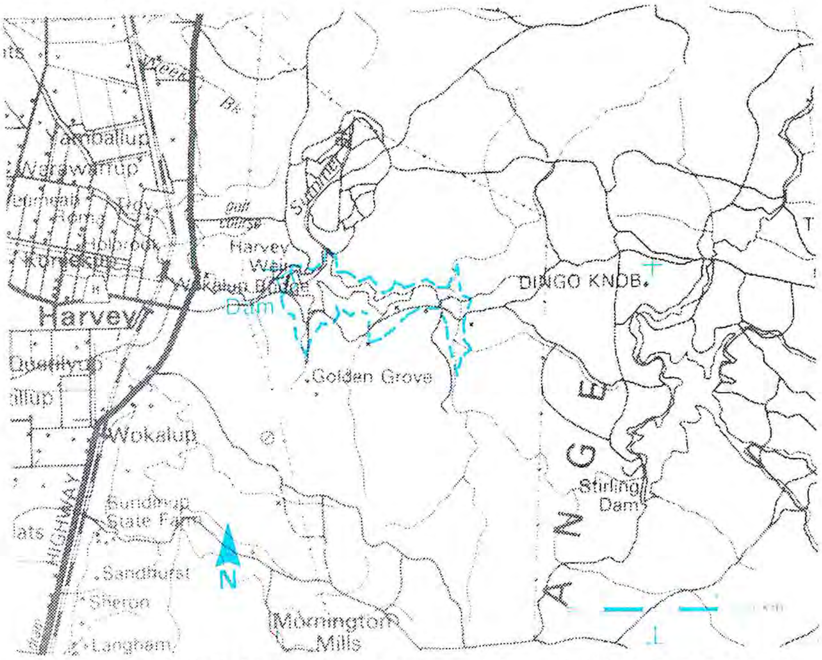
SCHEME: LOWER HELENA PUMPBACK to Helena Reservoir (R3). Also used to transfer water from the MWS distribution system to Helena Reservoir when required by the Mundaring Integration Scheme (see R33).

SPECIAL NOTES: Catchment contains part of Kalamunda townsite and Pickering Brook orchards.

Land use	% of area
Forest	70
Horticulture	8
Special rural	19
Urban	3

STATUS OF OPTION: Existing

R12 HARVEY RIVER DAM



Map reference Ea

Catchment Area
353 sq.km

Streamflow (1911-80)
106.4 mill.cu.m/yr

Reservoir
Area
600 ha
Capacity
140 mill.cu.m

Yield benefit
40.0 mill.cu.m/yr

Cost
46.0 cents/cu.m
(see SPECIAL NOTES)

Treatment
Disinfection

Most likely date
Post 2012

SCHEME: HARVEY RIVER DAM redevelopment including transfer of water to Mandurah area.

SPECIAL NOTES: Harvey Dam will continue to provide water for the Harvey townsite and for irrigation purposes. The quoted yield is additional to a current use of 56 mill.cu.m/yr. This cost assumes a supply of water to Forrestdale for distribution into the MWS system.

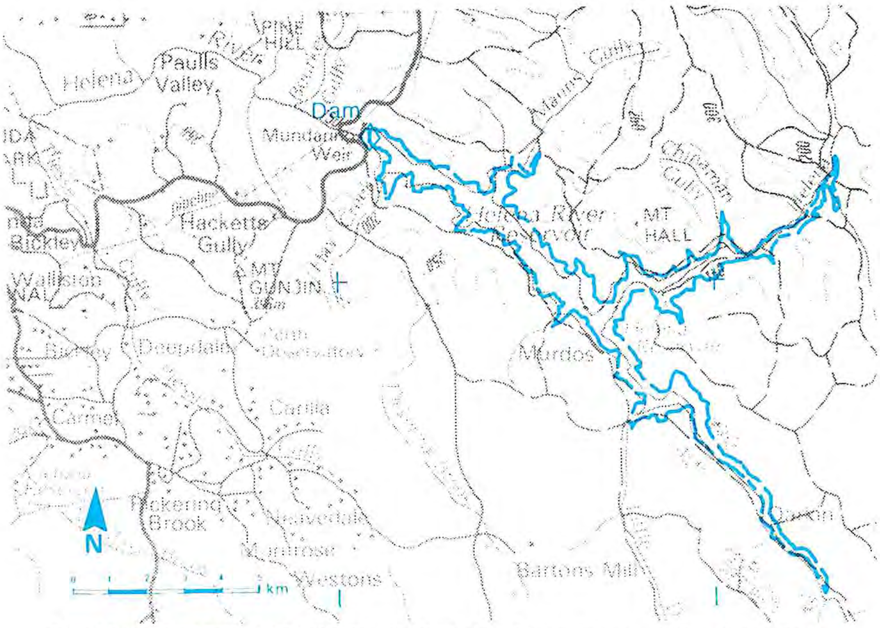
Land use	% of area
Forest	75
Pasture	25

STATUS OF OPTION: Currently preferred option, further investigation is required.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R13 HELENA RES. RAISED DAM



Map reference Gn

Catchment Area
1482 sq.km

Streamflow (1947-86)
38.3 mill.cu.m/yr

Reservoir
Area
1400 ha
Capacity
200 mill.cu.m

Yield benefit
additional
10.0 mill.cu.m/yr
Cost
19.0 cents/cu.m

Treatment
Disinfection

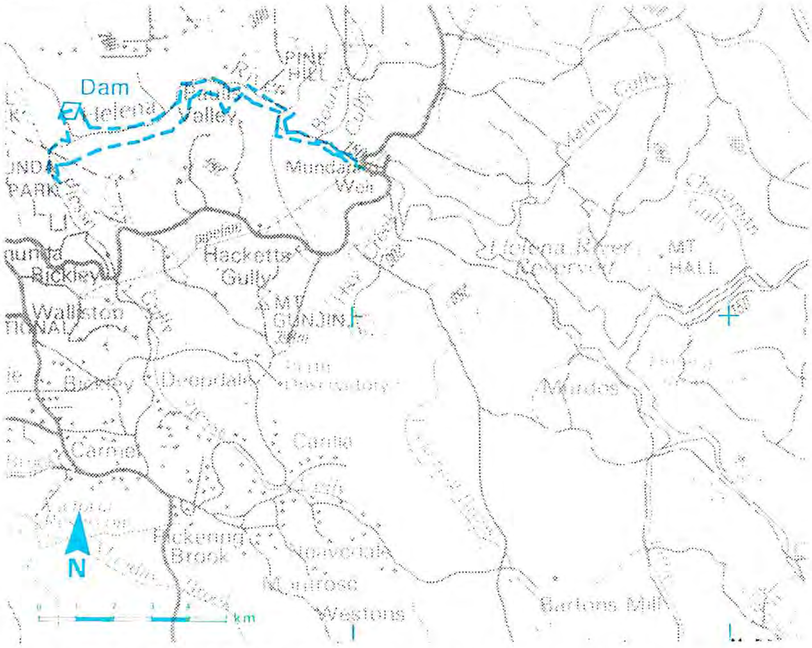
Most likely date
2000/01

SCHEME: HELENA RESERVOIR RAISED by 12 metres. (R3) capacity increased by raising Mundaring Weir.

Land use	% of area
Forest	95
Pasture	5

SPECIAL NOTES: Mundaring Weir has been raised before.
In its recommendations to Government on the 'Next Major Public Water Supply Source for Perth (Post 1992)' ERMP, the EPA has stated that this scheme is environmentally acceptable.
Yield benefit as next major source i.e. before more pumpbacks added to system would be 7.5 mill.cu.m/yr at a cost of 25.3 cents/cu.m.
STATUS OF OPTION: Preferred option.

R13a HELENA LOWER DAM



Map reference Fn

Catchment Area
118 sq.km

Streamflow (1911-80)
18.9 mill.cu.m/yr

Reservoir
Area
390 ha
Capacity
80 mill.cu.m

Yield benefit
13.5 mill.cu.m/yr

Cost
66.5 cents/cu.m

Treatment
Disinfection

Most likely date
N/A

SCHEME: HELENA LOWER DAM at the site of the existing Lower Helena Pumpback (R11).

SPECIAL NOTES:

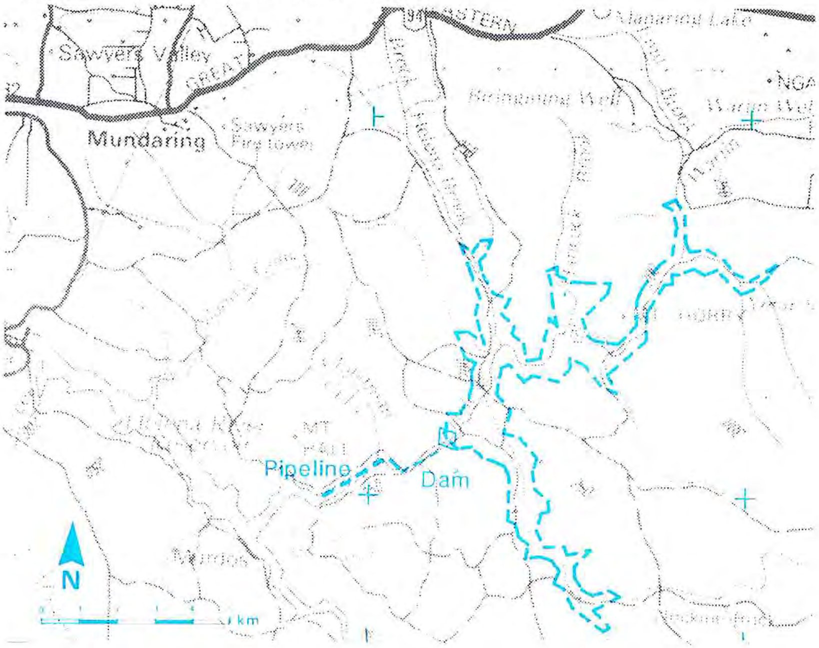
Land use	% of area
Forest	70
Horticulture	8
Special rural	19
Urban	3

STATUS OF OPTION: Not preferred due to high cost compared to raising Helena Reservoir.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R13b HELENA UPPER DAM (HELENA)



Map reference	Hn

Catchment Area
583 sq.km

Streamflow (1911-80)
13.1 mill.cu.m/yr

Reservoir
Area
1700 ha
Capacity
247 mill.cu.m

Yield benefit
8.9 mill.cu.m/yr

Cost
40.2 cents/cu.m

Treatment
Nil

Most likely date
N/A

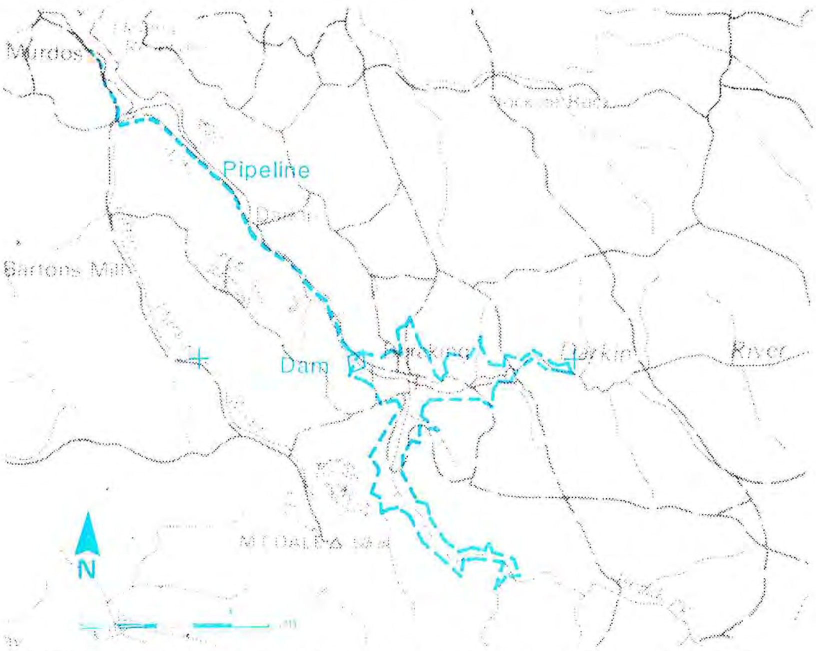
SCHEME: UPPER HELENA DAM on Helena River with pumping from Helena Reservoir (R3) into upper reservoir.

Land use	% of area
Forest	95
Pasture	5

SPECIAL NOTES: Pine plantations at present in part of reservoir basin. Stored water likely to have high salt content due to clearing in catchment for agriculture and reservoir basin.

STATUS OF OPTION: Not preferred due to high cost compared to raising Helena Reservoir.

R13c HELENA UPPER DAM (DARKIN)



Map reference	Hm

Catchment Area
664 sq.km

Streamflow (1911-80)
5.7 mill.cu.m/yr

Reservoir
Area
914 ha
Capacity
<200 mill.cu.m

Yield benefit
<12 mill.cu.m/yr

Cost
38.3 cents/cu.m

Treatment
Nil

Most likely date
N/A

SCHEME: UPPER HELENA DAM on Darkin River with pumping from Helena Reservoir (R3) into upper reservoir.

Land use	% of area
Forest	100
Pasture	*

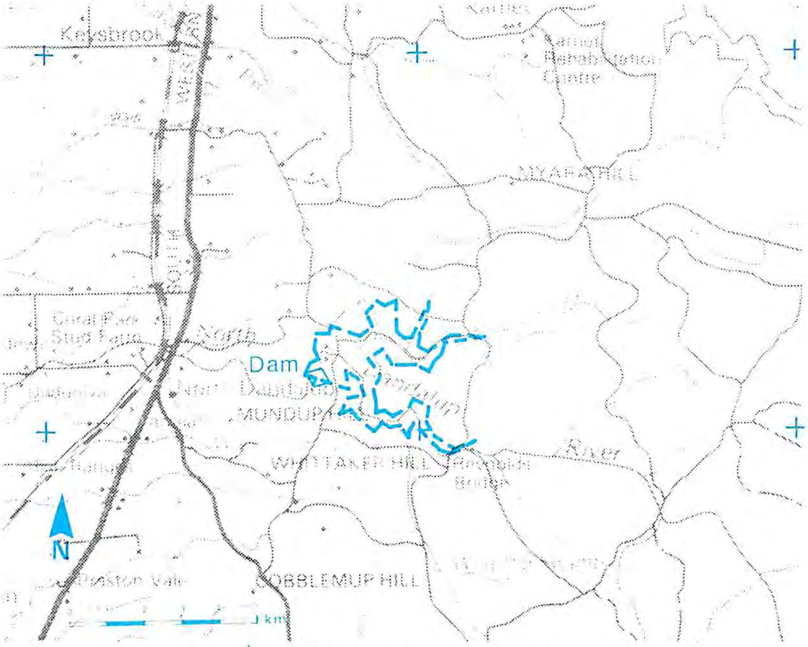
SPECIAL NOTES: Geological problems at damsite. Conservation Reserve adjacent to proposed reservoir. Effects on salinity due to clearing reservoir basin have not been investigated.

STATUS OF OPTION: Not preferred due to high cost compared to raising Helena Reservoir.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R14 NORTH DANDALUP DAM



Map reference Eh

Catchment Area
153 sq.km

Streamflow (1947-86)
28.0 mill.cu.m/yr

Reservoir
Area
500 ha
Capacity
75 mill.cu.m

Yield benefit
11.2 mill.cu.m/yr

Cost
30.0 cents/cu.m

Treatment
Disinfection

Most likely date
1996/97

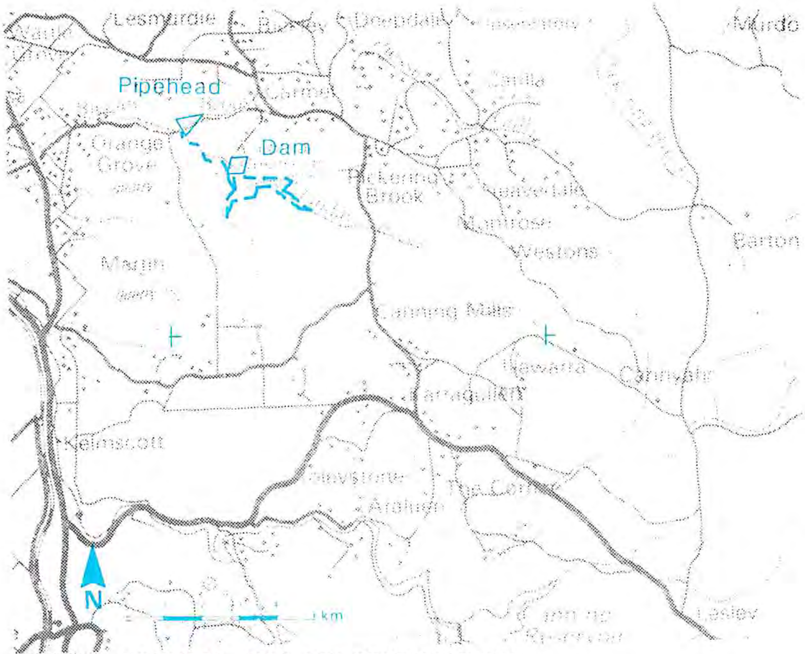
SCHEME: NORTH DANDALUP DAM to replace North Dandalup Pipehead (R8). Uses existing pipe from pipehead.

Land use	% of area
Forest	100

SPECIAL NOTES: Yield is additional to the yield of the existing pipehead. Some of proposed works at damsite would lie within System 6 reserve C49. In its recommendations to Government on the 'Next Major Public Water Supply Source for Perth (Post 1992)' ERMP, The EPA has stated that this scheme is environmentally acceptable, and that the Water Authority should proceed with preparing its environmental management proposals.

STATUS OF OPTION: Preferred option.

R15,21 VICTORIA/BICKLEY REDEVELOPMENT



Map reference Fm

Catchment Area
52 sq.km

Streamflow (1911-80)
7.9 mill.cu.m/yr

Reservoir
Area
82 ha
Capacity
10 mill.cu.m

Yield benefit
6.0 mill.cu.m/yr

Cost
25.0 cents/cu.m

Treatment
Pump-back water detained in new res.
Draw from reservoir disinfected

Most likely date
1991/92

SCHEME: VICTORIA /BICKLEY REDEVELOPMENT.
Pumpback from below join of Munday and Bickley Brooks to new larger reservoir.

Land use	% of area
Forest	95
Horticulture	5
Pasture	*

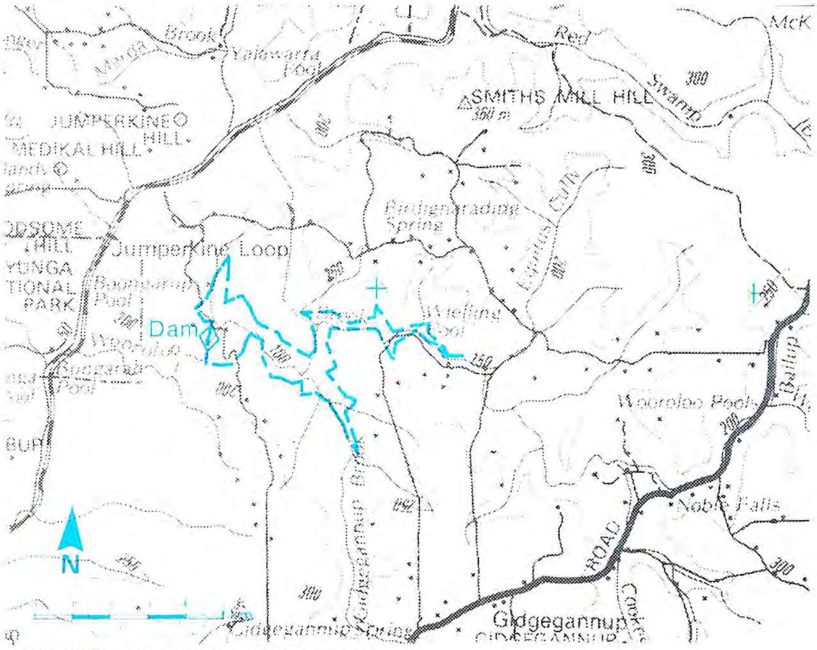
SPECIAL NOTES: Bickley catchment is at present a declared Water Reserve, but does not contribute to MWS. Pumpback site selected to avoid damage to historic bridge on Hardinge Rd alignment.

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R16 WOOROLOO BROOK DAM



SCHEME: WOOROLOO BROOK DAM.

SPECIAL NOTES: Outlet pipe route from dam uncertain. Could receive pumpback water from schemes R22, R26 and R31.

STATUS OF OPTION: Currently preferred option, further investigation is required.

Map reference Fp

Catchment Area
536 sq.km

Streamflow (1911-85)
42.8 mill.cu.m/yr

Reservoir
Area
360 ha
Capacity
180 mill.cu.m

Yield benefit
26.6 mill.cu.m/yr

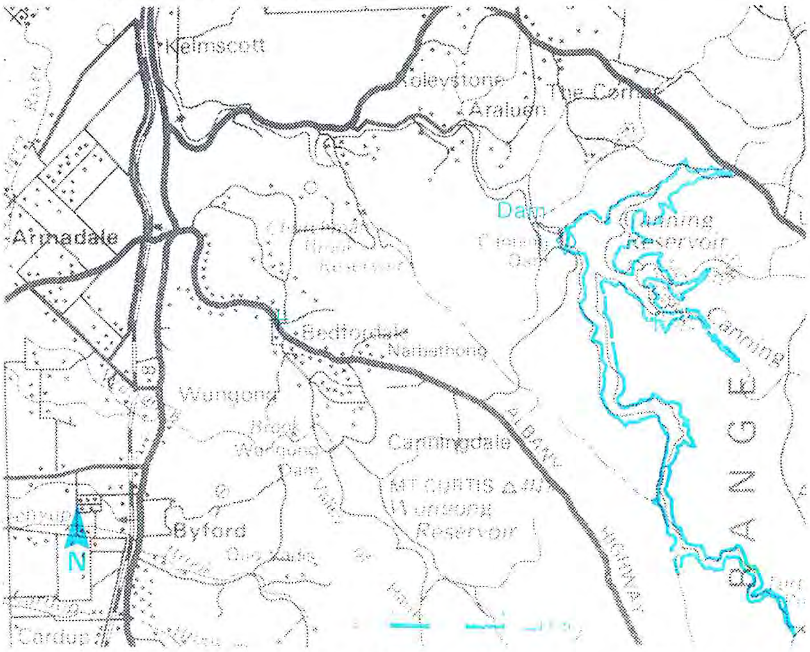
Cost
68.0 cents/cu.m

Treatment
Full treatment & desalination

Most likely date
Post 2012

Land use	% of area
Forest	50
Pasture	50
Horticulture	*
Industrial	*
Special rural	*
Urban	*

R17 RAISE CANNING DAM



SCHEME: Canning Reservoir (R1) capacity increased by raising CANNING DAM by 11.6 metres.

SPECIAL NOTES: Extension of cleared area for enlarged reservoir basin is much less than clearing required for South Canning (R17). Extremity of southern arm extends into Monadnock Reserve (System 6 reserve C36). In its recommendations to Government on the 'Next Major Public Water Supply Source for Perth (Post 1992)' ERMP, the EPA stated that this scheme was environmentally acceptable.
STATUS OF OPTION: Preferred Option.

Map reference F1

Catchment Area
727 sq.km

Streamflow (1911-80)
61.5 mill.cu.m/yr

Reservoir
Area
990 ha
Capacity
170.5 mill.cu.m

Yield benefit
additional
9.8 mill.cu.m/yr
Cost
34.2 cents/cu.m

Treatment
Disinfection

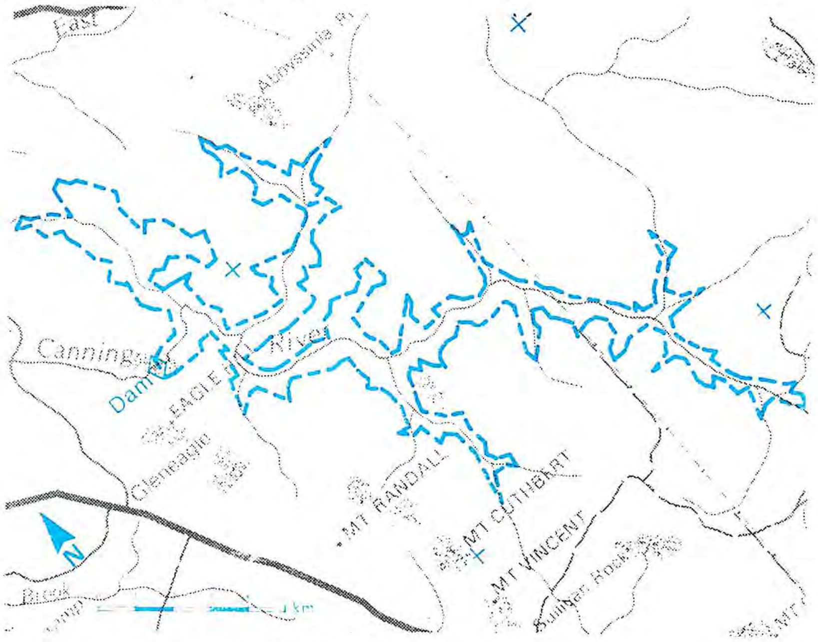
Most likely date
Post 2012

Land use	% of area
Forest	100

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

*** small but significant area**

R17a SOUTH CANNING DAM



Map reference Gk

Catchment Area
495 sq.km

Streamflow (1911-80)
24 mill.cu.m/yr

Reservoir
Area
2500 ha
Capacity
210 mill.cu.m

Yield benefit
14.6 mill.cu.m/yr

Cost
16.1 cents/cu.m

Treatment
Nil

Most likely date
N/A

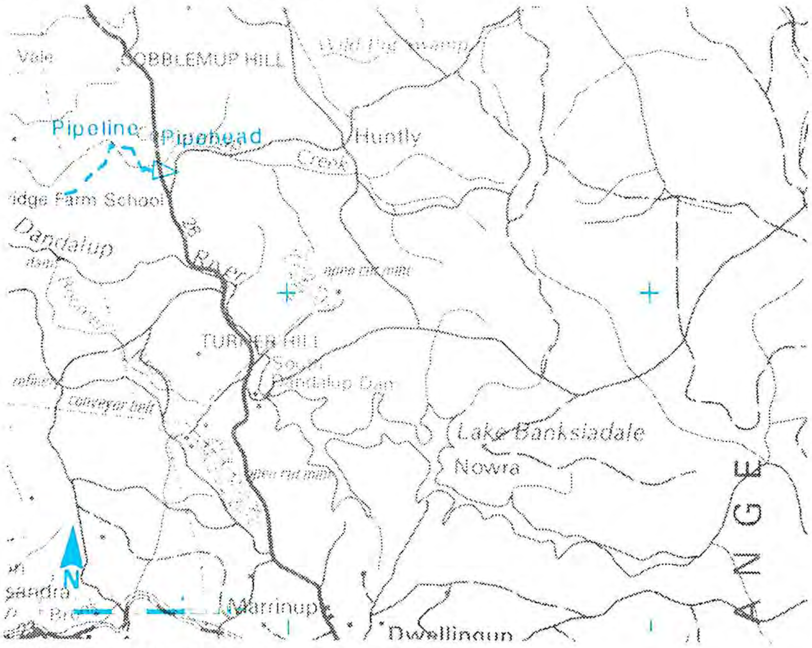
Land use	% of area
Forest	100

SCHEME: SOUTH CANNING DAM.
Upper dam to Canning Reservoir (R1).

SPECIAL NOTES: Increased salinity due to clearing reservoir basin and evaporation from reservoir have been given special consideration. Yield benefit is affected by position of scheme in the development timetable. If developed as next major source, yield benefit would be 11 mill.cu.m/yr, and extra yield would be developed by pumpback schemes R23, R24, R27 and R29.

STATUS OF OPTION: Rejected due to uncertainity of yield benefit when considering Climate change and possible salinity problems.

R18 CONJURUNUP PIPEHEAD



Map reference Eg

Catchment Area
39.2 sq.km

Streamflow (1947-86)
9.5 mill.cu.m/yr

Reservoir
Area
10 ha
Capacity
100 thou.cu.m

Yield benefit
4.5 mill.cu.m/yr

Cost
10.0 cents/cu.m

Treatment
Disinfection

Most likely date
1994/95

Land use	% of area
Forest	100

SCHEME: CONJURUNUP PIPEHEAD.

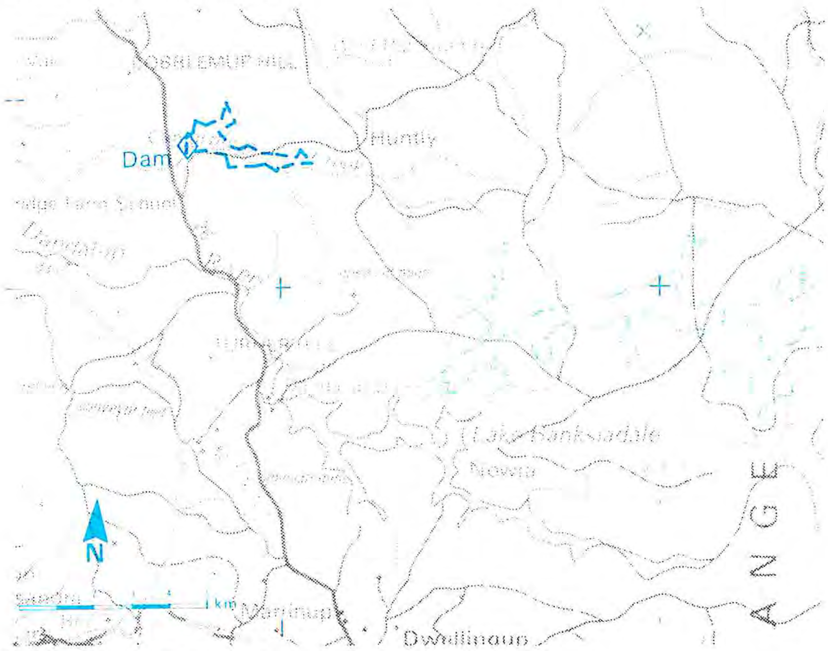
SPECIAL NOTES: This scheme is presently under review.

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R18a CONJURUNUP DAM



SCHEME: CONJURUNUP DAM.

SPECIAL NOTES:

STATUS OF OPTION: Not preferred due to high cost compared to Conjurunup Pipehead (R18). May replace pipehead when cost of alternative sources exceeds 28.2 cents/cu.m. This scheme is presently under review.

Map reference Eg

Catchment Area
37 sq.km

Streamflow (1911-80)
10.5 mill.cu.m/yr

Reservoir
Area
100 ha
Capacity
49 mill.cu.m

Yield benefit
8.2 mill.cu.m/yr

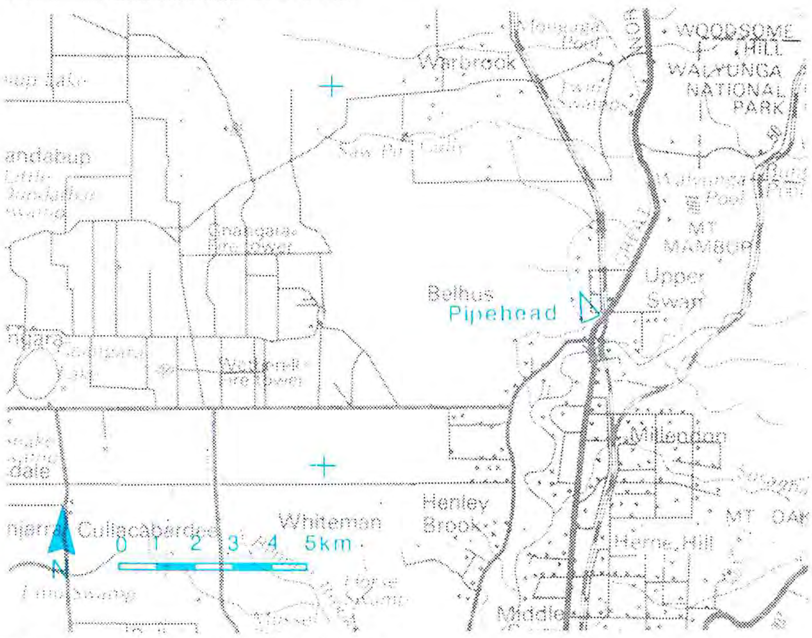
Cost
28.2 cents/cu.m

Treatment
Disinfection

Most likely date
N/A

Land use	% of area
Forest	100

R19 ELLEN BROOK PIPEHEAD



SCHEME: ELLEN BROOK PIPEHEAD

SPECIAL NOTES: Details of site for treatment have not been assessed. Design of pipehead will need sensitive consideration of nearby residential land.

STATUS OF OPTION: Currently preferred option, further investigation is required.

Map reference Ep

Catchment Area
590 sq.km

Streamflow (1911-85)
26.2 mill.cu.m/yr

Reservoir
Area
<40 ha
Capacity
110 thou.cu.m

Yield benefit
7.1 mill.cu.m/yr

Cost
41.0 cents/cu.m

Treatment
As for Groundwater Treatment

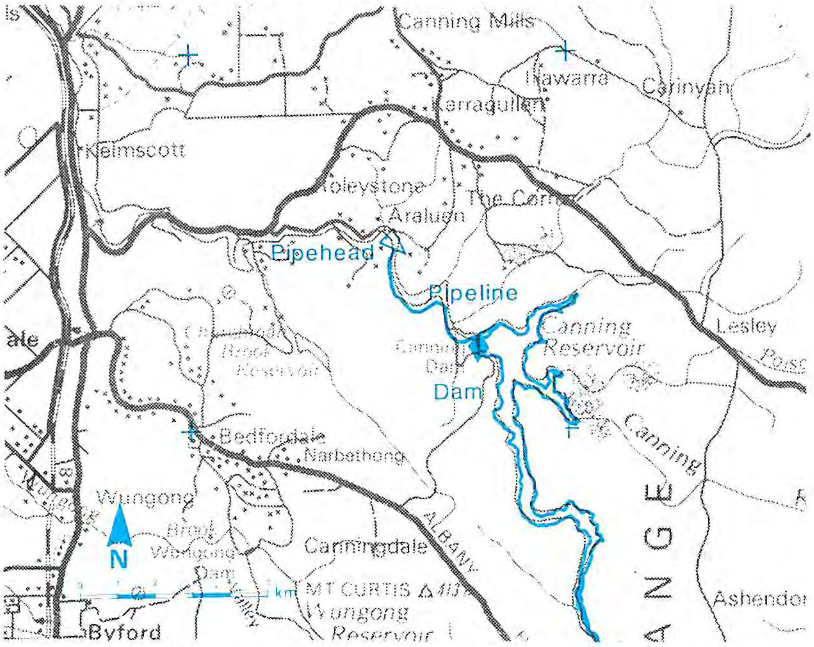
Most likely date
Post 2012

Land use	% of area
Forest	40
Pasture	20
Special rural	25
Horticulture	10
Urban	5
Industrial	*
Intensive animal husbandry	*

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R20 ARALUEN PUMPBACK



Map reference F1

Catchment Area
20.4 sq.km

Streamflow (1947-86)
3.5 mill.cu.m/yr

Reservoir
Area
<5 ha
Capacity
55 thou.cu.m

Yield benefit
1.2 mill.cu.m/yr

Cost
29.0 cents/cu.m

Treatment
Detention in Canning Reservoir

Most likely date
2000/01

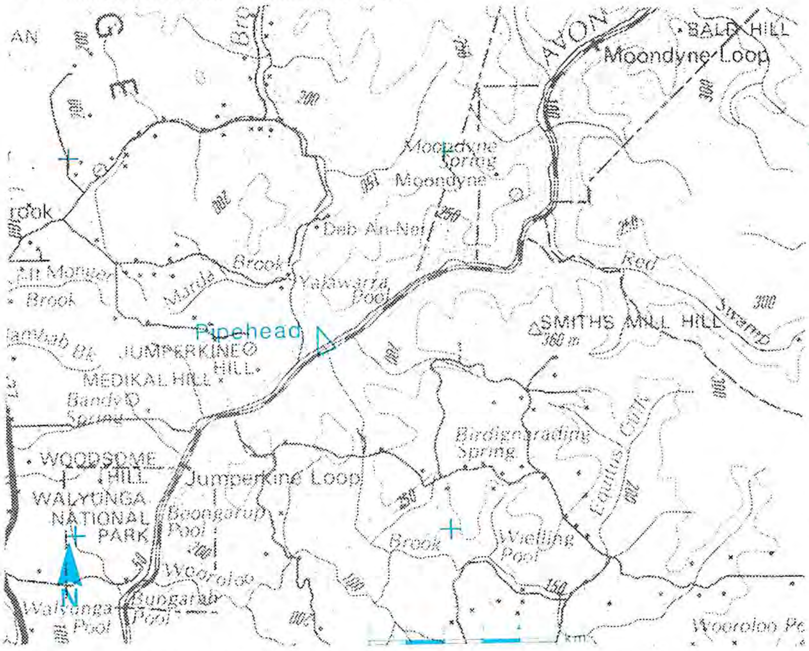
SCHEME: ARALUEN PUMPBACK to replace temporary pumpback to Canning Reservoir (R1).

Land use	% of area
Forest	100
Pasture	*

SPECIAL NOTES: Located on Canning R. upstream of confluence with Stinton Ck. Includes overflows of Kangaroo Gully.

STATUS OF OPTION: Preferred option.

R22 BROCKMAN RIVER PUMPBACK



Map reference Fq

Catchment area
1510 sq.km

Streamflow (1911-85)
45.8 mill.cu.m/yr

Reservoir
Area
40 ha
Capacity
140 thou.cu.m

Yield benefit
15 mill.cu.m/yr

Cost
$1.02 /cu.m

Treatment
Retention in Wooroloo Reservoir

Most likely date
Post 2012

SCHEME: BROCKMAN RIVER PUMPBACK to Wooroloo Brook Dam (R16).

Land use	% of area
Forest	60
Horticulture	5
Pasture	35
Urban	*

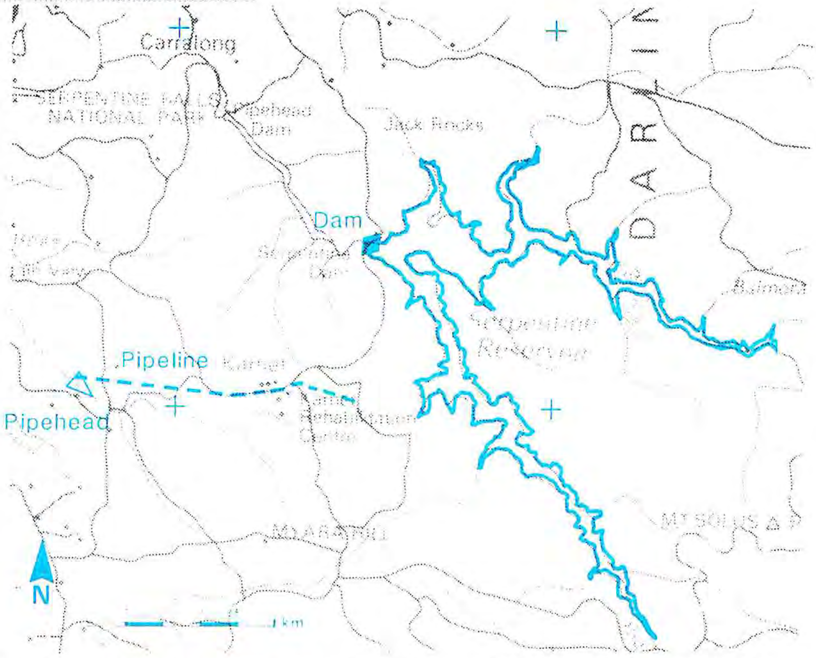
SPECIAL NOTES: Pipe route to Wooroloo Brook not yet known. Main dam option at site not preferred due to impact of reservoir on Chittering Valley. Pumpback dam approximately 300m upstream of confluence of Brockman and Avon Rivers. Wooroloo outlet main will require duplicating when Brockman comes on line.

STATUS OF OPTION: Currently preferred option, further investigation is required.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R23 DIRK PUMPBACK



Map reference	Ei
Catchment area	30.7 sq.km
Streamflow (1947-86)	9.5 mill.cu.m/yr
Reservoir Area	<5 ha
Capacity	<70 thou.cu.m
Yield benefit	3.5 mill.cu.m/yr
Cost	32.0 cents/cu.m
Treatment	Retention in Serpentine Reservoir
Most likely date	2006/07

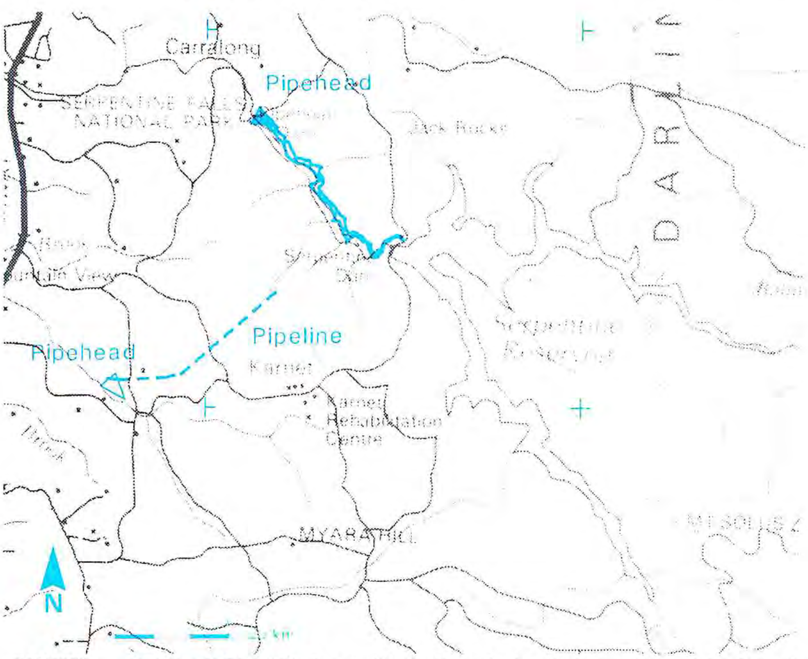
Land use	% of area
Forest	85
Pasture	15
Horticulture	*
Industry	*
Urban	*

SCHEME: PUMPBACK from Dirk Brook to Serpentine Reservoir (R4).

SPECIAL NOTES: Catchment contains Karnet Rehabilitation Centre.

STATUS OF OPTION: Preferred option.

R23a DIRK PUMPBACK TO PIPEHEAD



Map reference	Ek
Catchment area	26.6 sq.km
Streamflow (1911-80)	7.7 mill.cu.m/yr
Reservoir Area	<5 ha
Capacity	<70 thou.cu.m
Yield benefit	3.0 mill.cu.m/yr
Cost	30.7 cents/cu.m
Treatment	Retention in Serpentine Pipehead Reservoir
Most likely date	N/A

Land use	% of area
Forest	85
Pasture	15
Horticulture	*
Industry	*
Urban	*

SCHEME: DIRK PUMPBACK from Dirk Brook to Serpentine Pipehead Reservoir (R9). Demonstrates a) alternative site and b) alternative pipe route.

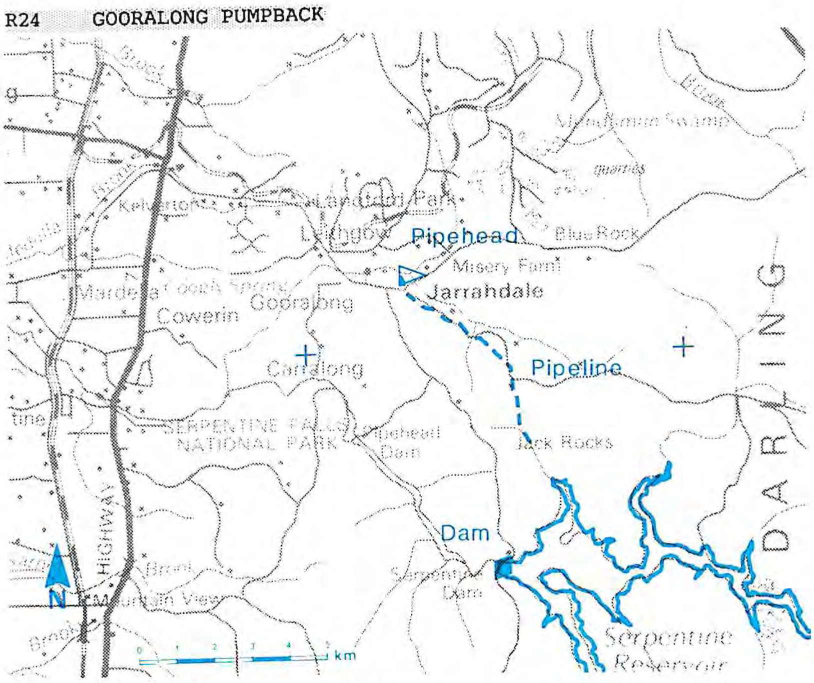
SPECIAL NOTES: a) Alternative site has smaller catchment than R23. b) Pipe route is shortest possible, but discharged water flows through Conservation Reserve (M86) and retention time of water in pipehead reservoir may not be adequate.

STATUS OF OPTION: Not preferred.
a) Alternative site is less economic.
b) Alternative pipe route has environmental and operational disadvantages.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R24 GOORALONG PUMPBACK



Map reference Fj

Catchment area
42.4 sq.km

Streamflow (1947-86)
9.0 mill.cu.m/yr

Reservoir
Area
<20 ha
Capacity
<70 thou.cu.m

Yield benefit
4.4 mill.cu.m/yr

Cost
14.0 cents/cu.m

Treatment
Retention in Serpentine Reservoir

Most likely date
1999/2000

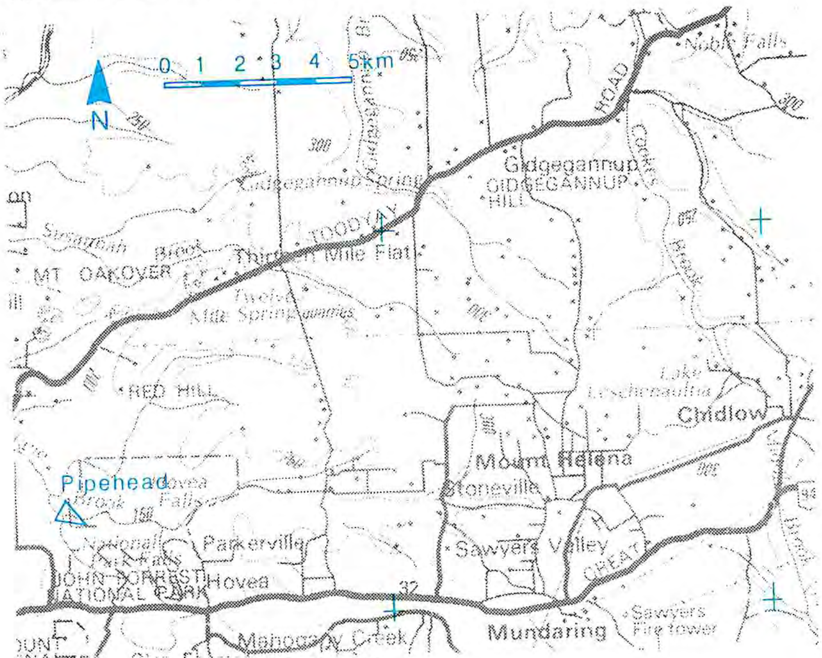
Land use	% of area
Forest	90
Horticulture	5
Pasture	5

SCHEME: GOORALONG PUMPBACK to Serpentine Reservoir (R4).

SPECIAL NOTES: Development of Lower Serpentine Catchment in conjunction with Lower Serpentine Pumpback (R27). A design objective will be to minimise flooding of local properties at pipehead dam site.

STATUS OF OPTION: Preferred option.

R25 JANE BROOK PIPEHEAD



Map reference Fo

Catchment area
83 sq.km

Streamflow (1911-80)
14.8 mill.cu.m/yr

Reservoir
Area
<5 ha
Capacity
72 thou.cu.m

Yield benefit
9.4 mill.cu.m/yr

Cost
26.0 cents/cu.m

Treatment
As for groundwater treatment

Most likely date
Post 2012

Land use	% of area
Spec. Rural	46
Forest	39
Urban	10
Horticulture	5

SCHEME: JANE BROOK PIPEHEAD.

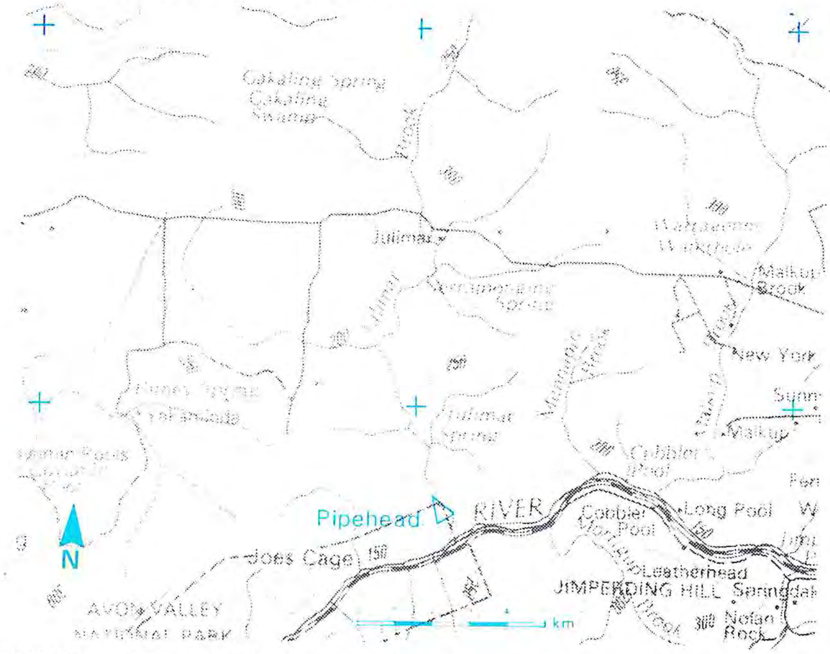
SPECIAL NOTES: Boosted pipehead from a site downstream of Rocky Pool, to the Mirrabooka GWTP. Design of pipehead will require sensitive consideration of nearby residential land.

STATUS OF OPTION: Preferred option, further investigation is required.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R26 JULIMAR BROOK PUMPBACK



Map reference Hr

Catchment area
179 sq.km

Streamflow (1911-80)
4.6 mill.cu.m/yr

Reservoir
Area
3 ha
Capacity
28 thou.cu.m

Yield benefit
2 mill.cu.m/yr

Cost
100.4 cents/cu.m

Treatment
Retention in
Wooroloo Reservoir

Most likely date
Post 2012

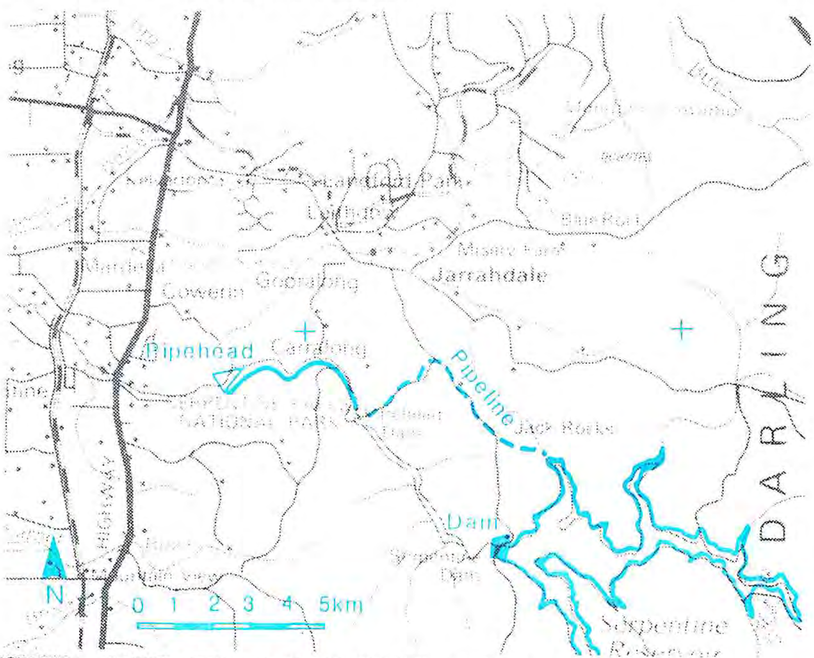
Land use	% of area
Forest	80
Pasture	20

SCHEME: JULIMAR BROOK PUMPBACK to Wooroloo Brook Dam (R16).

SPECIAL NOTES: Pipe route to Wooroloo Dam not yet known. Cost includes full treatment and desalination of water drawn from Wooroloo Brook Reservoir.

STATUS OF OPTION: Currently preferred opt..., further investigation is required.

R27 LOWER SERPENTINE PUMPBACK



Map reference Ei

Catchment area
29.4 sq.km

Streamflow (1947-86)
9.6 mill.cu.m/yr

Reservoir
Area
<5 ha
Capacity
40 thou.cu.m

Yield benefit
4.6 mill.cu.m/yr

Cost
18.0 cents/cu.m

Treatment
Retention in
Serpentine
Reservoir

Most likely date
2001/02

Land use	% of area
Forest	83
Pasture	12
Horticulture	2
Urban	3

SCHEME: LOWER SERPENTINE PUMPBACK to Serpentine Reservoir (R4).

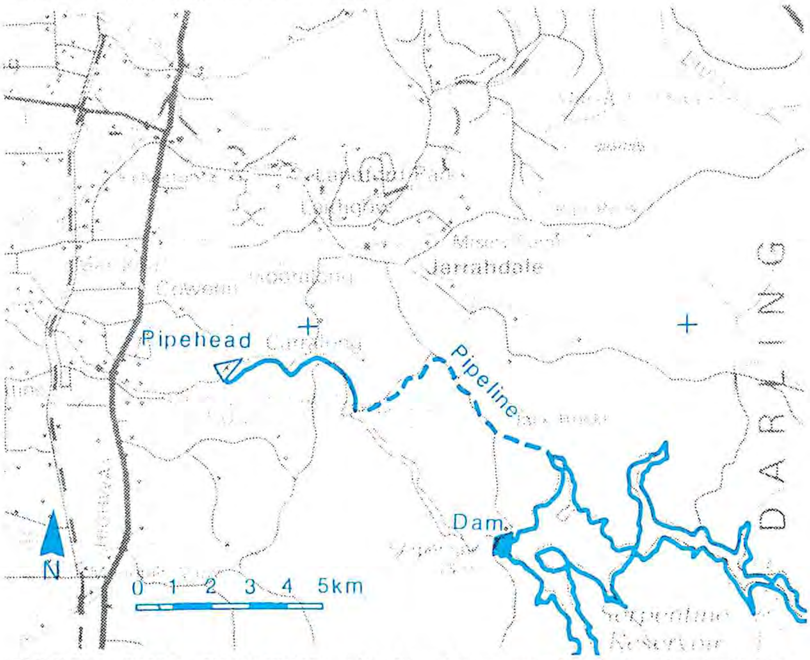
SPECIAL NOTES: Development of Lower Serpentine Catchment subsequent to Gooralong Pumpback (R24). Jarrahdale townsite within catchment. Pipehead reservoir on boundary of National Park. Pipe route crosses Conservation Reserve (M87) along Day Rd.

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R27a LOWER SERPENTINE PUMPBACK



Map reference Ei

Catchment area
71.8 sq.km

Streamflow (1911-80)
13.9 mill.cu.m/yr

Reservoir
Area
10 ha
Capacity
110 thou.cu.m

Yield benefit
5.3 mill.cu.m/yr

Cost
26.9 cents/cu.m

Treatment
Retention in Serpentine Main Dam reservoir

Most likely date
N/A

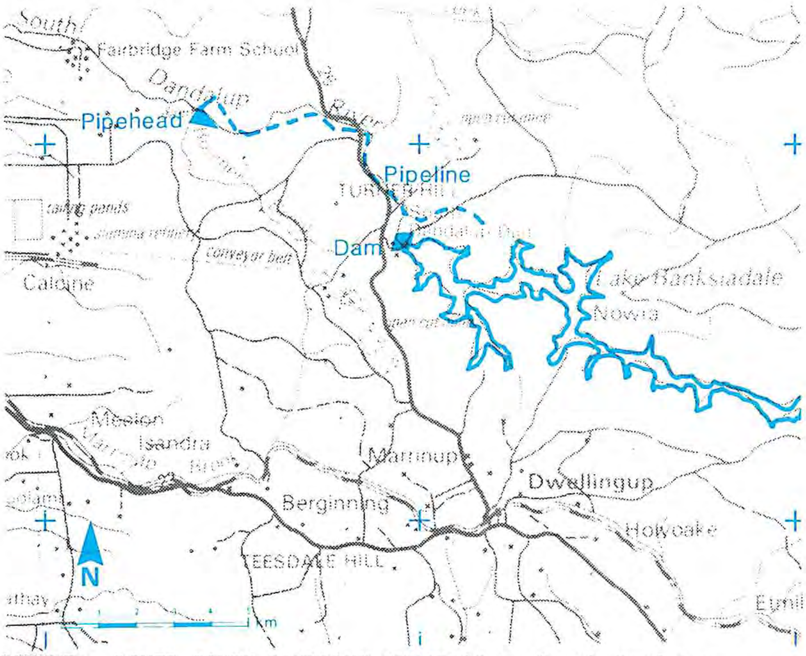
Land use	% of area
Forest	77
Pasture	12
Industry	7
Horticulture	3
Urban	1

SCHEME: LOWER SERPENTINE single stage pumpback to Serpentine Reservoir as an alternative to the two stage development (Gooralong (R24) and Lower Serpentine (R27)).

SPECIAL NOTES: Impacts are the same as the Lower Serpentine Pumpback.

STATUS OF OPTION: Not preferred because it is more costly than the two stage development (R24, R27).

R28 LOWER SOUTH DANDALUP



Map reference Eg

Catchment area
37.8 sq.km

Streamflow (1947-86)
12.3 mill.cu.m/yr

Reservoir
Area
<5 ha
Capacity
43 thou.cu.m

Yield benefit
2.3 mill.cu.m/yr

Cost
58.0 cents/cu.m

Treatment
Retention in South Dandalup Reservoir

Most likely date
2010/11

Land use	% of area
Forest	93
Pasture	7

SCHEME: LOWER SOUTH DANDALUP PUMPBACK to South Dandalup Reservoir. The pipehead structure already exists as the Pinjarra Pipehead. Pinjarra townsite and Alcoa's Pinjarra Refinery currently use this pipehead. Alcoa will continue to use the pipehead whilst Pinjarra will be fed from South Dandalup Dam. This scheme allows greater use of winter flows.

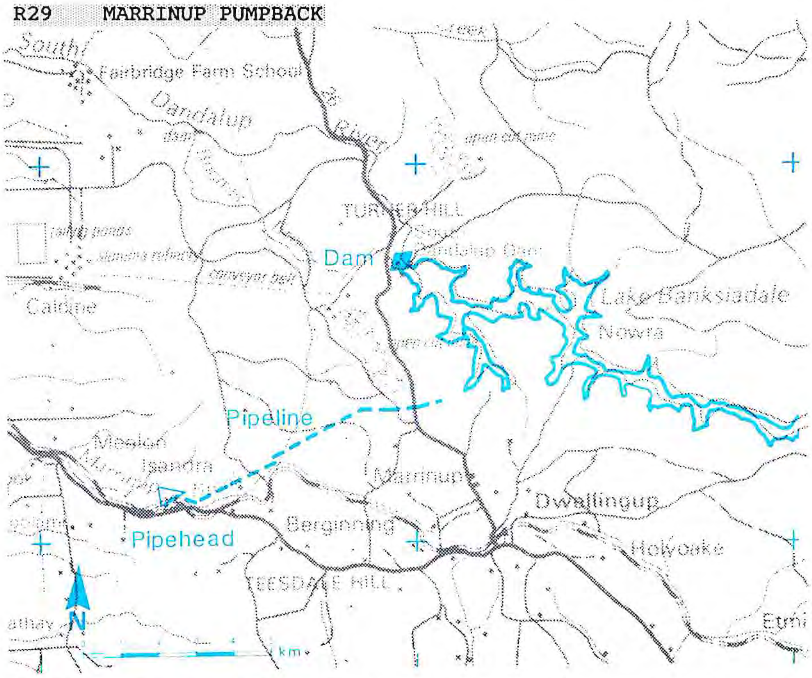
SPECIAL NOTES:

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R29 MARRINUP PUMPBACK



Map reference Ef

Catchment area
46.1 sq.km

Streamflow (1947-86)
12.3 mill.cu.m/yr

Reservoir
Area
<5 ha
Capacity
<80 thou.cu.m

Yield benefit
6.1 mill.cu.m/yr

Cost
29.0 cents/cu.m

Treatment
Retention in South Dandalup Reservoir

Most likely date
2003/04

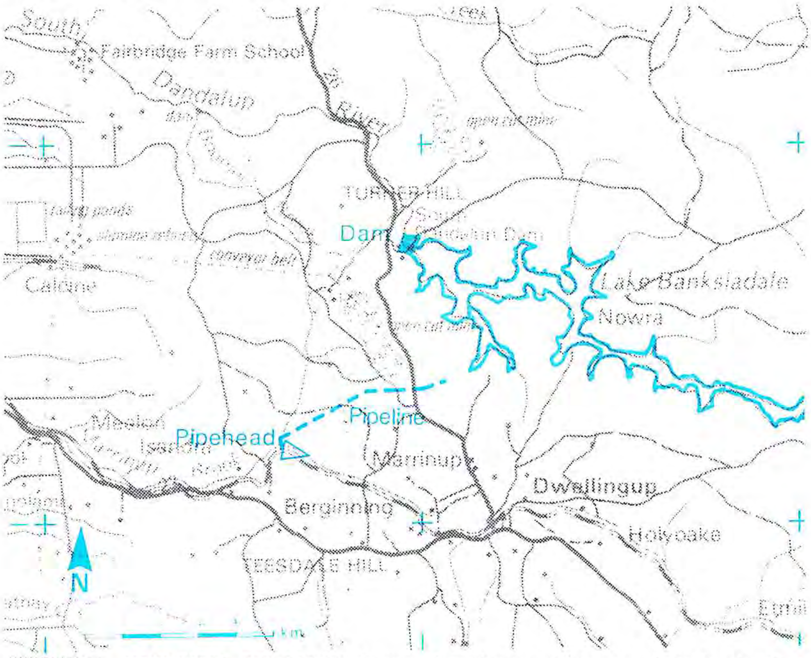
Land use	% of area
Forest	85
Pasture	15
Urban	*

SCHEME: MARRINUP PUMPBACK from the Lower Site to South Dandalup Reservoir (R5).

SPECIAL NOTES: The Hotham Valley Railway runs near the proposed pipehead and will restrict the size of the development. Bauxite mining is active within the catchment.

STATUS OF OPTION: Preferred option.

R29a MARRINUP PUMPBACK



Map reference Ef

Catchment area
28.1 sq.km

Streamflow (1911-80)
7.5 mill.cu.m/yr

Reservoir
Area
<5 ha
Capacity
<130 thou.cu.m

Yield benefit
4.2 mill.cu.m/yr

Cost
27.7 cents/cu.m

Treatment
Retention in South Dandalup Reservoir

Most likely date
N/A

Land use	% of area
Forest	95
Pasture	5
Urban	*

SCHEME: MARRINUP PUMPBACK from the Upper Site to South Dandalup Reservoir.

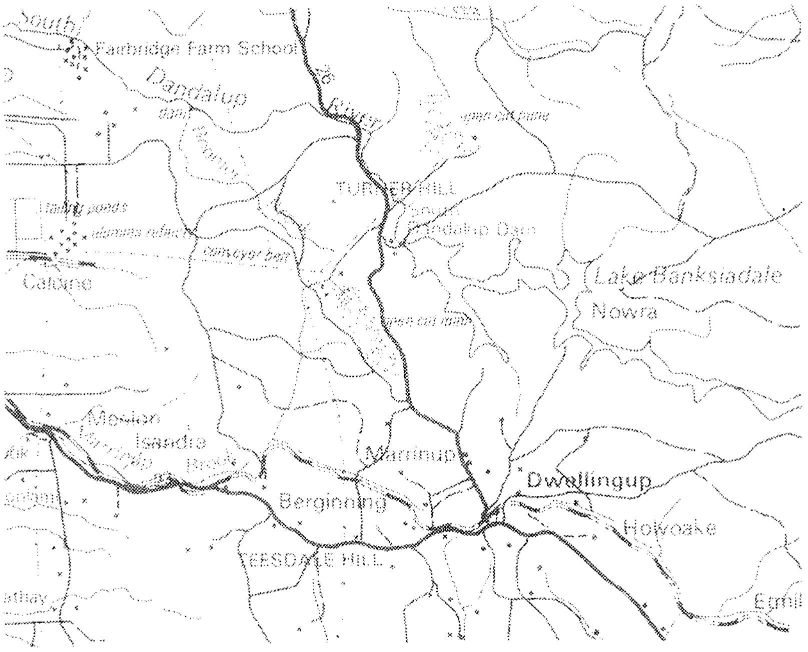
SPECIAL NOTES: As for pumpback from Lower Site (R29).

STATUS OF OPTION: Not preferred. Economically feasible but doesn't contribute as much yield as a pumpback at the Lower Site (R29).

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R29b MARRINUP DAM



Map reference Ef

Catchment area
28.1 sq.km

Streamflow (1911-80)
7.5 mill.cu.m/yr

Reservoir
Area
35 ha
Capacity
4800 thou.cu.m

Yield benefit
7.1 mill.cu.m/yr

Cost
33.8 cents/cu.m

Treatment
Disinfection

Most likely date
N/A

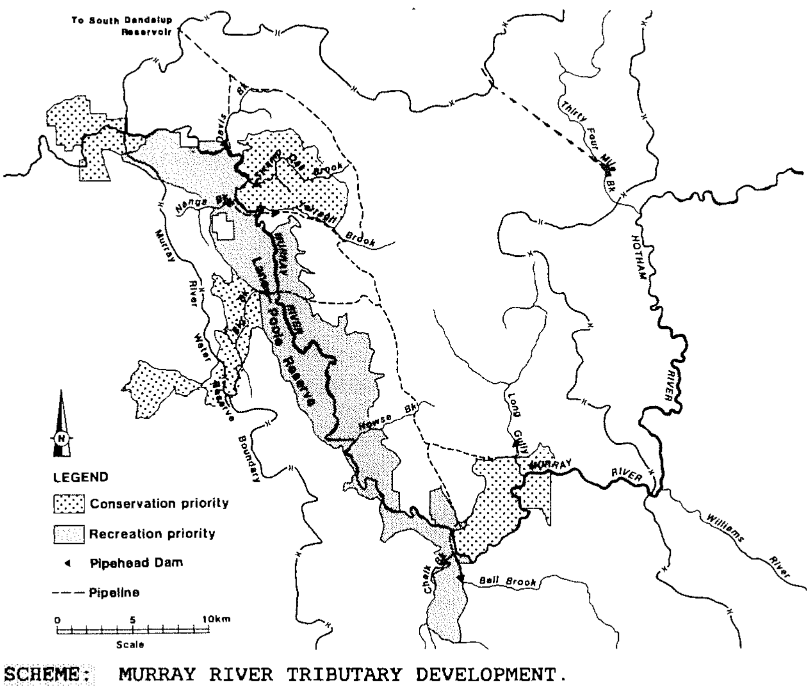
SCHEME: MARRINUP DAM at Upper Site.

SPECIAL NOTES: Inundates a section of the Hotham Valley Railway.

Land use	**% of area**
Forest	95
Pasture	5
Urban	*

STATUS OF OPTION: Not preferred. More costly than preferred option (R29).

R30 MURRAY RIVER



Map reference Gd

Catchment area
738 sq.km

Streamflow (1911-80)
37.2 mill.cu.m/yr

Reservoir
Area
200 ha
Capacity
35 mill.cu.m

Yield benefit
21 mill.cu.m/yr

Cost
35.2 cents/cu.m

Treatment
Retention in South Dandalup Reservoir

Most likely date
Post 2012

SCHEME: MURRAY RIVER TRIBUTARY DEVELOPMENT.

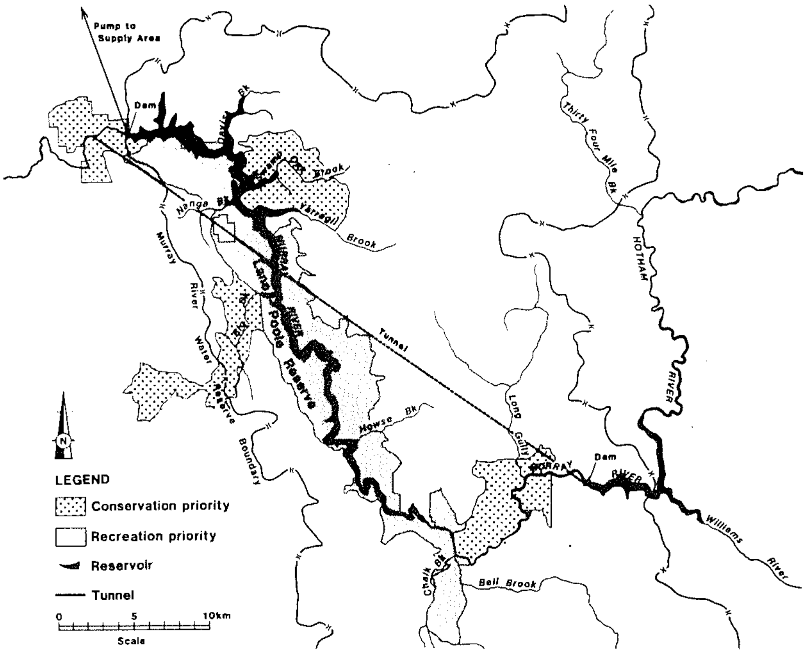
Land use	**% of area**
Forest	100
Pasture	*

SPECIAL NOTES: This development involves a series of pumpbacks to South Dandalup Dam from tributaries of the Murray River. Some pipelines and pipehead dams are located within the Lane-Poole Reserve which are expected to have minimal effect on the purposes of the Reserve. 34 Mile Brook could not be used while goldmining is active within its' catchment. Davis Brook could be developed completely outside Lane-Poole Reserve.
STATUS OF OPTION: There is no provision made for water supply development in the vesting of the Lane-Poole Reserve.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R30a MURRAY OUTSIDE LANE-POOLE



Map reference Ee

Catchment area
6903 sq.km

Streamflow (1911-80)
350 mill.cu.m/yr

Reservoir
Area
3100 ha
Capacity
300 mill.cu.m

Yield benefit
150 mill.cu.m/yr

Cost
91.5 cents/cu.m

Treatment
Desalination

Most likely date
Post 2012

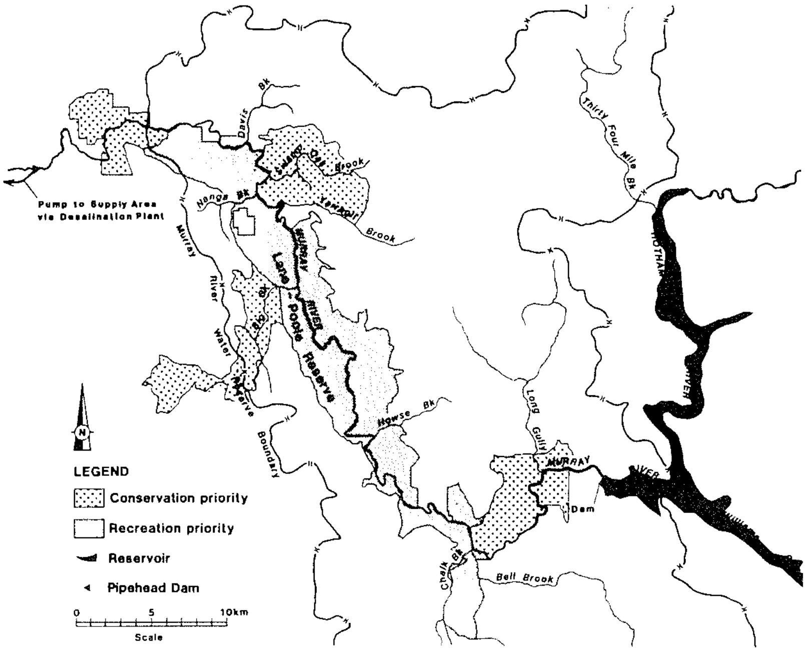
Land use	**% of area**
Forest	49
Pasture/crop	51
Horticulture	*
Urban	*

SCHEME: DAM below confluence of HOTHAM and WILLIAMS river to control flow to PIPEHEAD on MURRAY river at foot of Darling Scarp, downstream of Lane-Poole Reserve.

SPECIAL NOTES: Average flows through the Lane-Poole Reserve would be unchanged but winter floods would be reduced and flow would be maintained in summer. Some agricultural land would be flooded by upper dam.

STATUS OF OPTION: A possible development outside Lane-Poole Reserve, but would not be economic until well after 2012. Further investigation required.

R30b MURRAY TWO DAMS



Map reference Hc

Catchment area
1056 sq.km

Streamflow (1911-80)
100 mill.cu.m/yr

Reservoir
Area
2700 ha
Capacity
400 mill.cu.m

Yield benefit
70 mill.cu.m/yr

Cost
47.4 cents/cu.m

Treatment
Disinfection

Most likely date

Land use	% of area
Forest	99
Horticulture	*
Pasture	*
Urban	*

SCHEME: DAM on the MURRAY RIVER at HUGHES BRIDGE to store fresh streamflow, plus DAM below confluence of HOTHAM and WILLIAMS river with tunnel to divert saline flow.

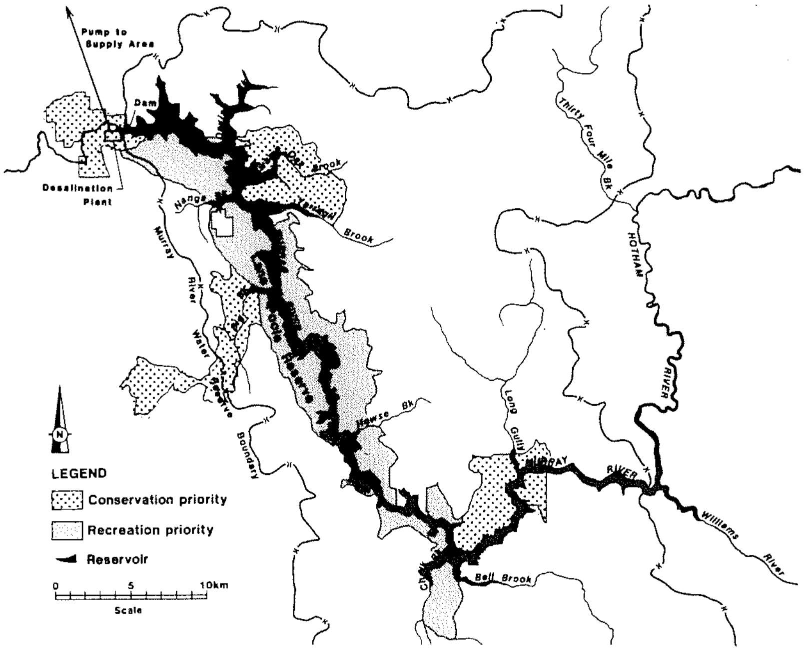
SPECIAL NOTES: Although the dam at Hughes Bridge is smaller than for the single dam option, significant flooding of Lane-Poole Reserve will still occur. Catchment of upper dam not included in assessment of catchment or land use.

STATUS OF OPTION: Rejected due to impact on Lane-Poole Reserve.

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R30c MURRAY SINGLE DAM



Map reference Ee

Catchment area
6840 sq.km

Streamflow (1911-80)
330 mill.cu.m/yr

Reservoir
Area
6500 ha
Capacity
1000 mill.cu.m

Yield benefit
200 mill.cu.m/yr

Cost
83.8 cents/cu.m

Treatment
Desalination

Most likely date

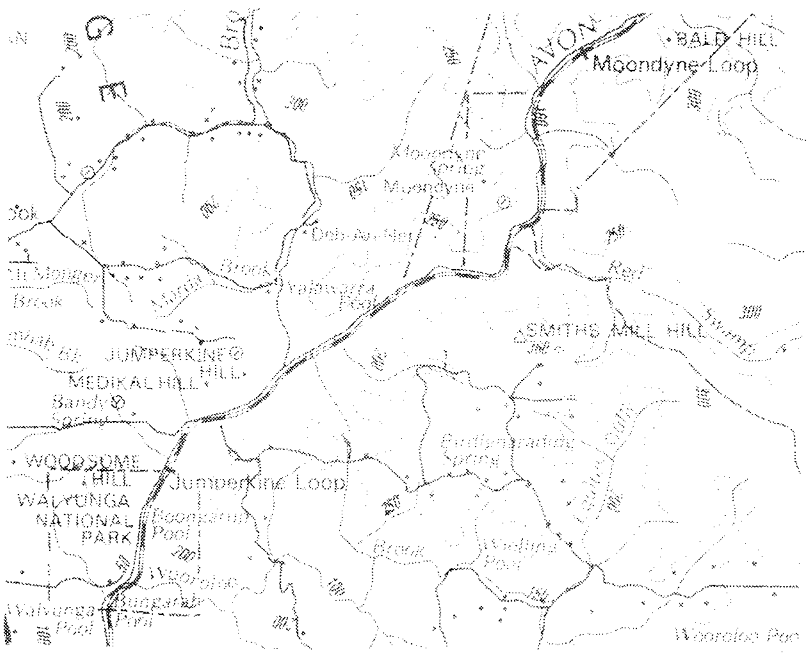
SCHEME: DAM on the MURRAY RIVER at Hughes Bridge with desalination.

SPECIAL NOTES: Severe inundation of Lane-Poole Reserve with loss of conservation and some recreation values.

Land use	% of area
Forest	49
Pasture/Crop	51
Horticulture	*
Urban	*

STATUS OF OPTION: Rejected due to impact on Lane-Poole Reserve.

R31 RED SWAMP BROOK PUMPBACK



Map reference Gq

Catchment area
134 sq.km

Streamflow (1911-80)
5.9 mill.cu.m/yr

Reservoir
Area
3 ha
Capacity
30 thou.cu.m

Yield benefit
3.0 mill.cu.m/yr

Cost
101.5 cents/cu.m

Treatment
Retention in Wooroloo Reservoir

Most likely date
Post 2012

SCHEME: RED SWAMP BROOK PUMPBACK to Woorooloo Brook Dam.

SPECIAL NOTES: Pipe route to Woorooloo Dam not yet known.

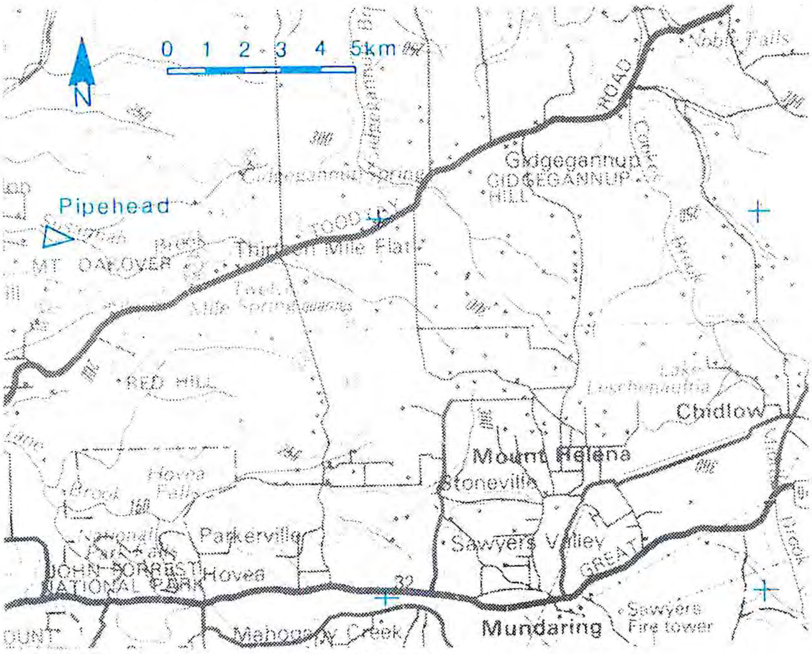
Land use	% of area
Forest	75
Pasture	25

STATUS OF OPTION: Currently preferred option, further investigation is required.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

R32 SUSANNAH BROOK PIPEHEAD



SCHEME: SUSANNAH BROOK PIPEHEAD.

SPECIAL NOTES: Storage pipehead located 9 km upstream of confluence with Swan River, to a new treatment plant in the Swan Valley.

STATUS OF OPTION: Currently preferred option, further investigation is required.

Map reference Fo

Catchment Area
44 sq.km

Streamflow (1911-80)
3.8 mill.cu.m/yr

Reservoir
Area
13 ha
Capacity
750 thou.cu.m

Yield benefit
3.4 mill.cu.m/yr

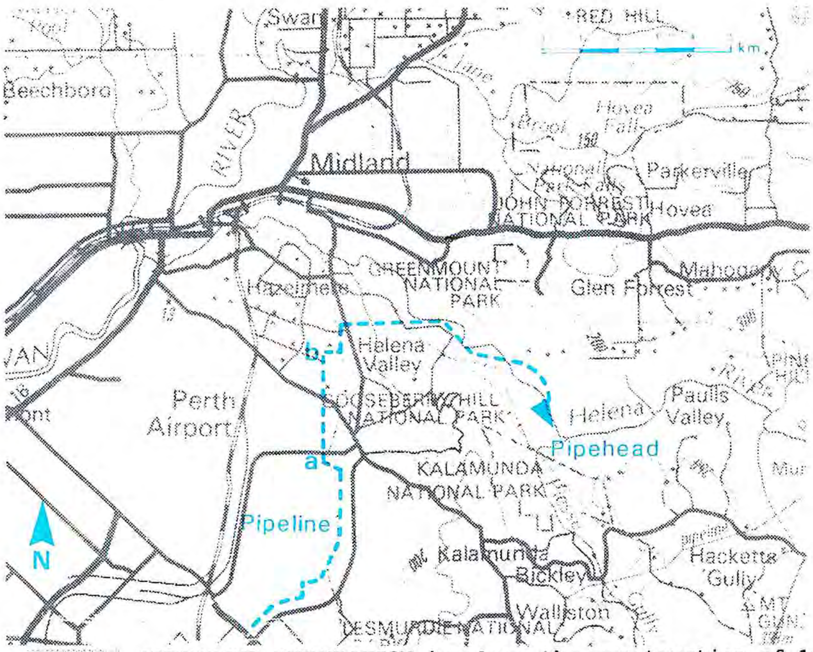
Cost
36.4 cents/cu.m

Treatment
As for groundwater treatment

Most likely date
Post 2012

Land use	% of area
Forest	35
Pasture	40
Special rural	25

R33 MUNDARING INTEGRATION



SCHEME: MUNDARING INTEGRATION involves the construction of 16 km of 1065 mm diameter pipe to increase the capacity to transfer water from the MWS to Helena Reservoir (R3) to meet increasing G&AWS needs and counteract increasing use of pipes in the existing Mundaring Integration Scheme to supply MWS demands. The total scheme includes some use of water from Helena Reservoir by the MWS in summer.

SPECIAL NOTES: a-b on above map marks 1st stage due 1990. Remainder most likely after 2004.

STATUS OF OPTION: Preferred option.

Map reference Fn

Catchment Area
N/A sq.km

Streamflow
N/A mill.cu.m/yr

Reservoir
Area
N/A ha
Capacity
N/A mill.cu.m

Yield benefit
0 mill.cu.m/yr

Cost
N/A cents/cu.m

Treatment
N/A

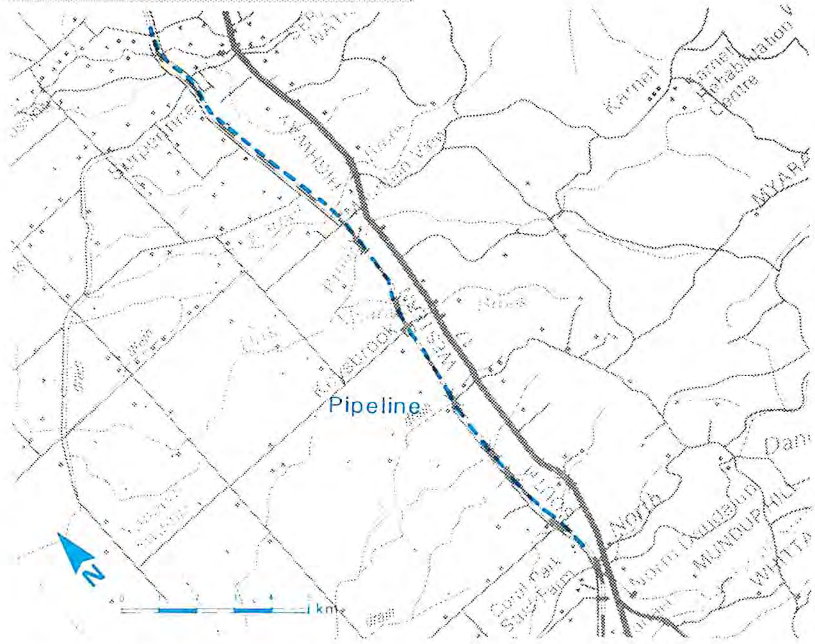
Most likely date
See Special Notes

Land use	% of area
N/A	

Existing Works shown as solid symbols and lines.
Proposed Works shown as open symbols and dashed lines.

* small but significant area

R34 NORTH DANDALUP MAINS AMP.



Map reference Eh

Catchment Area
N/A sq.km

Streamflow
N/A mill.cu.m/yr

Reservoir
Area
N/A ha
Capacity
N/A mill.cu.m

Yield benefit
2.9 mill.cu.m/yr

Cost
30.0 cents/cu.m

Treatment
N/A

Most likely date
2006/07

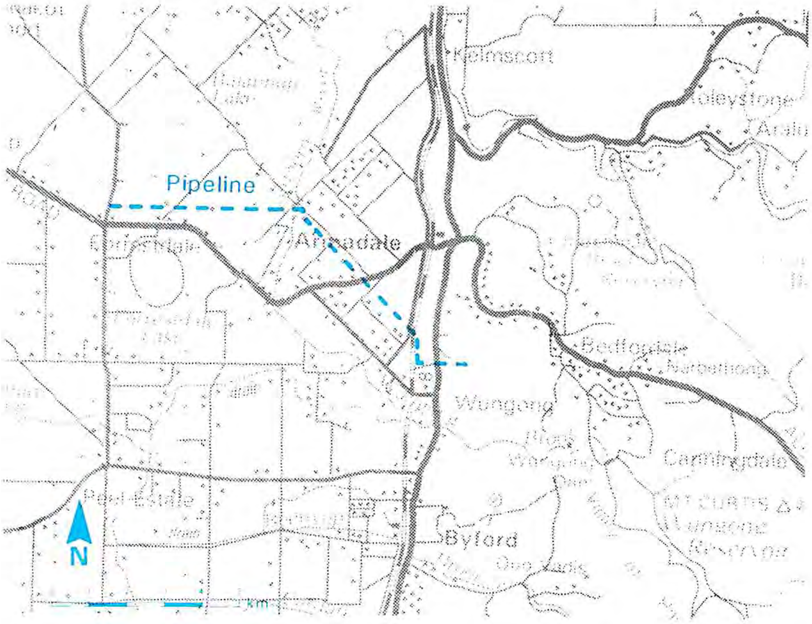
Land use % of area
N/A

SCHEME: NORTH DANDALUP MAINS AMPLIFICATION involves a duplication of the existing 1065 mm diameter pipeline from the North Dandalup Dam Outlet Main to its junction with the Serpentine Outlet Main.

SPECIAL NOTES: The duplication is required when the Conjurunup Pipehead (R18) and the North Dandalup Dam (R14) are both operational. The yield benefit can be regarded as the yield which would be lost from these sources if the pipe was not constructed.

STATUS OF OPTION: Preferred option.

R35 WUNGONG OUTLET AMP.



Map reference Ek

Catchment Area
N/A sq.km

Streamflow
N/A mill.cu.m/yr

Reservoir
Area
N/A ha
Capacity
N/A mill.cu.m

Yield benefit
0.9 mill.cu.m/yr

Cost
$13.31 million

Treatment
N/A

Most likely date
1993/94

Land use % of area
N/A

SCHEME: WUNGONG DAM MAINS OUTLET AMPLIFICATION adds a 1400 mm diameter pipe to the end of the Wungong Dam Outlet Tunnel (R7).

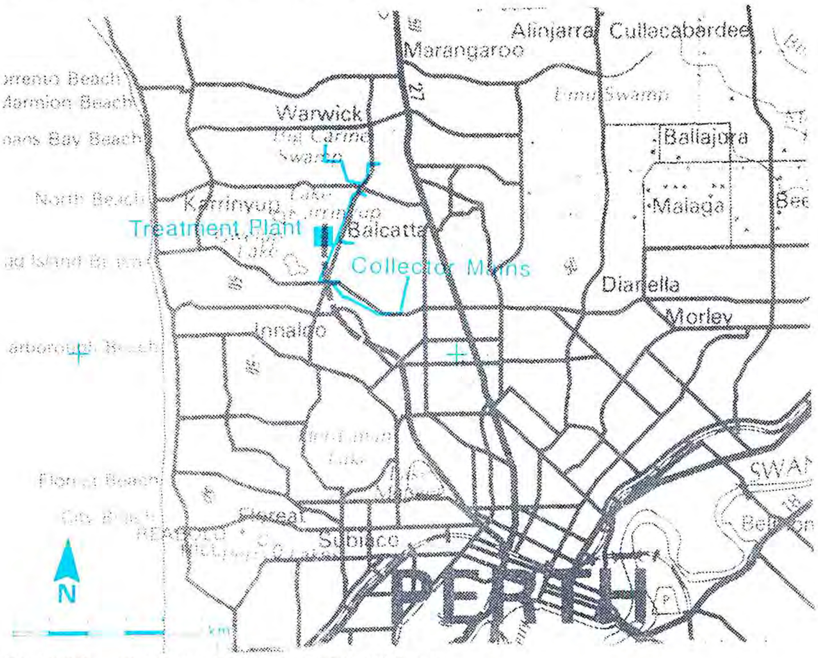
SPECIAL NOTES: This scheme is required for peak demand requirements, hence the cost is not expressed 'per cu.m of yield'. It is included in the Sources Development Timetable because it also produces a small increase in system yield.

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G1 GWELUP GROUNDWATER SCHEME



SCHEME: GWELUP GROUNDWATER SCHEME.

SPECIAL NOTES:

STATUS OF OPTION: Existing.

Map reference Co

Resource area
(Gwelup PWSA)
17 sq.km

Quota
12.0 mill.cu.m/yr

No of wells
12 shallow g/w

5 artesian g/w

Water used
12.0 mill.cu.m/yr

Cost
19.2 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
Existing

Land use	% of area
Industry	10
Urban	75
Wetlands	15

G2 JANDAKOT G/WATER SCHEME

SCHEME: JANDAKOT GROUNDWATER SCHEME (Stage I).

SPECIAL NOTES: Liquid waste disposal site is located within PWSA. Refer to G15 for proposed extension.

STATUS OF OPTION: Existing.

Map reference D1

Resource area
(Jandakot PWSA)
104 sq.km

Quota
5.25 mill.cu.m/yr

No of wells
15 shallow g/w

2 artesian g/w

Water used
4.0 mill.cu.m/yr

Cost
28.2 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

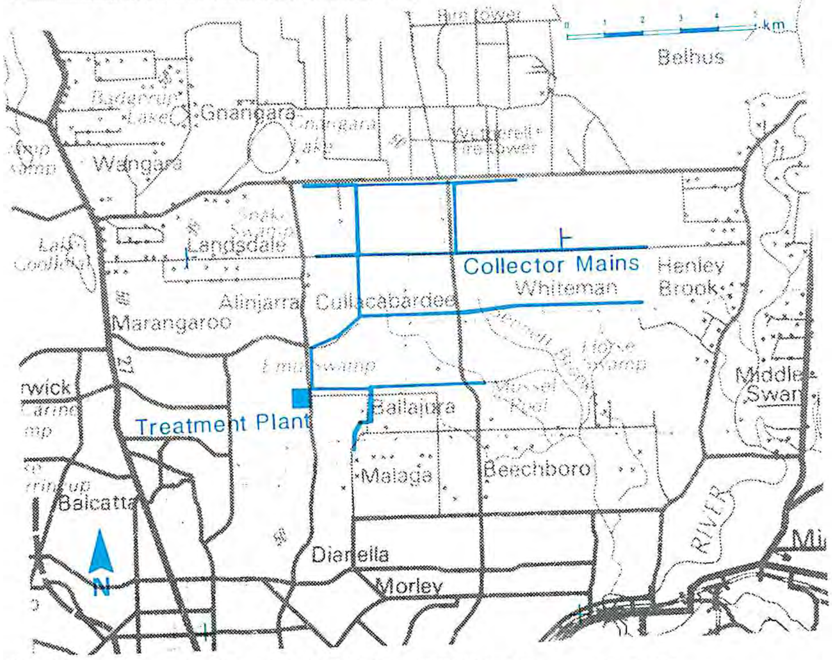
Most likely date
Existing

Land use	% of area
Horticulture	55
Natural veg.	35
Wetlands	5
Industrial	*
Urban	*

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G3 MIRRABOOKA G/WATER SCHEME



SCHEME: MIRRABOOKA GROUNDWATER SCHEME (Stages 1 & 2).

SPECIAL NOTES: Refer to G14 for proposed extension.

STATUS OF OPTION: Existing.

Map reference Do

Resource area
(Mirrabooka PWSA)
87 sq.km

Quota
22.0 mill.cu.m/yr

No of wells
34 shallow g/w

5 artesian g/w

Water used
22.0 mill.cu.m/yr

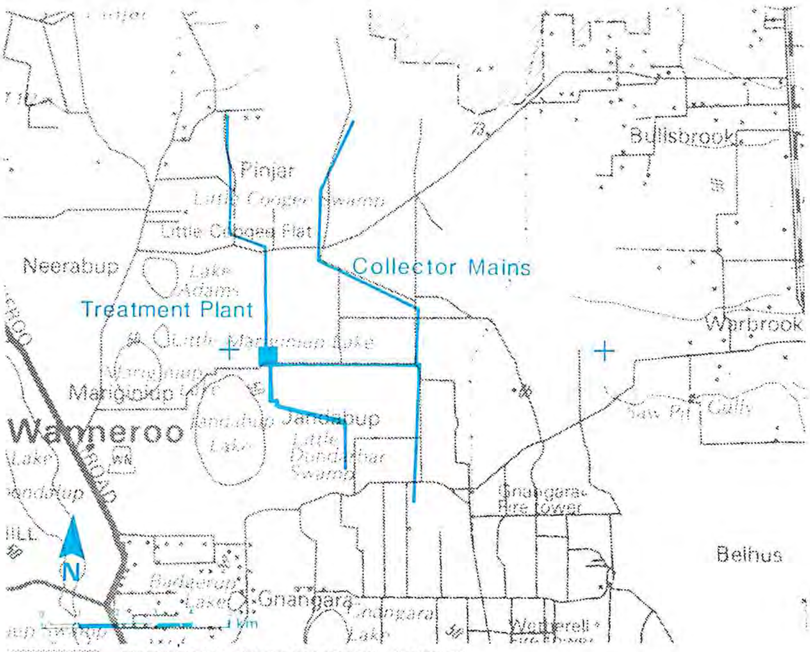
Cost
24.8 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
Existing

Land use	% of area
Horticulture	30
Natural veg.	60
Pines	5
Industrial	*
Urban	*
Wetlands	*

G4 WANNEROO G/WATER SCHEME



SCHEME: WANNEROO GROUNDWATER SCHEME.

SPECIAL NOTES: Refer to Lexia Scheme (G19).

STATUS OF OPTION: Existing.

Map reference Dq

Resource area
(Wanneroo PWSA)
144 sq.km

Quota
21.2 mill.cu.m/yr

No of wells
24 shallow g/w

8 artesian g/w

Water used
21.2 mill.cu.m/yr

Cost
19.5 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
Existing

Land use	% of area
Natural veg.	40
Pines	60

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G5-9 EXISTING DEEP ART'N WELLS

LOCATIONS MARKED ON MAP A1

SCHEME: DEEP ARTESIAN WELLS at Melville (G6, 1 well at Cm)
Bold Park (G5, 2 wells at Cn)
Mt Eliza (G8, 6 wells at Dn)
Yokine (G9, 4 wells at Do)
Mirrabooka (G7, 1 well at Do)

SPECIAL NOTES:

STATUS OF OPTION: Existing.

Map reference see SCHEME

Resource area
N/A sq.km

Quota
12 mill.cu.m/yr

No of wells
0 shallow g/w
14 artesian g/w

Water used
12 mill.cu.m/yr

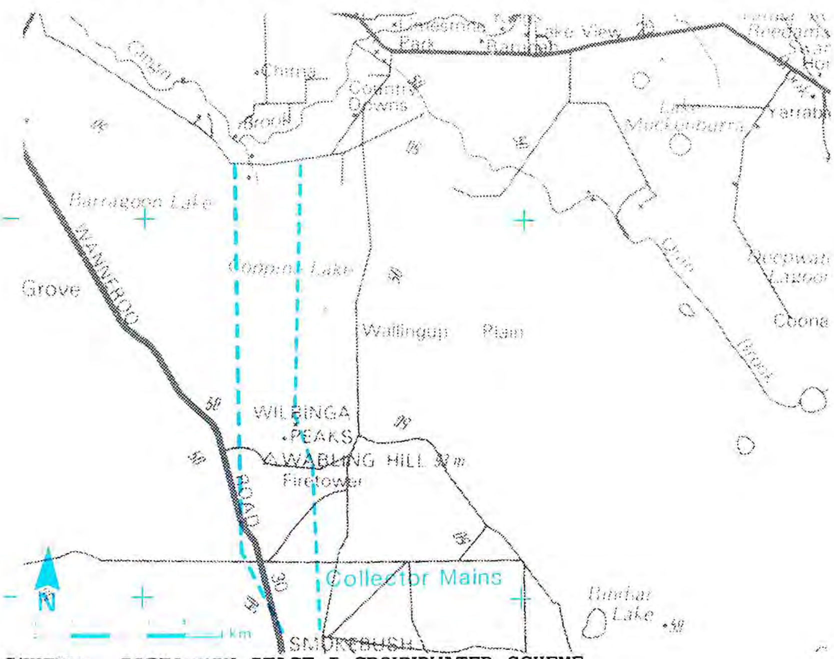
Cost
7.7 cents/cu.m

Treatment
Dilution in service reservoir and disinfection

Most likely date
Existing

Land use	% of area
N/A	

G10 BARRAGOON STAGE I



SCHEME: BARRAGOON STAGE I GROUNDWATER SCHEME.

SPECIAL NOTES: The Barragoon Groundwater scheme will be treated at the Yeal GWTP (G23). Barragoon Stage I and II (G11) will be developed mainly within the Gnangara Water Reserve, north of Yeal. However, some wells will be located just north of the Water Reserve. Artesian wells have been deleted from this scheme due to reduction in mean volume to be drawn from deep artesian aquifer.
STATUS OF OPTION: Preferred option.

Map reference Bt

Resource area
(Gnangara WR)
680 sq.km

Quota
4.8 mill.cu.m/yr

No of wells
12 shallow g/w
0 artesian g/w

Yield benefit
6.0 mill.cu.m/yr

Cost
42.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

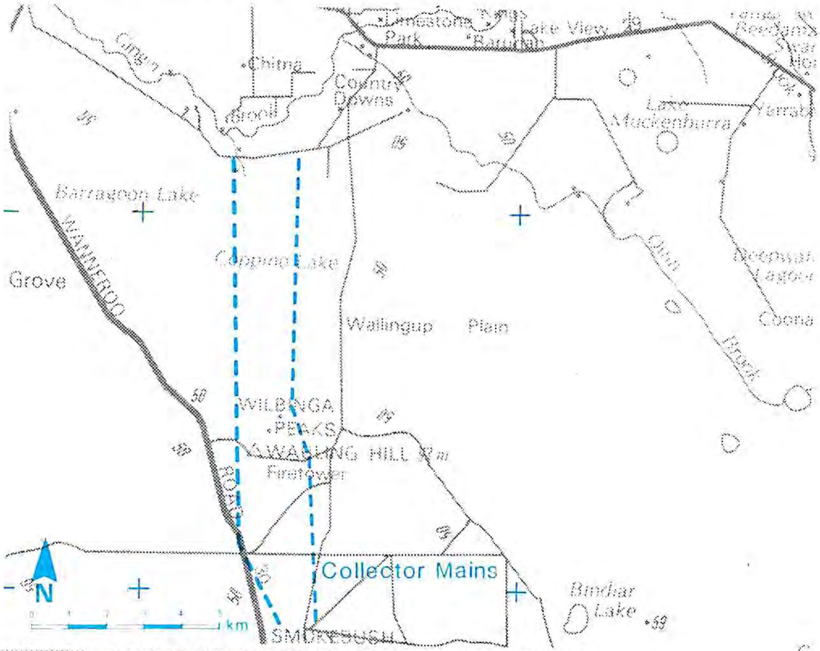
Most likely date
2011/12

Land use	% of area
Natural veg.	80
Pines	10
Wetlands	10

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G11 BARRAGOON STAGE II



SCHEME: BARRAGOON STAGE II GROUNDWATER SCHEME.

SPECIAL NOTES: See special note for Barragoon Stage I (G10).

STATUS OF OPTION: Preferred option.

Map reference Bt

Resource area
(Gnangara WR)
680 sq.km

Quota
4.8 mill.cu.m/yr

No of wells
11 shallow g/w

0 artesian g/w

Yield benefit
6.0 mill.cu.m/yr

Cost
42.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
Post 2012

Land use % of area
As for Barragoon St I

G12 COCKLESHELL GULLY ART'N

LOCATIONS MARKED ON MAP A1

SCHEME: 3 DEEP ARTESIAN WELLS (North, Central and South) tapping the COCKLESHELL GULLY FORMATION.

SPECIAL NOTES: Direct use of the water is not possible due to the high iron content. The quoted cost allows for the treatment of the water or for retention in a reservoir such as Serpentine Dam (R4) or Wungong Dam (R7). A test well is located at the central site.

STATUS OF OPTION: Rejected due to severe reductions in water levels in nearby shallow wells when pumping from test well.

Map reference Eg

Resource area

N/A sq.km

Quota
3.7 mill.cu.m/yr

No of wells
0 shallow g/w

3 artesian g/w

Yield benefit
3.7 mill.cu.m/yr

Cost
17.6 cents/cu.m

Treatment
See special notes

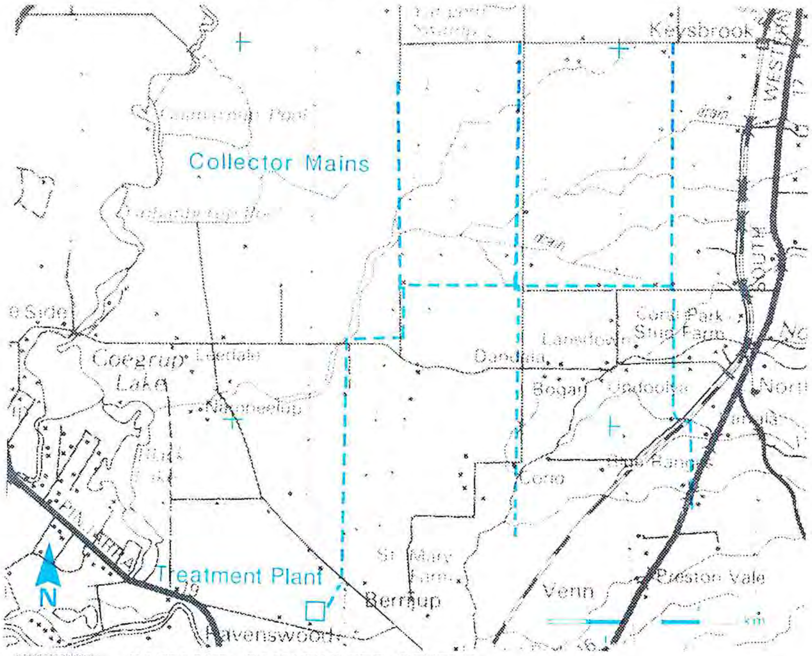
Most likely date
N/A

Land use % of area
N/A

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G13 DANDALUP G/WATER SCHEME



SCHEME: DANDALUP GROUNDWATER SCHEME.

SPECIAL NOTES: Will serve the southern areas of Perth and Mandurah. The wellfield for this scheme will extend outside of the Peel Groundwater Area into the Murray Groundwater Area.

STATUS OF OPTION: Preferred option.

Map reference Dh

Resource area
(Murray GA)
996 sq.km

Quota
10.6 mill.cu.m/yr

No of wells
20 shallow g/w

25 artesian g/w

Yield benefit
10.6 mill.cu.m/yr

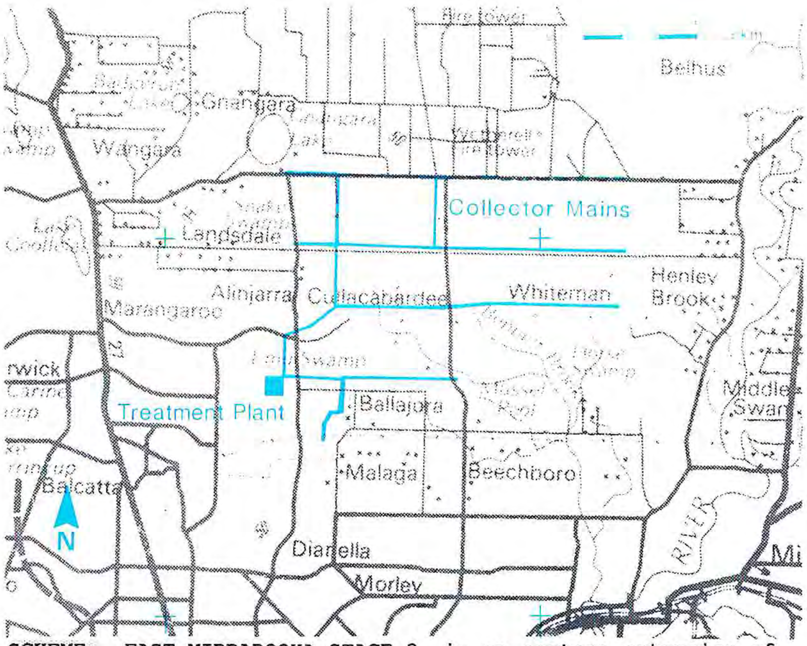
Cost
39.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
Post 2012

Land use	% of area
Horticulture	80
Natural veg.	10
Wetlands	10

G14 EAST MIRRABOOKA STAGE 3



SCHEME: EAST MIRRABOOKA STAGE 3, is an eastern extension of Mirrabooka Stage I and II (G3).

SPECIAL NOTES: Water from this scheme will be treated at the existing Mirrabooka GWTP (see G3).

STATUS OF OPTION: Preferred option.

Map reference Ep

Resource area
(Mirrabooka PWSA)
87 sq.km

Quota
2 mill.cu.m/yr

No of wells
4 shallow g/w

0 artesian g/w

Yield benefit
1.5 mill.cu.m/yr

Cost
37.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

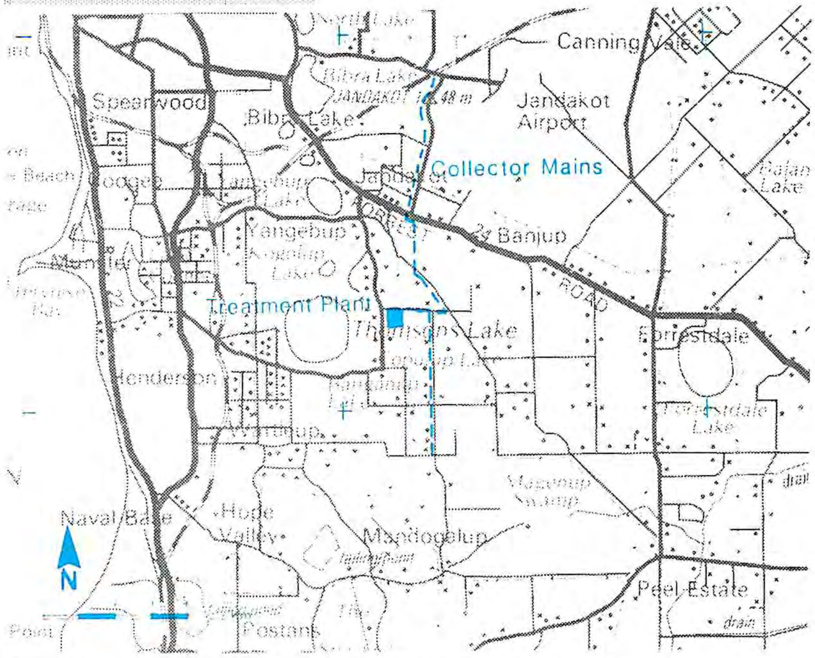
Most likely date
2011/12

Land use	% of area
Horticulture	30
Natural veg.	60
Pines	5
Industrial	*
Urban	*
Wetlands	*

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G15 JANDAKOT STAGE II



Map reference	Dl
Resource area (Jandakot PWSA)	104 sq.km
Quota	4.0 mill.cu.m/yr
No of wells	20 shallow g/w 1 artesian g/w
Yield benefit	4.7 mill.cu.m/yr
Cost	18.0 cents/cu.m
Treatment	Removal of iron, colour & turbidity and disinfection
Most likely date	1995/96

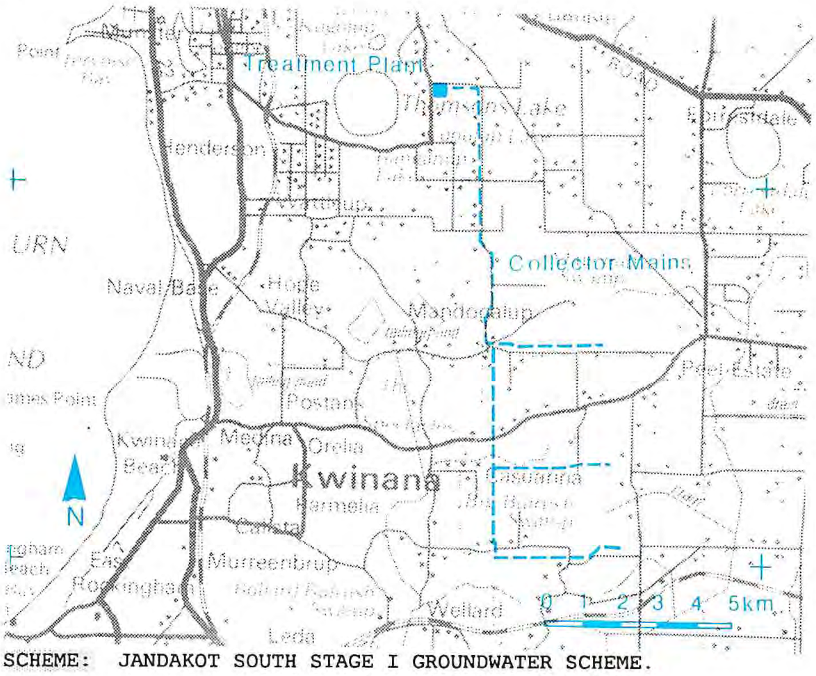
SCHEME: JANDAKOT STAGE II GROUNDWATER SCHEME, is an extension to the west of Jandakot Stage I (G2).

SPECIAL NOTES: Water will be treated at the existing Jandakot GWTP (see G2). A liquid waste disposal site is located within the PWSA. Scheme details will be revised to account for proposed urbanisation in the area of the wellfield. Scheme will be operated to minimise drainage outflows from the area which are not required for wetland maintenance.

STATUS OF OPTION: Preferred option.

Land use	% of area
Horticulture	55
Natural veg.	35
Wetlands	5
Industrial	*
Urban	*

G16 JANDAKOT SOUTH STAGE I



Map reference	Dk
Resource area (Jandakot PWSA)	104 sq.km
Quota	3.1 mill.cu.m/yr
No of wells	7 shallow g/w 2 artesian g/w
Yield benefit	3.3 mill.cu.m/yr
Cost	33.0 cents/cu.m
Treatment	Removal of iron, colour & turbidity and disinfection
Most likely date	2007/08

SCHEME: JANDAKOT SOUTH STAGE I GROUNDWATER SCHEME.

SPECIAL NOTES: The water will be treated at the existing Jandakot GWTP (see G2).

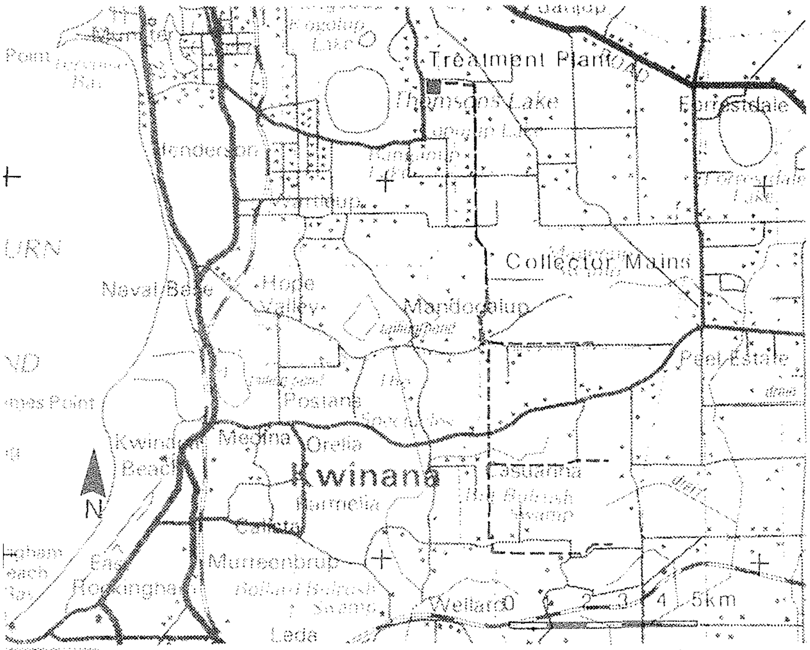
Land use	% of area
Horticulture	10
Natural veg.	60
Wetlands	30

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G17 JANDAKOT SOUTH STAGE II



Map reference Dk

Resource area
(Serpentine GA)
427 sq.km

Quota
3.1 mill.cu.m/yr

No of wells
7 shallow g/w

1 artesian g/w

Yield benefit
3.3 mill.cu.m/yr

Cost
33.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
2007/08

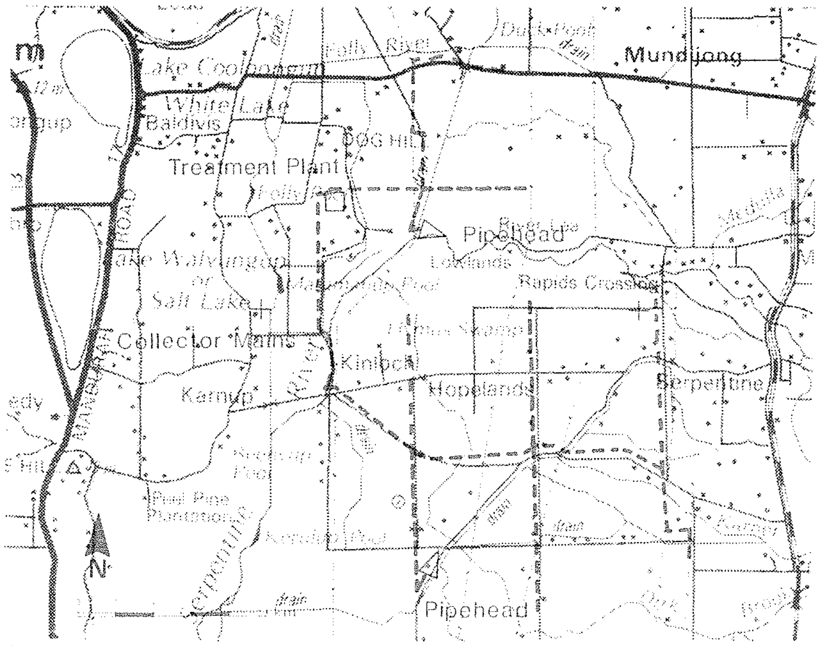
SCHEME: JANDAKOT SOUTH STAGE II GROUNDWATER SCHEME is a southwards extension of the scheme for Stage I (G16).

SPECIAL NOTES: Water will be treated at the existing Jandakot GWTP (see G2).

Land use % of area
AS for Jandakot South St I

STATUS OF OPTION: Preferred option.

G18 KARNUP GROUNDWATER SCHEME



Map reference Di

Resource area
(Serpentine GA)
427 sq.km

Quota
7.5 mill.cu.m/yr

No of wells
20 shallow g/w

15 artesian g/w

Yield benefit
7.4 mill.cu.m/yr

Cost
39.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
Post 2012

SCHEME: KARNUP GROUNDWATER SCHEME.

SPECIAL NOTES: Will be developed to serve the southern areas of Perth as the population growth extends southward. Some surface water will be delivered to the Treatment Plant from the pipeheads.

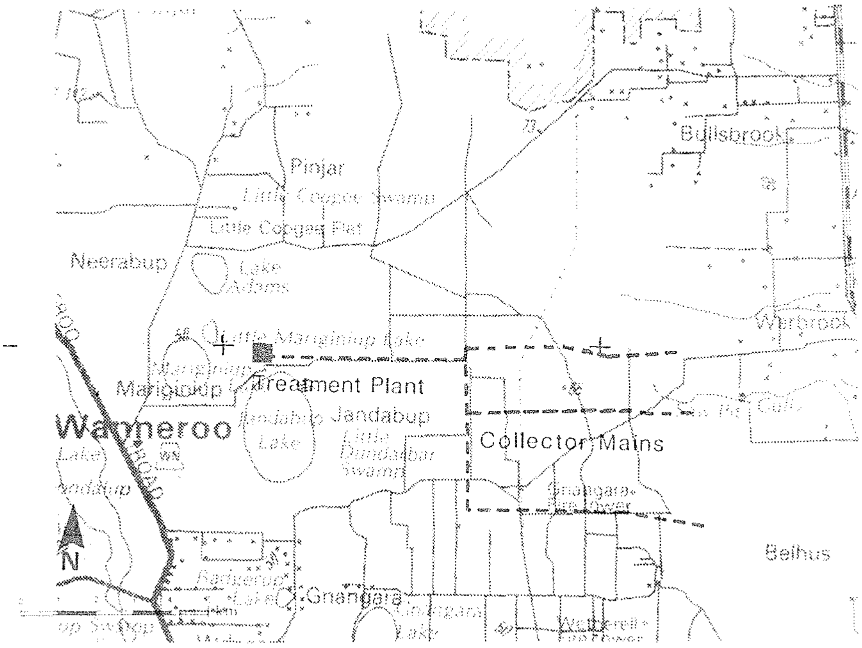
Land use	% of area
Horticulture	80
Natural veg.	10
Wetlands	10

STATUS OF OPTION: Preferred option.

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G19 LEXIA GROUNDWATER SCHEME



Map reference Dp

Resource area
(Wanneroo PWSA)
144 sq.km

Quota
6.5 mill.cu.m/yr

No of wells
15 shallow g/w

0 artesian g/w

Yield benefit
6.9 mill.cu.m/yr

Cost
26.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
2002/03

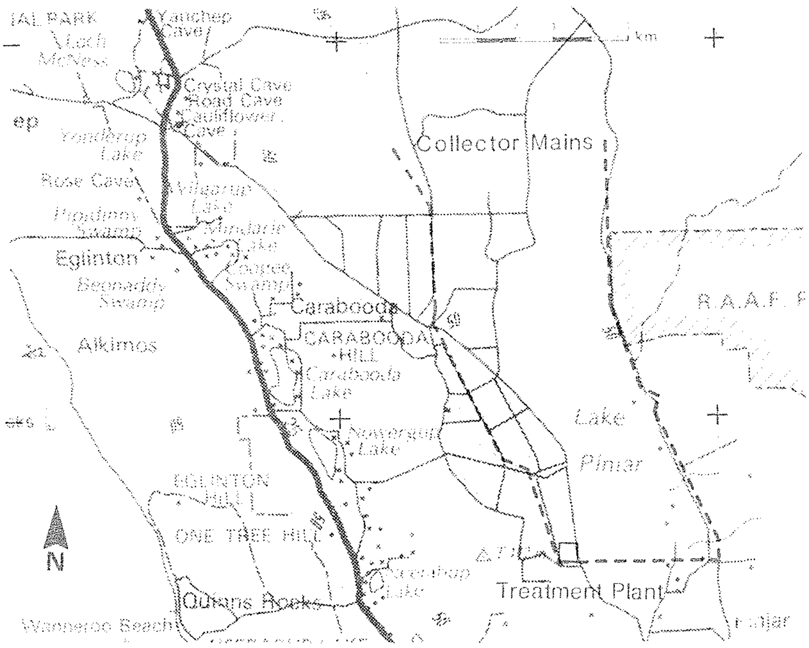
SCHEME: LEXIA GROUNDWATER SCHEME.

Land use	% of area
Natural veg.	40
Pines	60

SPECIAL NOTES: The Lexia Scheme lies mainly within the the Wanneroo PWSA. However, some of the wells will be located outside of the existing PWSA. The groundwater will be treated at the existing Wanneroo GWTP unless urban development in the Swan Valley makes it practical to establish a new treatment plant closer to the wellfield.

STATUS OF OPTION: Preferred option.

G20 PINJAR STAGE I



Map reference Cq

Resource area
(Gnangara WR)
680 sq.km

Quota
12.7 mill.cu.m/yr

No of wells
9 shallow g/w

5 artesian g/w

Yield benefit
14.1 mill.cu.m/yr

Cost
17.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
1988/89 & 1989/90

SCHEME: PINJAR STAGE I GROUNDWATER SCHEME. Parts 1 & 2.

Land use	% of area
Natural veg.	70
Pines	10
Wetlands	20

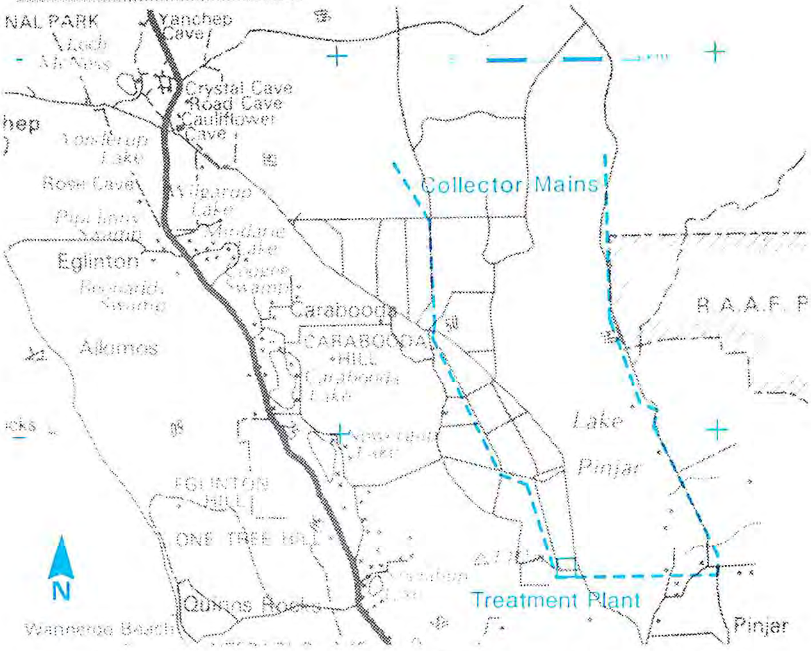
SPECIAL NOTES: The development is within the Gnangara Water Reserve, north of the Wanneroo PWSA (which is not included in the area stated for the Gnangara Water Reserve). Development is to occur in two separate parts (1 & 2) with treatment at Wanneroo GWTP.

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G21 **PINJAR STAGE II**



Map reference Cq

Resource area
(Gnangara WR)
680 sq.km

Quota
7.2 mill.cu.m/yr

No of wells
9 shallow g/w
3 artesian g/w

Yield benefit
8.0 mill.cu.m/yr

Cost
27.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
2000/01 & 2004/05

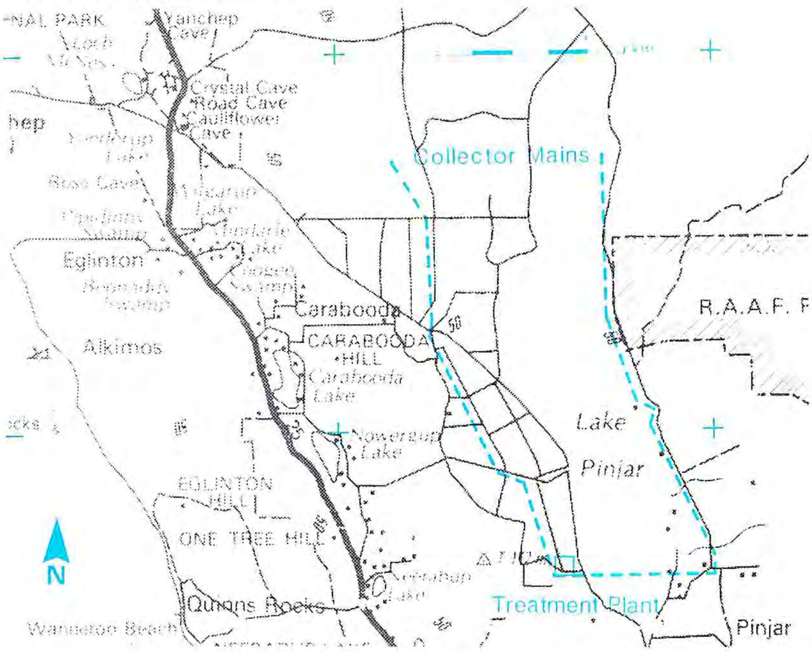
SCHEME: PINJAR STAGE II GROUNDWATER SCHEME. Parts 1 & 2.

Land use **% of area**
As for Pinjar St I

SPECIAL NOTES: Part 1 wells are on eastern leg of wellfield and will be treated at Wanneroo GWTP. Pinjar GWTP will be constructed to treat water for Part 2 wells which are on western leg of wellfield. Some artesian wells have been deleted from this scheme due to reduction in mean volume to be drawn from the deep artesian aquifer.

STATUS OF OPTION: Preferred option.

G22 PINJAR STAGE III



Map reference Cq

Resource area
(Gnangara WR)
680 sq.km

Quota
5.6 mill.cu.m/yr

No of wells
10 shallow g/w
2 artesian g/w

Yield benefit
6.0 mill.cu.m/yr

Cost
29.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
2005/06

SCHEME: PINJAR STAGE III GROUNDWATER SCHEME.

Land use % of area
As for Pinjar St I

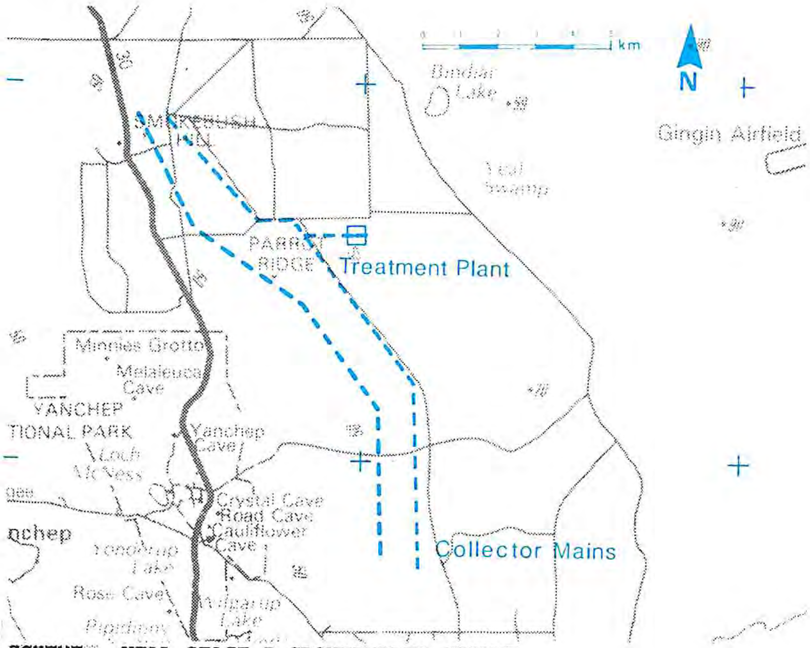
SPECIAL NOTES: Water will be treated at Pinjar GWTP (see G21). Some artesian wells have been deleted as per note in G21.

STATUS OF OPTION: Preferred option.

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G23 YEAL STAGE I



SCHEME: YEAL STAGE I GROUNDWATER SCHEME.

Map reference Cs

Resource area
(Gnangara WR)
680 sq.km

Quota
6.1 mill.cu.m/yr

No of wells
12 shallow g/w

0 artesian g/w

Yield benefit
6.7 mill.cu.m/yr

Cost
42.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

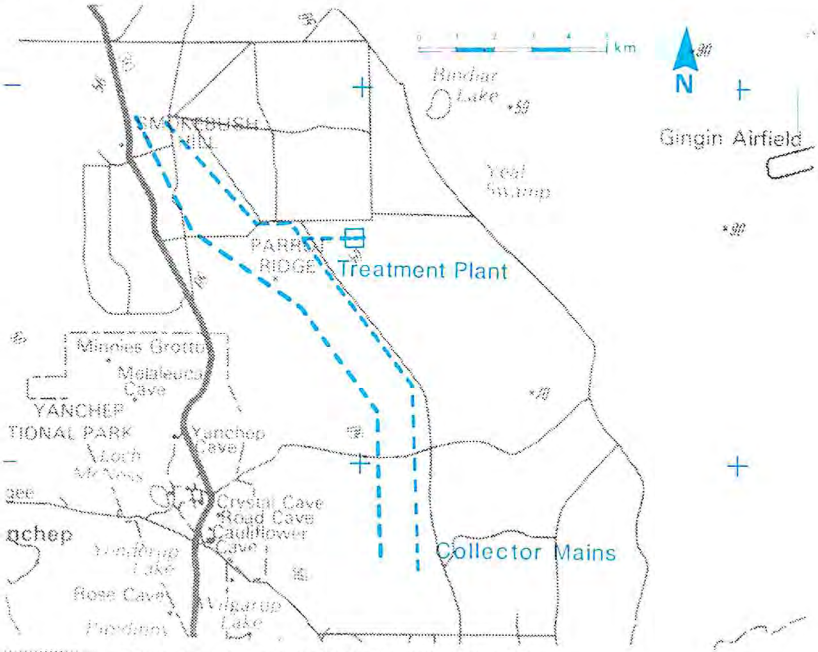
Most likely date
2008/09

Land use	% of area
Natural veg.	80
Pines	10
Wetlands	10

SPECIAL NOTES: The 2 stages of the Yeal Scheme (G23 & G24) will be developed within the Gnangara Water Reserve, north of the Pinjar development (G20,G21,G22). Yeal GWTP will treat the flow for both stages and eventually for the Barragoon Scheme (G10). Artesian wells have been deleted as per note in G21.

STATUS OF OPTION: Preferred option.

G24 YEAL STAGE II



SCHEME: YEAL STAGE II GROUNDWATER SCHEME.

Map reference Cs

Resource area
(Gnangara WR)
680 sq.km

Quota
6.1 mill.cu.m/yr

No of wells
12 shallow g/w

0 artesian g/w

Yield benefit
6.4 mill.cu.m/yr

Cost
44.0 cents/cu.m

Treatment
Removal of iron, colour & turbidity and disinfection

Most likely date
2009/10

Land use **% of area**
As for Yeal St I

SPECIAL NOTES: See special note for Stage I.

STATUS OF OPTION: Preferred option.

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G25-31 SERVICE RES. DEEP ART'N

LOCATIONS MARKED ON MAP A1

SCHEME: DEEP ARTESIAN WELLS, 1 each at Wanneroo (G29,Cp), Whitfords (G30,Co), Yanchep (G31,B5), McNess East (G27,Br), L. Thomson (G26,D1), Hamilton Hill (G25,C1) and Tamworth (G28,C1).

SPECIAL NOTES: Construction of wells other than Wanneroo would cause new limit on mean draw from deep artesian aquifer to be exceeded. Cost of Wanneroo DAW is 8.0 cents/cu.m.

STATUS OF OPTION: Preferred option for Wanneroo DAW. Other wells rejected to avoid excessive draw on deep artesian aquifer.

Map reference see SCHEME
Resource area
N/A sq.km

Quota
10.5 mill.cu.m/yr

No of wells
0 shallow g/w
7 artesian g/w

Yield benefit
14 mill.cu.m/yr

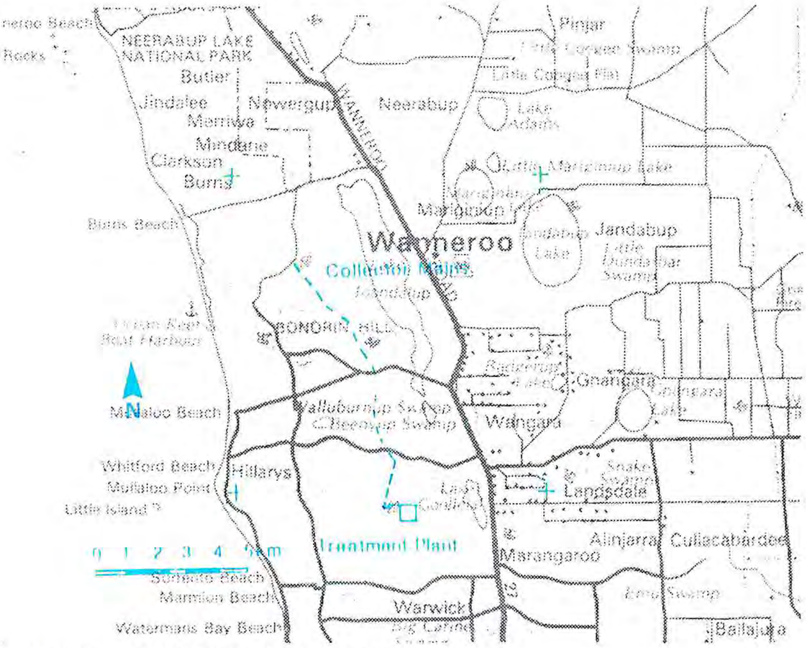
Cost
11.3 cents/cu.m

Treatment
Dilution in service reservoir and disinfection

Most likely date
1988/89
(See Special note)

Land use % of area
N/A

G32 WHITFORDS GROUNDWATER SCHEME



SCHEME: WHITFORDS GROUNDWATER SCHEME.

SPECIAL NOTES: This scheme is currently under review. Preliminary cost estimates assume full treatment will be required. Town Planning for future land use indicates that a substantial portion of the scheme area may be urban at the time of development.
STATUS OF OPTION: Requires further investigation. Scheduling of this source will occur in the next Source Development review when investigations are further advanced.

Map reference Cp
See Map 4
Resource area
(Whitford-Quinns Coastal Strip)
110 sq.km
Quota
6.0 mill.cu.m/yr

No of wells
12 shallow g/w
0 artesian g/w

Yield benefit
6 - 7 mill.cu.m/yr

Cost
32.0 cents/cu.m

Treatment
Full treatment.
See SPECIAL NOTES

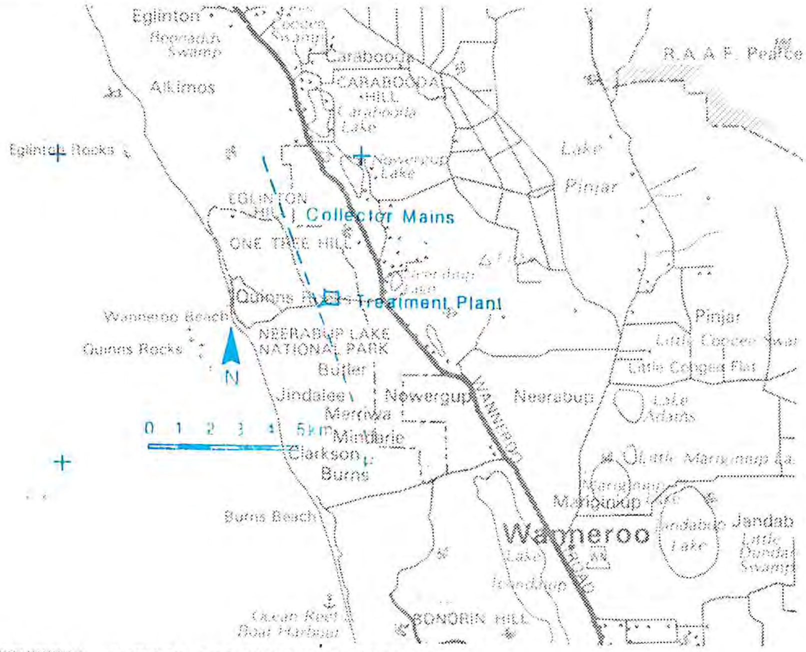
Most likely date
See STATUS OF OPTION

Land use	% of area
Natural veg.	45
Urban	55

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G33 QUINNS GROUNDWATER SCHEME



SCHEME: QUINNS GROUNDWATER SCHEME.

SPECIAL NOTES: This scheme is currently under review. Preliminary cost estimates assume full treatment will be required. Town Planning for future land use indicates that a substantial portion of the scheme area may be urban at the time of development.
STATUS OF OPTION: Requires further investigation. Scheduling of this source will occur in the next Source Development review when investigations are further advanced.

Map reference Bq

Resource area
(Whitford-Quinns Coastal Strip)
110 sq.km

Quota
6 - 8 mill.cu.m/yr

No of wells
12 - 14 shallow g/w
0 artesian g/w

Yield benefit
7 - 8 mill.cu.m/yr

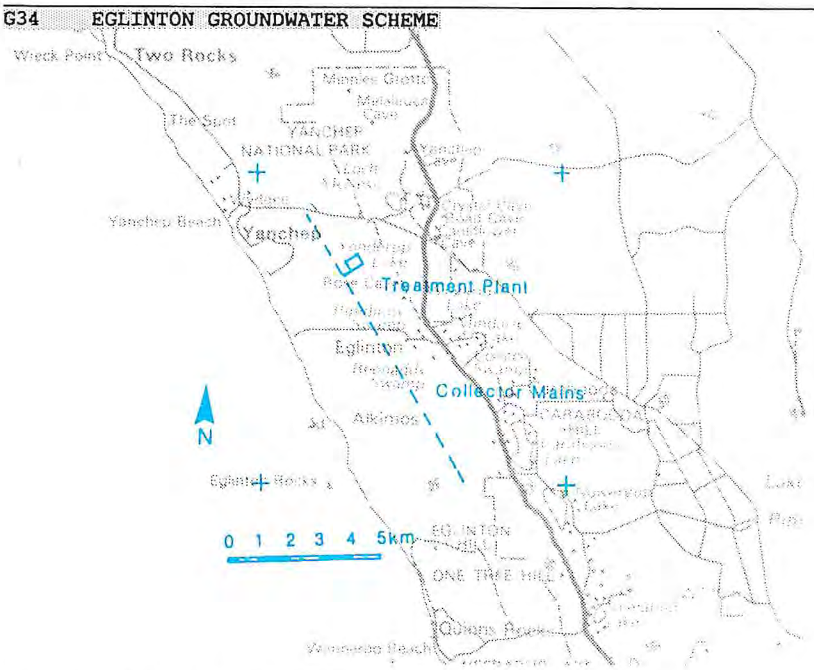
Cost
30.2 cents/cu.m

Treatment
Full treatment.
See SPECIAL NOTES

Most likely date
See STATUS OF OPTION

Land use	% of area
Natural veg.	95
Urban	*

G34 EGLINTON GROUNDWATER SCHEME



SCHEME: EGLINTON GROUNDWATER SCHEME.

SPECIAL NOTES: This scheme is currently under review. Preliminary cost estimates assume full treatment will be required. Town Planning for future land use indicates that a substantial portion of the scheme area may be urban at the time of development.
STATUS OF OPTION: Requires further investigation. Scheduling of this source will occur in the next Source Development review when investigations are further advanced.

Map reference Br

Resource area
(Yanchep GA)
85 sq.km

Quota
7 - 10 mill.cu.m/yr

No of wells
14 shallow g/w
0 - 2 artesian g/w

Yield benefit
7 - 11 mill.cu.m/yr

Cost
30.0 cents/cu.m

Treatment
Full treatment.
See SPECIAL NOTES

Most likely date
See STATUS OF OPTION

Land use	% of area
Natural veg.	95
Wetlands	*

Existing Works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

G35 TWO ROCKS/YANCHEP GROUNDWATER SCHEME

Map reference As

Resource area
(Yanchep GA)
85 sq.km

Quota
6 - 10 mill.cu.m/yr

No of wells
12 - 14 shallow g/w

0 - 2 artesian g/w

Yield benefit
6 - 11 mill.cu.m/yr

Cost
30.6 cents/cu.m

Treatment
Full treatment.
See SPECIAL NOTES

Most likely date
See STATUS OF OPTION

Land use	% of area
Natural veg.	90
Urban	10

SCHEME: TWO ROCKS/YANCHEP GROUNDWATER SCHEME.

SPECIAL NOTES: This scheme is currently under review. Preliminary cost estimates assume full treatment will be required. Town Planning for future land use indicates that a substantial portion of the scheme area may be urban at the time of development.
STATUS OF OPTION: Requires further investigation. Scheduling of this source will occur in the next Source Development review when investigations are further advanced.

Existing works shown as solid symbols and lines
Proposed Works shown as open symbols and dashed lines

* small but significant area

Appendix B

IMPACTS OF LAND USE ON WATER RESOURCES AND IMPACTS OF WATER RESOURCE DEVELOPMENT ON LAND USE

Appendix B

IMPACTS OF LAND USE ON WATER RESOURCES AND IMPACTS OF WATER RESOURCE DEVELOPMENT ON LAND USE

The geographical relationship between proposed schemes and the surrounding land uses are shown in Map A1 in Appendix A and also for each scheme, in the map in the panel in Table A3 which gives the scheme details. An assessment of the significance of the relationships between water resource developments and surrounding land use can be made referring to the tables in this appendix. Table B1 is a key to the other tables in this appendix.

If it is evident that a scheme which is a preferred alternative will have an impact on other land uses in the area, then the Water Authority has assumed at this stage of investigation that the impact is acceptable. In some cases there are proposals to reduce impacts. These are mentioned in the 'Special Notes' in the scheme's panel in Appendix A. Other impacts may require special consideration at the project planning stage, with possible modification of the scheme if justified.

It would assist the planning process if readers draw to the attention of the Water Authority any potential impacts of the proposed schemes which are considered to be unacceptable.

Table B1 Key to Tables B2-B7

A. RIVERS

		forest land use	rural and urban land use
		conservation reserves timber production minor forest products mining service corridors recreation conservation of ecosystems	pasture crops horticulture industry special rural urban
impact of land use on water resource	flow volume salinity turbidity chemical pollution biological poll'n	TABLE B2	TABLE B4
impact of water resource development on land use	catchment areas storage dams a) dam & reservoir b) downstream pipehead dams pipelines	TABLE B3	TABLE B5

B. SHALLOW GROUNDWATER

		land use
		natural vegetation wetlands pine forest horticulture industry urban
impact of land use on water resource	volume available annually pollution	TABLE B6
impact of water resource development on land use	resource areas wells collector mains groundwater treatment plant	TABLE B7

Table B2 Rivers in Forest Land

IMPACTS OF LAND USE ON WATER RESOURCE

	CONSERVATION RESERVES	TIMBER PRODUCTION	MINOR FOREST PRODUCTS (Beekeeping, Charcoal, Firewood, Gravel)
FLOW VOLUME (yield)	High density forest has low yield.	Higher yield from forest with reduced density from logging.	As for Timber Production except less intense.
SALINITY	Streams in conservation reserves usually fresh.	If logging spreads dieback and/or forest density is permanently reduced, salinity could develop in lower rainfall areas.	As for Timber Production except less intense.
TURBIDITY (muddy water)	Minimal	Careful management required to avoid turbidity from erosion of logging tracks or disturbance of streamzones.	As for Timber Production except less intense.
CHEMICAL POLLUTION	Nil	Minimal (fuel spills)	As for Timber Production except less intense.
BIOLOGICAL POLLUTION	Minimal (illegal entry)	Minimal (operators)	As for Timber Production except less intense.

Table B2 (continued)

MINING	SERVICE CORRIDORS	RECREATION	CONSERVATION OF ECOSYSTEMS
Some increase in yield during mining due to open pits, possible reduction after mining if rehab. vegetation very dense.	Negligible effects.	Negligible effects.	Possible reduction of water available for water supply due to constraint on development site.
No risk in high rainfall areas. Risk of bauxite mining causing salinity in drier areas is being assessed.	May have indirect effects in low rainfall areas through spread of dieback.	As for Service Corridors.	May help prevent commencement of activities with risk of causing salinity.
Careful mine management required to avoid turbid water entering streams from runoff from pits and haul roads.	A serious source of turbidity.	Recreation causes little turbidity.	Nil
Minor risk of fuel spills. Acid from coal tailings. Cyanide from gold tailings.	Risk from transport of hazardous chemicals in catchments.	Low (litter, nutrients)	Nil
Minimal (operators)	High risk where roads encourage human access to streams.	High risk where camping is popular in catchment areas and close to water. Management strategy is required.	Nil

Table B3 Rivers in Forest Land

IMPACTS OF WATER RESOURCE DEVELOPMENT ON LAND USE

	CONSERVATION RESERVES	TIMBER PRODUCTION	MINOR FOREST PRODUCTS (Beekeeping, Charcoal, Firewood, Gravel)
CATCHMENT AREAS	Priority for conservation does not prevent use as catchment.	Imposes costs of careful management.	As for Timber Production.
STORAGE DAMS a) Impacts of dam site and reservoir basin.	Storage dams cannot be located in conservation reserves.	Some loss of timber growing land in reservoir basin, which is likely to be above average quality, due to richer soils in valley floors.	As for Timber Production.
b) Downstream impacts.	Flow quantity and variation reduced.	Nil	Nil
PIPEHEAD DAMS	Although incompatible at site of works, small size makes compromise easier if there is conflict.	Negligible	As for Timber Production.
PIPELINES	Similar to roads and powerlines.	Similar to roads and powerlines.	As for Timber Production.

Table B3 (continued)

MINING	SERVICE CORRIDORS	RECREATION	CONSERVATION OF ECOSYSTEMS
Imposes costs of careful management.	Prefer routes away from streamlines.	May constrain particular activities in particular areas.	Recognition of catchment areas has limited clearing of native forests for agriculture.
Some mineral may be lost under water. Dam and reservoir may constrain routes of haul roads and conveyors.	May constrain routes.	Adds tourist attraction, but active water pastimes may be restricted. Reduces lengths of wild rivers by inundation.	The total area of Murray Valley - type landform is proportionately most reduced by reservoirs, compared to other landforms.
Nil	Nil	Flow regulation may improve value of river downstream for recreation.	Flow quantity and variation reduced.
No impact except for especially careful mine management in vicinity of pipehead.	Negligible	Access usually restricted. Little impact on recreational value of downstream flows.	Creates long lasting pool in river where previously there was only occasional flooding.
Constrain routes of haul roads.	Slightly higher costs at intersections of pipes with other services.	May be visually intrusive in landscape. May improve walking access to forest.	Similar to roads and powerlines.

Table B4 Rivers in Rural and Urban Land

IMPACTS OF LAND USE ON WATER RESOURCE

	PASTURE	CROPS	HORTICULTURE
FLOW VOLUME (yield)	Large increase in yield compared to forested catchment. Irrigation may reduce yield if water is taken from surrounding catchment, or may increase yield if water is imported from another catchment.	As for Pasture.	As for Pasture.
SALINITY FROM GROUNDWATER DISCHARGE	In lower rainfall areas with substantial salt stored in the soil profile, discharge of salt to stream may start some years after clearing as deep groundwater levels rise. Stream may become brackish or saline.	As for Pasture.	Not usually in salinity - risk areas.
TURBIDITY (muddy water)	High risk of turbidity if animals have direct access to stream.	High risk of turbid run-off from ploughed areas.	As for crops.
CHEMICAL POLLUTION	Risk of pollution from agricultural chemicals, pesticides and fertilisers.	As for pasture.	High risk of pollution from pesticides and fertilisers if their application is not controlled.
BIOLOGICAL POLLUTION	Risk from human and stock acces to stream or reservoir.	Minimal	Usually higher density of human habitation than crops or pasture hence higher risk.

Table B4 (continued)

RURAL INDUSTRY (e.g. Abattoir, Refineries)	INTENSIVE ANIMAL HUSBANDRY (Piggeries)	SPECIAL RURAL (Hobby farms)	URBAN
Demand for industrial water supply may reduce flow.	Minor reduction in yield if water supply required.	As for intensive animal husbandry.	Increased run-off from roads and roofs, but not usually significant because urban areas are usually only a small fraction of catchment.
N/A	N/A	As for pasture.	N/A
Poor management of site or process can cause severe turbidity.	Turbidity is only a risk in some cases of poor management.	Low risk of turbidity with good soil management, but a significant level of poor management is likely when there is a large number of different land owners.	Run-off from roads and verges can cause turbidity.
Harmful chemicals may be discharged to stream if pollution is not controlled.	Risk of pollution from high nutrient loads in effluent and run-off from site unless adequately managed.	As for pasture.	Risk of pollution from urban run-off which contains rubber, fuel and oil from vehicles, or accidental spillage of poisons. Drainage from rubbish disposal sites is potentially dangerous if certain chemicals have been dumped.
Highly polluting effluent should be treated to acceptable standard before discharge to stream or preferably removed from catchment.	High risk if effluent not adequately treated or removed from catchment.	Relatively high density of housing using septic systems increases risk of badly located or malfunctioning units causing pollution of streams. Generally higher level of human activity near streams produces significant pollution.	Disposal of sewage can present a risk of pollution. High concentration of people increase risk of pollution from human contact with stream water or impounded water.

Table B5 Rivers in Rural and Urban Land

IMPACTS OF WATER RESOURCE DEVELOPMENT ON LAND USE

	PASTURE	CROPS	HORTICULTURE
CATCHMENT AREAS	No impact on conservative farming practices. Potential for rezoning to more densely inhabited or industrial land use may be restricted.	As for pasture.	As for pasture.
STORAGE DAMS a) Impacts of dam site and reservoir basin.	Private land would need to be resumed in reservoir basin and dam works area.	As for pasture.	As for pasture.
b) Downstream impacts.	Flows greater than required for riparian rights are markedly reduced. Flooding is reduced.	As for pasture.	As for pasture.
PIPEHEAD DAMS	As for storage dam except that required land area is very much smaller.	As for pasture.	As for pasture.
PIPELINES	Easement required on pipeline route. Above ground pipe can give problems of access and slight loss of productive land. Below ground pipe has minimal impact.	As for pasture.	As for pasture.

Table B5 (continued)

RURAL INDUSTRY (e.g. Abattoir, Refineries)	INTENSIVE ANIMAL HUSBANDRY (Piggeries)	SPECIAL RURAL (Hobby farms)	URBAN
Imposes costs of careful management. Industry producing toxic wastes should be excluded from catchment.	Imposes costs of careful management and possible relocation if near stream.	As for pasture and urban. Control on location of septic tanks.	Possibly extra costs for sewage and rubbish disposal. Need to keep urban development away from streams.
As for pasture.	As for pasture.	As for pasture.	As for pasture.
As for pasture. If industries have used stream for water supply, special arrangements for continued use may be required.	As for pasture.	As for pasture.	As for pasture.
As for storage dams except that impact on downstream flows is less.	As for pasture.	As for pasture.	As for pasture.
Pipe route would probably avoid industrial site.	As for special rural.	As for pasture, except pipe route would probably avoid private land.	If pipeline must pass through urban land, there may be difficulty fitting in with other services.

Table B6 Shallow Groundwater

IMPACT OF LAND USE ON WATER RESOURCE

	NATURAL VEGETATION	WETLANDS	PINE FOREST
VOLUME AVAILABLE ANNUALLY	No impact.	May be limited by requirement to maintain wetlands.	For approx. 10 years after clearing to plant pines, there is increased recharge. As trees grow older there is less recharge than with natural vegetation.
POLLUTION	No impact.	No impact unless wetlands receive drainage from urban, industrial or market garden areas.	No impact.

Table B7 Shallow Groundwater

IMPACTS OF WATER RESOURCE DEVELOPMENT ON LAND USE

	NATURAL VEGETATION	WETLANDS	PINE FOREST
UNDERGROUND WATER POLLUTION CONTROL AREAS, GROUNDWATER AREAS, PUBLIC WATER SUPPLY AREAS	No impact.	Conservation value is maintained through management plans implemented by Water Authority.	Plantation management may be modified to give priority to water production.
WELLS	In drought periods, the number of plant deaths may be greater near wells due to groundwater levels being drawn down deeper close to wells. 200 sq. m of land required for works at well site.	Locations of wells are chosen and wells operated to minimise effects on wetlands.	Viability of pines not affected by groundwater level. 200 sq. m of land required for works at well site.
COLLECTOR MAINS	Mains are generally buried but access is required along route. Existing roads used wherever possible.	Mains are not located in wetlands.	As for natural vegetation.
GROUNDWATER TREATMENT PLANTS	Approx. 6 ha site required for treatment works and disposal of sludges.	N/A	As for natural vegetation.

Table B6 (continued)

MARKET GARDEN HORTICULTURE SPECIAL RURAL	URBAN	RURAL INDUSTRY (e.g. Abattoirs, Refineries)	INTENSIVE ANIMAL HUSBANDRY
Water available for public supply is reduced by most of the amount drawn for irrigation. (Remainder soaks back to water table.)	Increased run-off from roads and roofs increases recharge, but stormwater drainage may divert some flow away from recharging groundwater.	Water available for public supply reduced by amount drawn from groundwater by industry.	As for market gardens.
Groundwater pollution by: Pesticides, Fertilisers, Effluent from septic tanks.	Groundwater pollution by: Pesticides, Fertilisers, Waste and leaked petroleum products, Drainage from rubbish disposal sites, Effluent from septic tanks.	Groundwater pollution specific to the industry may occur through waste disposal.	Groundwater pollution by effluent from treatment of wastes.

Table B7 (continued)

MARKET GARDEN HORTICULTURE SPECIAL RURAL	URBAN	RURAL INDUSTRY (e.g. Abattoirs, Refineries)	INTENSIVE ANIMAL HUSBANDRY
Licensing of private wells raises the awareness of the limited availability of the water resource and encourages efficient use. Management is required to prevent pollution of groundwater.	Private wells are licensed and care is taken by public authorities in siting of waste disposal and industry. Management is required to prevent pollution of groundwater.	Water Authority generally objects to industry with potential for groundwater pollution being sited in these areas. Other industries as for market gardens.	As for rural industry.
Operation of wells lowers the water table in their immediate vicinity. Where wells are situated very close together, they may need to be deeper than if farther apart. Allocation policy and management are required.	Sites for wells are usually found on public land where their impact is similar to other service installations.	Wells would not be sited in the vicinity of an industry with potential for pollution. Other industries as for market gardens.	As for rural industry.
An easement is required if mains must be located on private land. Impact of main on land use is minimal.	Routes for collector mains must be found in road reserves as for other services.	Routes for collector mains would avoid conflict with requirements of industry.	As for rural industry.
N/A	Works may be slightly obtrusive visually, and may be the source of some odour and noise for adjacent houses. Buffer zone required.	N/A	N/A

Appendix C

ASSUMPTIONS USED IN LONG-TERM PROJECTIONS OF WATER DEMAND

Appendix C

ASSUMPTIONS USED IN LONG-TERM PROJECTIONS OF WATER DEMAND

POPULATION

Population projections for the Perth Statistical Division were prepared by Treasury (WA Treasury, 1986) and used by SPC (SPC, 1987). Immigration rates were uncertain and values of 8000, 11000 and 15000 per year from now on were suggested, with 11000 stated as 'most likely'. The other values have been used for the 'minimum' and 'maximum' projections respectively. Population served by the MWS is assumed to be 94.4% of the Perth Statistical Division.

OCCUPANCY RATIO

The projection of overall occupancy ratio (the average number of people living in a residence) as used by SPC (SPC, 1987) was adopted. The ratio decreases from 2.73 in 1986 to 2.33 in 2011.

RATIO OF FLATS TO HOUSES

The 'maximum' projection assumed that the ratio of flats to houses would remain constant at the 1986 value of 0.166. Gradual increases of the ratio to 0.18 and 0.20 were assumed for the 'most likely' and 'minimum' projections respectively. The occupancy ratio of flats is assumed constant at 2.0, and the occupancy ratio of houses is assumed to reduce to the degree necessary to give the overall occupancy ratio as per projection.

INCREASE IN RESIDENTIAL DEMAND PER SERVICE

Rates of increase in per service demand were assumed for the volumes of water used 'within flats', 'within houses' and 'outside houses'. The assumptions correspond to the Water Conservation Strategy having immediate effect, delayed effect, and no effect, for the 'minimum', 'most likely' and 'maximum' projections respectively. 'Immediate effect' allowed no further increase in any of the types of use. 'Delayed effect' allowed some increase in all types of use for 2 years, followed by a reduction in rates to achieve the 1986 use per service again in 1991, and thereafter no increase. The rates of increase assumed for 'no effect' correspond to the rates observed in recent years, which are 1 kl/service per year for 'within house', and 2 kl/service per year for 'outside house' and 'within flats'.

EFFECT OF PRICE OF WATER

Water used 'outside houses' was assumed to be reduced when the price of water increased more than the rate of inflation, the price increase being needed to cover the cost of more expensive sources as they are added to the system. The amount of reduction was derived from the Domestic Water Use Study (MWA, 1985) and is -0.31% per 1% price increase. No reduction was applied in the 'maximum' projection.

INDUSTRIAL AND COMMERCIAL DEMANDS

Industrial and commercial demand was assumed to grow in proportion to population. For the 'minimum' and 'most likely' projections, a reduction totalling 5% was also applied over the first 5 years, being the expected effect of the Water Conservation Strategy. Future proposals for new industries with large demands for water which cannot be accommodated within the bounds of this assumption will require special consideration for their source of water.

PRIVATE WELLS

The 'most likely' projection assumed that the percentage of services using private wells would remain constant at 28% until the maximum number of private wells that could be sustained in the Perth area (estimated as 124000) was reached in 2003. The 'minimum' projection assumed an increase of 0.5% per year until the maximum number of wells was reached in 1998. The 'maximum' projection assumed a decrease of 0.5% per year for 11 years, followed by a decrease of 0.25% per year. In this case, the maximum number of wells was not reached in the projection period of 25 years. Demand corresponding to the number of wells in excess of (or less than) 28% of services was subtracted (or added) to the demand projection at the rate of 200 kl/well per year.

UNACCOUNTED-FOR WATER

Unaccounted-for water has been 16.4% (on average) of the total water produced by the MWS over the last 5 years, but the annual amount varies considerably. For projection, the average value was allowed in all years. In the 'maximum' and 'minimum' projections, the average value was assumed higher and lower, at 17.4% and 15.4% respectively, which is the maximum variation in the mean expected to be possible over 25 years, based on the variability of the recorded data.

COUNTRY SUPPLIES

Projections of demand for the G & AWS and for Mandurah were based on advice from the operators of their respective schemes, and were not varied between 'minimum', 'most likely' or 'maximum' projections.

OTHER ALLOWANCES

Allowances for riparian releases, service reservoir cleaning and firefighting were all held constant at 2.5 mill. cu. m. per year throughout all projections.

Appendix D

WATER QUALITY OBJECTIVES

Appendix D

WATER QUALITY OBJECTIVES*

CHARACTERISTIC	NH&MRC/AWRC DESIRABLE CURRENT CRITERIA	NH&MRC/AWRC LONG TERM OBJECTIVES	MWS OBJECTIVES
	MAXIMUM	LEVELS	
PHYSICAL			
Colour units	50	5	5
Turbidity units	25	5	5
Odour	Unobjectionable	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable	Unobjectionable
pH range	6.5 to 9.2	7.0 to 8.5	7.0 to 8.5
CHEMICAL	mg/L	mg/L	mg/L
Total solids	1500	500	500
Calcium	200	75	75
Chloride	600	200	200
Sulphate	400	200	200
Total iron	1.0	0.1	0.15
Nitrate (as N)	10	10	10
Total hardness (as CaCO3)	600	100	150
Manganese	0.5	0.05	0.05
MICROBIOLOGICAL			
i. Coliforms	Throughout any year, 90% of all samples should not contain levels in excess of 20 per 100 mL.	1. Throughout any year, 95% of samples should not contain any coliform organisms in 100 mL. 2. No samples should contain more than 10 coliform organisms per 100 mL 3. Coliform organisms should not be detectable in 100 mL of any two consecutive samples.	
ii. E. coli	Throughout any year, 90% of all samples should not contain levels in excess of 2 per 100 mL.	No sample should contain E. coli in 100 mL.	

- NH&MRC - National Health and Medical Research Council
- AWRC - Australian Water Resources Council
- Desirable current criteria set out maximum levels which may be used as current criteria appropriate to present Australian conditions to give a drinking water of satisfactory quality.
- Long-term objectives set out more stringent levels which could be aspired to and which, if achieved, result in drinking water of excellent quality. These levels are based on World Health Organisation International Standards for Drinking Water, 1971.
- The NH&MRC/AWRC guidelines are currently under review.

*(Quoted from Water Authority, 1987c)

Appendix E

CONSTRAINTS ON TIMING OF SCHEMES IN THE SOURCE DEVELOPMENT TIMETABLE

Appendix E

CONSTRAINTS ON TIMING OF SCHEMES IN THE SOURCE DEVELOPMENT TIMETABLE

1. In the 1987 version of this report (Mauger, 1987) it was explained that groundwater schemes on the Gnangara Mound were to be built in time to provide capacity to meet peak rates of demand in local areas, when that time was sooner than the ecomomically ideal time to build the schemes for the purpose of increasing the system yield. In this revision of the report, the projection of total demand is significantly lower than it was in the 1987 version. One consequence is that it is econcomically preferable to augment the capacity of trunk mains to enable peak demands to be met by other sources, rather than to build new groundwater schemes just to meet the peaks. Thus the times for developing Gnangara Mound groundwater schemes are now only based on the cost of the schemes compared to other available sources.

2. As stated in Chapter 8, the redevelopment of Victoria Dam must occur within 10 years to meet safety standards. The time selected for construction of the new dam and the Bickley Pumpback is the earliest that the normal processes of gaining environmental approval, design, and construction will allow.

3. Three projects are listed in Table 4 which involve increasing pipe capacity in the trunk main network. Their timing in the Source Development Timetable is controlled by a variety of factors, namely:

   - Wungong Stage 2 outlet amplification is introduced when its extra flow capacity is required to meet summer peak demands. The works also result in an increase in the System Yield through improved capability for more flexible operation of the system, which is why the project is shown in the Source Development Timetable.

   - Mundaring Integration Stage 2 involves constructing connecting pipes to allow the MWS to maintain security of supply to the G&AWS. It is required at a time when growing demands in both the MWS and G&AWS make the capacity of the existing connection inadequate.

   - North Dandalup main amplification involves amplification of a section of trunk main from North Dandalup to Serpentine river. The main adds to the System Yield by improving the flexibility of operating sources south of Serpentine. It is introduced at a time when the cost of the works is justified by the associated System Yield Benefit.

4. Pipehead and pumpback schemes effectively increase the total streamflow supplying the system without increasing the hills reservoir storage capacity. The percentage of this additional streamflow which can be used is smaller for smaller total storage capacities. Consequently the System Yield Benefit of a pipehead or pumpback may appear smaller if it is introduced before the development of a major storage dam than if it is introduced afterwards. 'Lost' yield from prior development is made up when the dam is built, but lower yields must be taken into account when scheduling pipeheads and pumpbacks in this situation.