Water Authority
of Western Australia

Water Conserving Design for Gardens and Open Space

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of Western Australia

WATER RESOURCES DIRECTORATE
Water Resources Planning Branch

Water Conserving Design for Gardens and Open Space

Based on a paper presented to the

Urban Water Demand Management Conference
Institution of Engineers Australia
Australian Water and Wastewater Association
Sydney 30-31 October 1989

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Published by the

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Report No. WP 89

December 1989

STREAMLINE ABSTRACT

WATER CONSERVING DESIGN FOR GARDENS AND OPEN SPACE

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This paper reviews design options for improved water resource utilisation in gardens and open space. It provides a structure to assist practitioners to incorporate water conserving design into present and future urban areas. Emphasis is placed on an approach to design which complements regional and local water management. Design options are considered under the headings of irrigation reduction, scheme water irrigation replacement, water quality management, water balance management and town planning regulation. Selected examples of innovative design are provided.

Key Words: water conservation, water conserving design, water sensitive design, drainage, low water garden, land use planning, environmental planning, water resource planning, ecologically sustainable development.

Water Authority of Western Australia, Perth, 1989,
ISBN 0 7 309 1813 0, x 32 pp, 13 Figures,
Water Resources Directorate,
Water Resources Planning Branch Report No. WP89.

ACKNOWLEDGEMENTS

This paper is a synthesis of work done by practitioners in Australia and America. The foundations provided by The Domestic Water Use in Perth Study (Metropolitan Water Authority, 1985; WAWA, 1987), the Perth Urban Water Balance Study (Cargeeg *et al*, 1987), and the contributions to the WAWRC (1986) *Water Conservation Through Good Design* publication in particular, are acknowledged.

Cover: Low Water Garden at the Karratha residence of C.J. Nicholson.

Edited by Dr. B. Wykes, Enviro-Ed Services.
Layed out and set by Scribe D.T.P.

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1. INTRODUCTION

Enormous quantities of water are wasted annually on Australian gardens and open space. This waste consists of excessive amounts of scheme water used directly on the garden, excessive use of backyard and other privately supplied bore water, lost rainfall runoff and groundwater drainage. The waste in many cases is caused and exacerbated by poor design. Improved garden and open space design can convert much of the waste into additional available water resources.

Water conservation* or the effective and efficient utilisation of water resources must begin with an understanding of regional, local area, and house lot water management. Understanding water management at each level enables regional planners, developers and gardeners to consider options appropriate to the conditions that prevail at any particular site. The conditions which should be taken into consideration include climate, topography, soils, water availability, water balance, water quality management and the appropriateness of local native vegetation for landscaping.

The concept of 'water conserving' or 'water sensitive' design for Australian conditions has evolved in recent years from work done in Western Australia, South Australia, the Australian Capital Territory, and the United States of America. Papers have been presented on water harvesting at the National Urban Demand Management Conference in Perth (Nicholson & Edgecombe, 1986) and at the Australian Institute of Landscape Architecture's Xeric Australia Conference in Adelaide (Nicholson, 1986), and in the WAWRC (1987) publication *Water Conservation Through Good Design.*

This report reviews current water use in Perth, and then considers how recent understanding and innovation in water sensitive design can be used in gardens and open space to improve water conservation in Perth and other areas of this dry continent. It also considers how town planning regulations can be used to bring better design options into general practice. The report is intended to assist engineers, environmental scientists, landscape architects and town planners. The report is also relevant to the urban development, garden and nursery industries as a guide to improved water and environmental management in their sector.

**This report uses the World, National and State (W.A.) Conservation Strategy definition:*

Conservation is . . . "The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations. Thus conservation is positive, embracing preservation, maintenance, sustainable utilisation, restoration, and enhancement of the natural environment".

2. WATER, GARDENS AND OPEN SPACE

The early Europeans visiting Australia commented on the unique vegetation covering the sites of today's suburbs. Many of these plants became the wonder of European gardeners and were highly fashionable. Today, where these plants grew naturally from rainfall and runoff, foreign plants depend on engineering and imported water for existence.

Now accustomed to imported lush greenery, todays suburban culture needs to recognise the challenges to garden landscaping set by the costs associated with public water supplies and by nature, particularly during drought years. The response of approximately 30% of Perth households is to use a backyard bore (WAWRC, 1987:85), tapping an average of 1000m³ each of shallow groundwater per year.

The water used in Perth at suburban and house lot levels comes from public and private supplies. Public supplies are those supplied by the Water Authority of Western Australia in its water supply schemes from dams and borefields. Private water supplies are generally from bores tapping unconfined aquifers on the sandy Swan Coastal Plain. While commerce, industry and agriculture are subject to some use restriction by bore licences and quotas, allowing conservation by regulation, domestic bore owners have virtually unrestricted access to 'free' water.

Of water used inside Perth's households, 52% (MWA, 1985:25) results in grey water which in many cases is capable of replacing irrigation water from other sources.

TABLE 1. ESTIMATES OF WATER USE IN PERTH 1982/83
(Scheme water distribution losses are distributed proportionally across the different sectors in public use. Modified after MWA, 1985; Cargeeg *et al*, 1987)

(Million m^3/year)	PRIVATE	PUBLIC	TOTAL
Domestic Excluding Irrigation	0	79	79
Domestic Irrigation	**77**	**42**	**119**
Local Govt, Schools and Institutions	**55**	**12**	**67**
Commerce and Industry	23	29	52
Agriculture	50	2	52
TOTAL	205	164	369

The resultant lush, green, over-watered gardens and road verges have unfortunately become a symbol of Perth's suburban goodlife, heavily promoted by the housing, nursery and irrigation industries. In Western Australian vernacular the home is not considered complete without 'putting down a bore and laying on the retic'.

The home owner without a bore is clearly under pressure to conform to this lush landscape idiom. The standards set by the 'Water Wallys' in turn provide further encouragement to civic leaders in local government, schools and institutions to use an estimated 67 million cubic metres per year, equivalent to approximately one third of Perth's total scheme water consumption (Cargeeg *et al*, 1987:5).

Table 1 above provides an overview of Perth's total water use.

This report focuses on water management, irrigation reduction and scheme water replacement at the three levels of house lot gardens, local area open space, and regional open space.

Local Government, schools and institutions (the regional and local area design levels) account for 55 million cubic metres per year of privately supplied water use. Most of this is used on local parks, institution grounds and gardens (Cargeeg *et al*, 1987).

Domestic irrigation (the house lot design level) in 1982/83 used 119 million cubic metres, accounting for 32% of Perth's water use. Irrigation is therefore a major consumer of Perth's water resources and can be seen to be a worthwhile target for water conservation strategies. Of domestic irrigation, 35% was supplied by scheme water, with Perth's then population of one million using 42 million cubic metres of scheme water on house gardens for growing plants for utility, pleasure and recreation. This amount is equivalent to the next 16 years of water source development planned for Perth (Mauger, 1989) (allowing for a 20% reduction in system yield by 2040 due to the greenhouse effect).

required in some coastal and riverside suburbs where salt water intrusion is a risk.

The Karratha Low Water Garden programme (see Section 8) showed that in the case of a hot arid town, individual house lot water consumption could be halved by replacing the conventional thirsty lawn gardens previously accepted as the norm, with a water sensitive garden design (Edgecombe, 1983).

Around the State, many millions of cubic metres of urban runoff and subsurface drainage and treated sewage effluent are currently diverted unutilised to the river systems, wetlands or the ocean. This water could be used for irrigation if properly treated with the appropriate guidelines and infrastructure in place whereas it presently poses risks to water quality and water balance in the natural environment.

TABLE 2. AVERAGE SCHEME WATER USE BY BORE AND NON BORE OWNERS IN PERTH 1981/82 (MWA, 1985)

		All Users m^3/year*	Bore Users m^3/year	Non Bore Users m^3/year
In House	Total	173	175	172
Ex House				
Irrigation		113	34	142
Pools		5	5	5
Other		7	5	8
	Total	125	44	155
HOUSE GRAND TOTAL		**298**	**219**	**327**

*(*NOTE: $1m^3$ = 1KL = 1000 Litres).*

As can be seen in Table 2, house lot bore owners used an average of $108m^3$ less scheme water in 1982/83 (MWA, 1985). However, bore owners currently use excessive volumes of ground water on the garden ($1000m^3$/year MWA, 1985; Cargeeg *et al,* 1987). At the house lot level, if more people had bores but on average used much less bore water, then more scheme water would be saved with less risk to ground water balance.

Significant bore water use reductions are

Considerable water savings can be achieved if designers take up the challenge of making water conservation a design objective.

3. DESIGN TO REDUCE IRRIGATION REQUIREMENTS

Total applied irrigation requirements can be reduced by:

1. New residential patterns
2. Hydrozones
3. Soil amendment
4. Improved turf management
5. Local native plants and other xerophytes
6. Windbreaks.

3.1 New residential patterns

The effectiveness of water conservation strategies in existing and future residential areas will be limited by reluctance of house lot and civic gardeners to change established gardening behaviour. However, changes to house lot size and urban structure can effectively set limits to water requirements. Ferguson (1987:148) states:

> 'In any urban development the fundamental choices that determine how much irrigation water will be required are made during the basic layout of the site. Once an urban development plan and its planting design are fixed the minimum amount of water required for maintenance of the landscape in acceptable condition is fixed as well. The complexity and creativity inherent in the process of urban design open a number of avenues for reducing the potential demand for irrigation water'.

The two principal subdivision design approaches to reduce garden and open space water demand are to reduce house lot sizes, thereby increasing house lot yield, and to redistribute land from house lots into local area and regional open space (Sanders *et al*, 1982). This is shown in Figure 1.

Smaller house lots can accommodate more people in a given area with less garden watering requirements. Preliminary analysis by the authors of house water consumption by postcode in Perth has shown low average consumption in older areas with smaller blocks and established gardens.

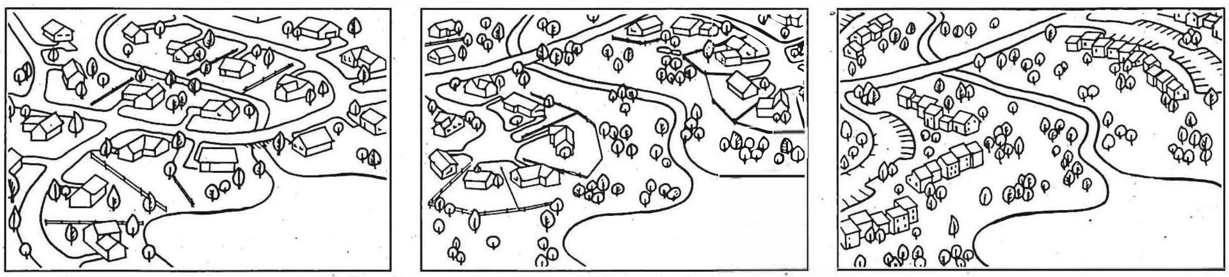
Water conserving house distribution patterns include cluster housing, attached housing and zero lot line housing. Clusters of houses built on higher land not requiring drainage, or land not subject to flooding, pose least problems for the area's water balance. The larger areas of open space can either be maintained on water harvesting or sophisticated irrigated technologies or, preferably, remain under their native vegetation. This also leaves wetlands and channels in more natural conditions which can then continue to provide flood control, ecological and recreational services and aesthetic values.

These water saving residential patterns are coincidentally being promoted by the Joint Venture for More Affordable Housing, as they are also very effective in reducing land development costs (JVMAH, undated). Sanders *et al* (1982:8) also notes how 'smaller, denser housing, although designed for greater affordability, helps to conserve water as well'.

Mugavin (1988) emphasises that increasing densities must be achieved by new approaches in design, particularly the treatment of open space, and by new development procedures that include landscape appraisal, infrastructure development along with allotment, street and open space design as one integrated process. He suggests that without these new approaches, urban consolidation

FIGURE 1. DISTRIBUTING OPEN SPACE FOR WATER CONSERVATION

Smaller, denser housing, although designed for greater affordability, helps to conserve water as well. (Sanders *et al*, 1982)



A: Conventional Development — *B: Cluster Development* — *C: Cluster Development using Attached Housing Units* will fail. Addressing the issues of water conservation, the need for urban design based on the relationship between topography and water becomes clear. The Western Australian Environmental Protection Authority (1989:11), commenting on the environmental aspects of planning for the future of Perth, lists a set of design principles '... to assist the development of design solutions associated with determining an appropriate urban form, design density, landscape and infrastructure', and lists specific design features for water conservation (see Appendix C).

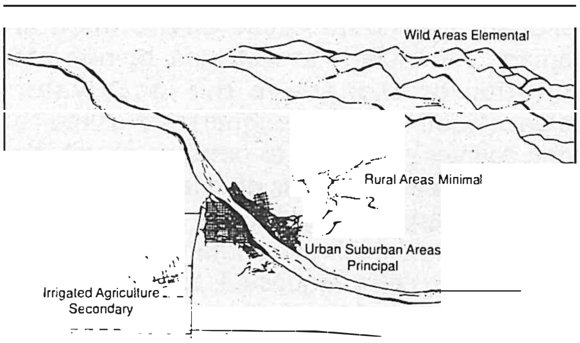
3.2 Hydrozones

Thayer and Richman (1984) partition areas according to expected intensity of use with the rationale that heavily used areas need more applied water. They called the areas so defined 'hydrozones' and prepared a matrix of hydrozones, presented as Table 3. Able to be used at any scale, the 'downzoning' of unnecessarily high hydrozones is a useful technique for water conserving design. At the house lot level, downzoning a front yard from a high use, high water requiring turf primary hydrozone to a low use, low water requiring local native elemental hydrozone would yield water conservation benefits.

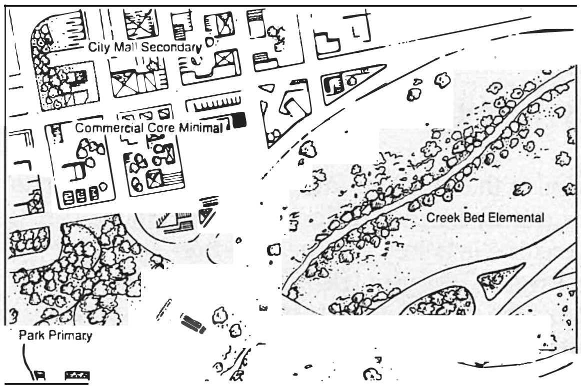
Table 3 suggests that heavily used turf areas fit into the primary hydrozone category while the secondary, minimal and elemental hydrozones require low water use turf and low water use plants such as local native vegetation.

When the water requirements of different vegetation complexes and species are understood, watering regimes using water harvesting or irrigation can be more finely tuned. Plants with similar water requirements should be grouped in the same area with the same irrigation schedule.

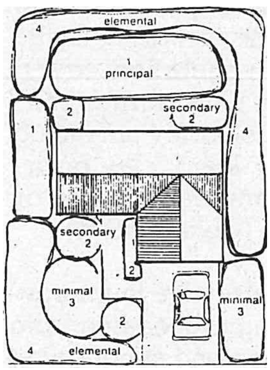
FIGURE 2. THREE LEVELS OF HYDROZONE
(Thayer *et al*, 1984:200)



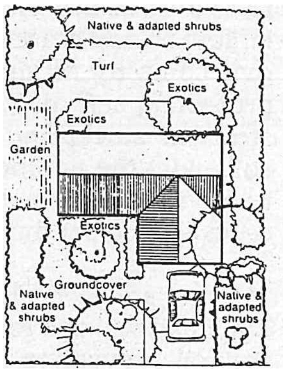
A: Hydrozone concept applied to regional scale.



B: Hydrozone concept applied to community scale.



C. (i) Hydrozone concept applied to a suburban lot.



(ii) example of application.

TABLE 3. MATRIX OF HYDROZONES (Thayer *et al*, 1984:199)

	Human Contact	Visual Importance	Water and Energy Needs
Primary Hydrozone	Direct, Intense, Active	Conspicuous	Greatest
Secondary Hydrozone	Less Direct, Less Intense, More Passive	Conspicuous	Reduced
Minimal Hydrozone	Little	Less Conspicuous	Slight
Elemental Hydrozone	None	Inconspicuous	None

This concept has been used quite independently in Western Australia by the Environmental Protection Authority to influence golf course design on sites where heavy water and fertiliser use could cause environmental damage, particularly to wetlands, by nutrient pollution or changes to the local water balance. Golf course designers are asked to zone courses according to pressure of use, so that low impact sections of fairways receive less water and fertiliser than impact areas which in turn receive less than greens. Soil amendment is also requested, to improve the water efficiency of the course.

The Low Water Garden also demonstrates these hydrozoning principles by restricting sprinkler irrigation to reduced areas of lawn and a vegetable garden.

3.3 Soil amendment

Soil is the medium into which water infiltrates and may be stored for plants to tap, and soil texture is a key factor in water conserving design. George (1986:36) reports that 'Soil texture has a vital influence on soil water storage, infiltration, fertility, runoff and erosion, irrigation practice and soil workability'.

Loss of structure will result in problems with infiltration and erosion. This can generally be overcome by retaining vegetation cover, protecting self mulching soils during construction, stockpiling topsoil or by amending soils with the addition of loam, clay or organic matter such as compost manure or sewage sludge or mulches (George, 1986).

Mulches are particularly effective in improving infiltration and reducing evaporation from the soil, preventing erosion and suppressing the growth of weeds which compete with other plants for water. Homemade compost is one very effective source of mulch.

Every contract involving soil disturbance should have a specification for soil management to ensure the soil on the site is improved, rather than destroyed as is most often the case. The Standards Association of Australia has a standard for topsoil which could well be part of any contract specification.

On the Swan Coastal Plain in Perth, the dominant Bassendean sands are very porous and have little ability to hold nutrients. The Department of Agriculture is researching techniques for clay and loam or red mud (from alumina processing) amendment to improve water holding and nutrient binding (Yeates in AIAS 1988:36).

It can be easily demonstrated that by amending sand with 15% clay (roughly a 5cm topdressing cultivated in 30cm) the amended soil will hold irrigation water and nutrients applied at correct rates within the main feeding and water uptake zone of most plants. We suggest that significant water savings could be made in Perth if home builders made soil amendment of primary hydrozones an integral part of the project. It is estimated that a truckload would be sufficient for a Low Water Garden on a modern small house block.

In the heavy soils of towns in the arid Pilbara, sewage sludge is a much sought after commodity for soil amendment to improve infiltration and water holding capacity. Taxpayers not only appreciate 'getting a bit of their own back' from the government, their demand for the dried sludge has saved money and reduced another environmental problem as the sludge was previously regarded as waste and was dumped and burnt.

In the future, improved soil investigations will be required for urban development areas. This will provide better information on runoff, infiltration, soil water storage and ponding information for water conserving design (George, 1986). Appropriate species for landscaping and soil amendments in the high use hydrozones can then be specified. Techniques for improving infiltration and its estimation are also required.

3.4 Improved turf management

Sports turf, lawns and large irrigated grassed areas are the big users of domestic and civic water in the arid and Mediterranean areas of Australia. Providing this water and managing these areas is a major expense for Local Authorities in Perth. The environmental side-effects of Perth's 'green lawns' syndrome, where groundwater consumption and nutrient export from fertiliser application contribute to wetland eutrophication and have the potential to affect water supply quality, have made turf research a legitimate interest of the Environmental Protection Authority and the Water

Authority (Humphries *et al* in WAWRC, 1989: 113).

Results of research on quality turf cultivation and irrigation by the Western Australian Department of Agriculture have been distributed in advisory notes, and published in *Water Conservation Through Good Design* (Parish, Cole in WAWRC, 1986). However, management for water conservation and nutrient pollution control is generally lacking. Turf managers need to develop new objectives and to understand their turf sites by applying more scientific techniques such as soil and leaf tissue analysis and computer controlled irrigation using remote sensors.

To assist turf managers in Local Authorities and other institutions to justify changing irrigation designs to their political decision makers, clear direction from water managers as to acceptable water consumption levels and guidelines to achieve them is required. The Water Authority has done some preliminary work in this area (del Marco, 1990).

Ownership of specific aspects of investigations by individual Local Authorities with agreement to share results ensures funding and acceptance by their elected leaders. This approach is working in Western Australia where combined Local Authority investigations are being co-ordinated by the Environmental Protection Authority.

Turf management can be improved in the following ways:

1. Hydrozoning: can the area of high quality turf be reduced?
2. Soil amendment
3. Selection of hardy grass with low water requirements
4. Improved irrigation planning
5. Lawn shaped to sprinkler delivery pattern
6. Improved fertiliser application
7. Improved mowing practice.

Hydrozoning: can the area of high quality turf be reduced?

Applying the hydrozone principle, we should always ask whether high water, high energy turf is really required. Many of us learnt to kick a football in the street or on an empty block. A bowling-green surface is not always needed for occasional sports. Synthetic surfaces are now available for many grass sports. Turf managers need to review their turf needs according to hydrozone principles with advice from landscape architects who are able to assess what is really needed, and where.

In passive open space, slashed rain-fed grass may suffice, with water harvesting of rainfall to extend the green season.

The Low Water Garden uses the basic principle that the best way to manage house lot turf to save water is to get rid of it. Removing large and generally useless lawns from the front yard and restricting the backyard lawn to a minimum functional size for high intensity use is the single most effective step towards saving water.

Soil amendment

After removing or downgrading unnecessary areas of lawn, proper soil preparation is the next most important factor governing how much turf irrigation water is saved. As discussed in 3.3 above, the soil must accept water readily without runoff, and store it within the root zone, that is the top 20 or 30cm of soil. Saline soils, however, require special treatment to ensure adequate leaching (George, 1986).

In Perth where the use of soil wetting agents is required when organic particles make sands water repellant when dry, it is common to see water from street verge irrigation running freely onto the road without penetrating the soil. Lawns on heavy soils also generate run-off or become boggy and the turf fails to thrive. Poor soil leads to a cycle of excessive water and fertilizer use and nutrient pollution as gardeners seek to correct failing lawns by simply adding more water and fertiliser.

Selection of hardy grass with low water requirements

The turfs recommended in a recent review of turf management, maintenance requirements and opportunity for water conservation by the Water Authority of Western Australia are warm season grasses and in particular common couch (or commercial selections of 'greenlees park', 'national park' and 'wintergreen'), kikuyu and buffalo (del Marco, 1990).

Improved irrigation planning

The water requirements of turf can most easily be compared and calculated as a percentage of net pan evaporation (%NPE). However the actual requirements of different species have not been rigorously described. This is a high priority for research. Preliminary work suggests 60% NPE as a safe interim estimate (WAWRC, 1986). However other work (CSIRO, 1979) and actual application rates of scheme water to lawns in Perth (MWA, 1985) suggest that lower application rates may suffice, especially in secondary hydrozone areas where the objective may be to keep the grass alive rather than thriving.

Average application rates of scheme water on lawns and gardens by non-bore owners in Perth were found to be slightly less than the 60% NPE of 6mm per day recommended above (MWA, 1985). However, in Melbourne it was reported that a 3 to 5 fold increase in garden water use occurred by householders installing automatic sprinkler systems (Heeps in AWRC, 1987:142). Caution is required in prescribing watering rates and promoting automatic reticulation systems until research is done to clarify irrigation requirements. Such information would then need to be communicated to gardeners.

In Perth, watering twice weekly in spring and autumn and three times weekly in summer is recommended. Application rates should not exceed soil infiltration rates, and watering should be done early in the morning where possible; where not, in the evening in still conditions so winds do not blow the spray off target.

The City of Stirling in Perth has developed a computer based irrigation system which monitors soil moisture and evapotranspiration rates and automatically delivers the required water to the turf. The City advises that a 30% water saving has been achieved at one major sports field using this system (Hounslow, pers comm). The system will also be developed to include 'fertigation', that is the delivery of soluble fertilizer with irrigation.

The Environmental Protection Authority is co-ordinating a research proposal in this area, funded by several Local Authorities, to produce a Nutrient and Irrigation Management Programme (NIMP) upon which the councils can base their own turf management. The objective is to use modern irrigation technology to eliminate wasteful water and fertiliser use and to reduce operating overheads through the manipulation of turf growth rates.

Lawn shaped to sprinkler delivery patterns

Consideration of the sprinkler distribution patterns before defining lawn boundaries can lead to an even distribution of water, limiting overthrow into non-target areas, and reducing total water use.

Water pressure is a critical factor in sprinkler efficiency. Too high a pressure causes the common problem of misting sprinklers with resulting high evaporation losses. The use of pressure reduction valves to keep sprinklers at a standard optimum operating pressure is required to keep the 'heavy handed tap turner' in check. Ideally this would lead to the identification of sprinklers by radius of throw and result in easy matching of lawn shape and sprinkler delivery for all water pressures.

Improved fertiliser application

Fertilisers are applied to correct any deficiencies in soils to meet the particular nutrient requirements of different plants at different stages of growth and in different seasons. Fertiliser requirements are thus site, species and season specific and should be determined by regular soil testing. In the absence of site information, light applications of a balanced fertiliser based on visible need have been recommended (del Marco, 1990). Healthy, properly fertilised turf may require less water than unfertilised turf (CSIRO, 1979).

Current malpractice tends towards heavy doses once or twice a year with large proportions of fertiliser leached within months of application and nutrient stress on the plant for the rest of the year. The Nutrient and Irrigation Management Programme research project referred to above will provide information for local authorities in Perth which will also be of value to the home gardener.

Improved mowing practice

Improved mowing practice can reduce water requirements. In general only one third of the green leaf area should be removed (CSIRO, 1979). Regular mowing, leaving short to moderate length blades of grass with the cuttings not removed, appears to reduce rates of evapotranspiration and increase water infiltration and return of nitrogen (del Marco, 1990).

3.5 Local native plants and other xerophytes

Xerophytes are plants from dry climatic areas which are able to endure conditions of prolonged drought. Many of our local native plants are xerophytes, but in the suburban situation were replaced over the years by exotic plants dependent on irrigation.

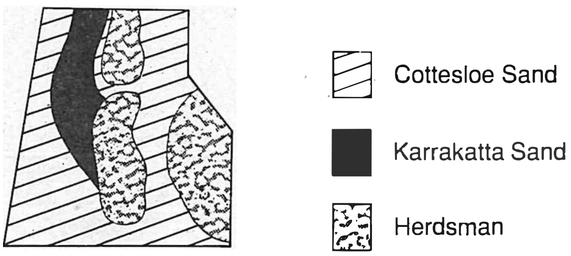
Native vegetation retention is now an urban as well as a country issue. Residents of Perth are realising that the uncleared block in their suburb is the last patch of bush near them and are forming action groups to protest against these blocks being built on, and further are willing to assist local councils in site surveys, weeding and management. Such areas of vegetation should be retained wherever possible as they usually require minimum maintenance and little water, while they also provide a future source of seed of the local vegetation provenances and expose city folk to their aesthetic appeal.

Where construction occurs in bushland all attempts should be made to retain soil and vegetation integrity and maintain the natural water balance of the site. Infiltration or runoff patterns which sustain local vegetation should be maintained.

The knowledge required for using local native plants at a regional, local and house lot level in Perth has recently become more readily available. Powell and Emberson (1979) provide a list of local plant species by soil type. Powell (1990) in *Leaf & Branch* further describes the features of Perth's native tall shrubs and trees, with additional notes on their associated wildlife. Marchant *et al*, (1987) in The Flora of

FIGURE 3. SOILS AND LOCAL VEGETATION INFORMATION (Sargent, 1987)

Local Authority Soils Map



Local Vegetation by Soil Type

Karrakatta Soils

SPECIES		COMMON NAME	ZONE	HEIGHT	WIDTH	FLOWER		DESCRIPTION
Kennedia	*prostrata*	Scarlet Runner	1	0.1	2.5	Red	Jul-Nov	Groover
Patersonia	*occidentalis*	Flag Iris	1	0.3		Blue	Sep-Oct	Dense Groover
Conostylis	*candicans*	White Cottonheads	1	0.4		Yellow	Aug-Nov	
Platytheca	*galioides*		1	0.5		Blue	Jul-Nov	Shrub
Dampiera	*linearis*		1	0.5		Blue	Jul-Nov	Groover
Hemiandra	*pungens*	Snakebush	1	0.6	2.0	W or P	Oct-Apr	Dense Groover
Hovea	*trisperma*	Common Hovea	2	0.7		Blue	Jun-Sep	Shrub
Hypocalymma	*robustum*	Swan River Myrtle	2	1.0		Pink	Jul-Oct	Shrub
Hardenbergia	*comptoniana*	Native Wisteria	2	1.0	6.0	Purple	Jun-Sep	Dense Groover/cl
Anigozanthos	*manglesii*	W.A. Kangaroo Paw	2	1.0		Red/Gr	Aug-Oct	
Acacia	*pulchella*	Prickley Moses	2	1.0		Yellow	Jun-Oct	Dense Shrub
Calytrix	*fraseri*	Pink Summer Calytrix	2	1.0		Pink	Nov-May	Shrub
Melaleuca	*seriata*		2	1.0		Mauve	Oct-Dec	Dense Shrub
Dianella	*revoluta*		2	1.0		Br/Yel	Oct-Nov	Shrub
Pimelea	*rosea*	Rose banjine	2	1		Pink	Aug-Nov	Dense Shrub
Verticordia	*densiflora*		2	1.0		Mauve	Nov-Jan	Shrub
Ricinocarpus	*glaucus*		2	1.0		White	Jun-Oct	Dense Shrub
Hovea	*pungens*	Devils Pins	2	1.5		Blue	Jun-Nov	Shrub
Calothamnus	*sanguinium*		2	1.5		Br/Red	Mar-Oct	Shrub

SPECIES		COMMON NAME	ZONE	HEIGHT	WIDTH	FLOWER		DESCRIPTION
Grevillea	*vestita*		3	2.0		White	Jun-Sep	
Jacksonia	*furcellata*		4	4.0		Yellow	Aug-Mar	Shrub
Jacksonia	*sternbergiana*		4	4.0		Yellow	Aug-Mar	Shrub
Conosperum	*triplinervium*	Tree smokebush	4	4.5		White	Aug-Nov	Dense Tree
Dryandra	*sessilis*	Parrot Bush	4	5.0		Cream	May-Nov	Tree
Nuytsia	*floribunda*	W.A. Christmas Tree	4	8.0		Orange	Oct-Jan	Dense Tree
Eucalyptus	*deicpens*	Limestone Marlock	4	8.0		White	Sep-Nov	Dense Tree
Eucalyptus	*todtiana*	Pricklybark	4	9.0		Cream	Feb	Dense Tree
Banksia	*menziesii*	Firewood Banksia	4	10.0		Red	Feb-Aug	Tree
Banksia	*attenuata*	Slender Banksia	4	1.0		Yellow	Sep-Feb	Dense Tree
Banksia	*grandis*	Bull Banksia	4	1.0		Yellow	Sep-Dec	Tree
Banksia	*prionotes*	Acorn Banksia	4	10.0		Orange	Feb-Aug	Dense Tree
Allocasuarina	*fraseriana*	Common Sheoak		15.0		Cone	May-Oct	Tree
Eucalyptus	*calophylla*	Marri, Red Gum		40.0		White	Jan-May	Dense Tree
Eucalyptus	*gomphocephala*	Tuart	4	43.0		White	Jan-Apr	Dense Tree
Eucalyptus	*marginata*	Jarrah	4	46.0		White	Irregular	Dense Tree

Landscaping Road Verges Using Height Zones

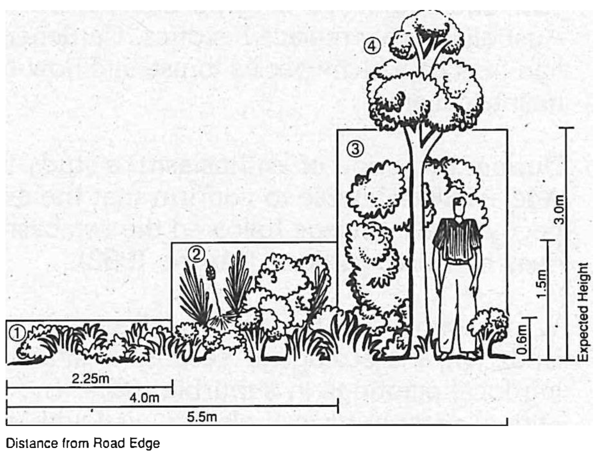


TABLE 4. AVERAGE PROPERTY AND GARDEN CHARACTERISTICS 1982 (MWA, 1985)

Average areas m^2	All users	Bore users	Non Bore users
Block	780	790	770
Verge	113	131	104
Irrigable	530	570	510
Irrigated	410	510	360
Lawn	290	380	250
Garden	120	130	110
Native Garden	70	60	70
Exotic Garden	50	70	40

Note: All areas except block area include road verge.

the Perth Region describes in detail plant habit and distribution. Targeting local authority managers, Sargent (1987) prepared lists by soil type of local species most readily available from nurseries with planting and landscape design guidelines. Recognising that revegetation should be with seeds of local plants, which have evolved to the environment of the district, Seabrook (1987) described the need to establish seed orchards for seed production for local revegetation projects.

Table 4 (MWA, 1985) shows the average area of house lots dedicated to different types of garden in Perth. As can be seen there is considerable scope for increasing the 7.6% of irrigable land dedicated to native vegetation in the garden.

After a period of drought, water restrictions and enthusiasm for Australian native plants in the 1970's, native gardens in the 1980's lost their appeal to some extent. One explanation is that garden design, style and methods did not change; 'natives' from varying climatic, soil and moisture origins elsewhere in Australia simply replaced exotics. Gardeners had no idea which species to use and how to maintain them.

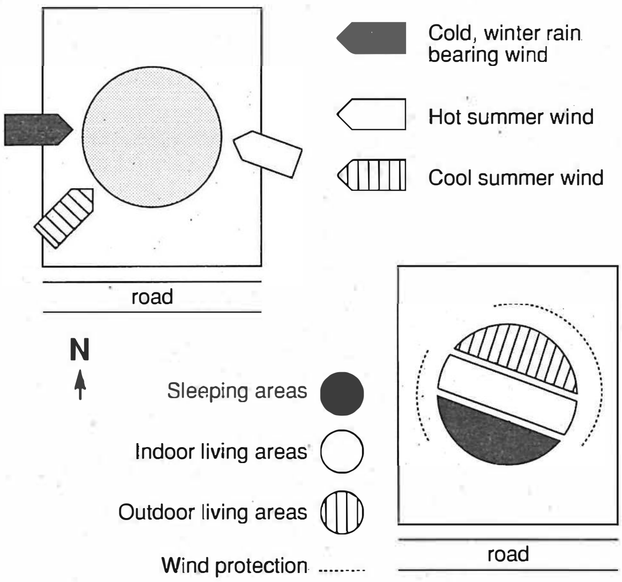
During the period of enthusiasm, a study in Adelaide was unable to confirm that the expected water savings followed the establishment of 'native gardens' (Moore, 1982).

While there are fundamental aesthetic, landscape and ecological reasons for increasing local plantings in suburbia, other (non-native) xerophytes can also do well without supplementary irrigation. Until the 1940's, Perth gardens were planted with hardy species mostly originating from mediterranean climates with a proven track record in drought tolerance, as garden irrigation was uncommon.

In 1987 in Perth's Mosman Park, a small water conserving memorial and heritage garden, established by Mrs F Cullen was planted with cuttings, slips and seeds from plants and gardens which were known to have existed for at least one generation with little or no irrigation. This true heritage garden for Perth provides a style of garden that could be promoted alongside the water conserving local native plants.

3.6 Windbreaks

FIGURE 4a. WINDBREAK PRINCIPLES
(Paolini,1979)



These wind direction diagrams show the general direction of the prevailing year round winds in Perth.

Generally, it is desirable to allow the cooling summer breeze to flow through the indoor living and sleeping areas and the outdoor living areas, excluding as far as possible, all other winds.

The orientation diagram indicates the ideal location for the indoor living areas, sleeping areas and outdoor living areas.

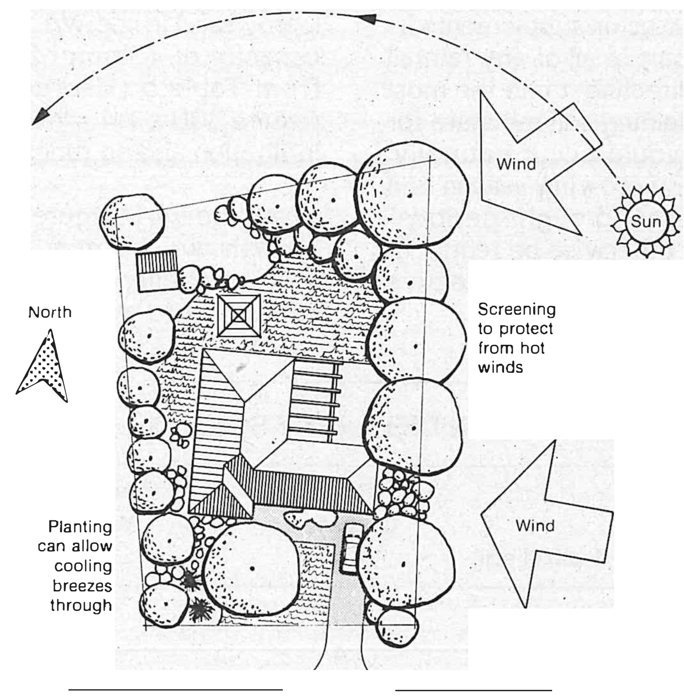
The location of wind barriers shown on the diagram, corresponds to the direction of the hot summer wind and the cold winter winds.

However, as already mentioned, there are many factors other than climatic which must be considered when locating the home and these must be kept in mind when studying the diagrams.

Wind is a major climatic factor causing higher rates of evapotranspiration from plants. Windbreaks can be used to deflect hot drying winds and reduce moisture stress and water loss from plants, see Figure 4b (Schmidt in WAWRC, 1986). Schmidt suggests that windbreaks should be at right angles to the prevailing winds and with an optimum density of 50-60%. Reductions in wind speed up to thirty times the height of the break on the downwind side, and from two to five times on the windward side, can be expected (Ibid).

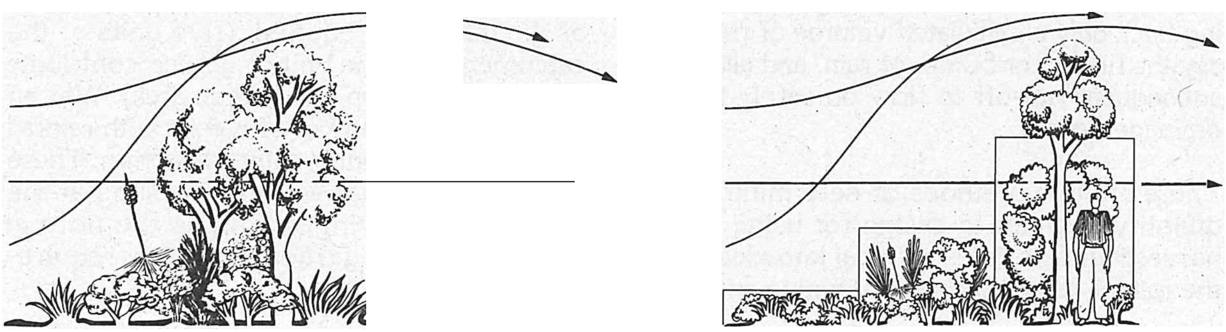
Lists of local plant species sorted by soil type and then into appropriate height zones provide a useful guide to the selection and placement of local plants for use as multiple purpose conservation corridors and windbreaks, see Figure 5 (Sargent, 1987).

FIGURE 4b. WINDBREAK PRINCIPLES IMPLEMENTED (Schmidt,1986)



Modification of microclimate and a corresponding reduction in water use can be achieved through the careful design and placement of windbreaks or other screening elements.

FIGURE 5. WINDBREAKS USING LOCAL SPECIES
(WAWRC,1986; SARGENT, 1987)



4. DESIGN TO REPLACE SCHEME WATER IRRIGATION

Design techniques can be used to replace or augment more conventional sources of irrigation water. In particular the following techniques can substantially reduce scheme water requirements:

1. Water harvesting
2. Access to private water supply
3. Water reuse.

4.1 Water harvesting

Water harvesting replaces or supplements irrigation by collecting part or all of any rainfall run-off on a site and directing it into the most beneficial areas, maintaining soil moisture for longer periods than would occur naturally. This extends the natural growing season and correspondingly reduces 'drought periods' when irrigation might otherwise be required. Good permeable soil is critical to effective artificial water harvesting.

When introducing water harvesting many people have concerns that water impounding structures could lead to flooding. It has to be made clear that water harvesting means holding back only a calculated volume of run-off, say the first 25 or 50mm of rain, and allowing subsequent run-off to flow on safely to the drainage system.

There are two methods of determining the quantity of water to design for using water harvesting. One relies on local knowledge of the rainfall required for germination and new growth. In the Western Australian wheat belt it is colloquially understood as one and a half inches. In the arid pastoral regions where rainfall is unreliable, 30mm is required in summer, 10mm in winter. The second method is to determine the field capacity of the soil on the site and calculate how much rain is required to wet an arbitrary root depth of say 300mm. In Perth sands, with a field capacity of 0.9mm of water per cm depth of soil, this will require 300 x 0.9 = 27mm of rain given total infiltration and no runoff or evaporation. On loamy sand in the WA wheat belt, with a field capacity of 1.4mm of water per cm of soil from Table 5 (George, 1986:39), this will require 300 x 1.4 = 42mm of rain given total infiltration and no runoff or evaporation.

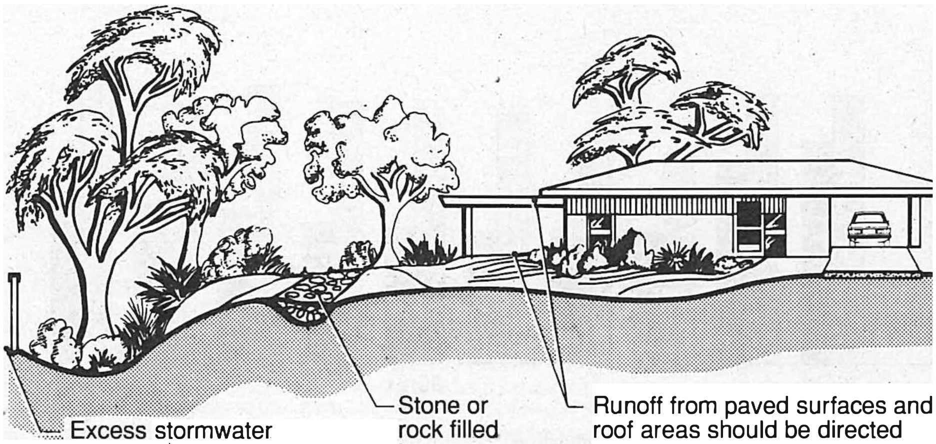
Given the Perth figure of 27mm required for growth we can now determine the catchment multiplier. As falls below 5mm are assumed lost to evaporation, we simply divide the 27mm required by the minimum collectable rainfall of 5mm. Thus in an area where 27mm is required, an area of catchment equivalent to approximately six times the area of the garden is required, (five units of the catchment and one unit of garden contribute to watering one unit of garden area). We can now count the number of weeks with rainfall less than 27mm but greater than 5mm. These are the weeks that water harvesting at the ratio of 5:1 (giving six times the normal rainfall) replace garden irrigation requirements.

TABLE 5. GUIDE TO WATER HELD IN DIFFERENT SOILS (George, 1987:39)

Soil texture (mm of water per cm depth of soil)	Field Capacity	Permanent Wilting	Available Water Point Capacity
Sand	0.9	0.2	0.7
Loamy Sand	1.4	0.4	1.0
Sandy Loam	2.3	0.9	1.4
Sandy Loam + Organic Matter	2.9	1.0	1.9
Loam	3.4	1.2	2.2
Clay Loam	3.0	1.6	1.4
Clay	3.8	2.4	1.4
Well Structured Clays	5.0	3.0	2.0

Note: Figures to be used as approximate guides.

FIGURE 6. WATER HARVESTING (WAWRC, 1986)



Runoff from paved surfaces and roofs can be used to maintain garden and lawn areas.

Water harvesting can be practised at all design levels. Examples are given by Schmidt and Hart in their chapters in *Water Conservation Through Good Design* (WAWRC, 1986).

At the smallest level, the microcatchment waters a single shrub or tree. At the house lot level, run-off from the roof and paved areas can be directed into gardens (Figure 6). Depressed basins in the front and back gardens can be the primary hydrozones growing the higher water consumption plants. If a zero run-off policy is not feasible in a particular area, then excess run-off from the house lot should be led to verge swales. Excess street run-off can be led to local parks or a landscaped drainage system using cul de sac ends, limanim, linear park berms, contour banks and ripping or using ovals for infiltration. Commercial centres, especially the ubiquitous (and either bleak or searing) shopping centre carpark, offer special design challenges for water harvesting engineers and landscape architects.

The Para Hills Paddocks Recreation Area, landscaped by the City of Salisbury, in South Australia and the National Capital Development Commission's pollution control ponds in Canberra are examples of large scale water harvesting. The Para Hills Paddocks disperses large concentrated volumes of urban stormwater with multiple benefits such as providing intensive but natural landscaped community recreation areas (primary hydrozones), irrigation replacement, water quality control and water balance management. The Canberra wetlands detain water in a series of landscaped water treatment ponds to improve water quality before flow to the Murrumbidgee River.

If the full potential for water harvesting design is realised at the house lot and local area level, the problems of regional water balance should be significantly reduced. This hierarchical approach to water harvesting appears to be the key to the success of the Bellevue urban stormwater management strategy described by Deissner (1989), and forms the basis of the Broome Case Study in Water Conservation Through Good Design (RMIT, 1989).

4.2 Access to private water supply

The increase in the number of bores in Perth in the late 1970's during a period of drought, coupled with the introduction of a pay for use water tariff system has drastically and permanently reduced the residential demand for scheme water per house (Figure 7).

However, application rates by bore owners have been shown to be over four times those of non-bore owners (Table 6).

In some suburbs of Perth, near the ocean or the Swan River, overextraction has led to problems of saline intrusion (Water Authority, 1987). In areas close to wetlands overextraction has also led to localised problems in the wetland systems.

FIGURE 7. TRENDS IN WATER CONSUMPTION PER HOUSE (WAWRC, 1988)

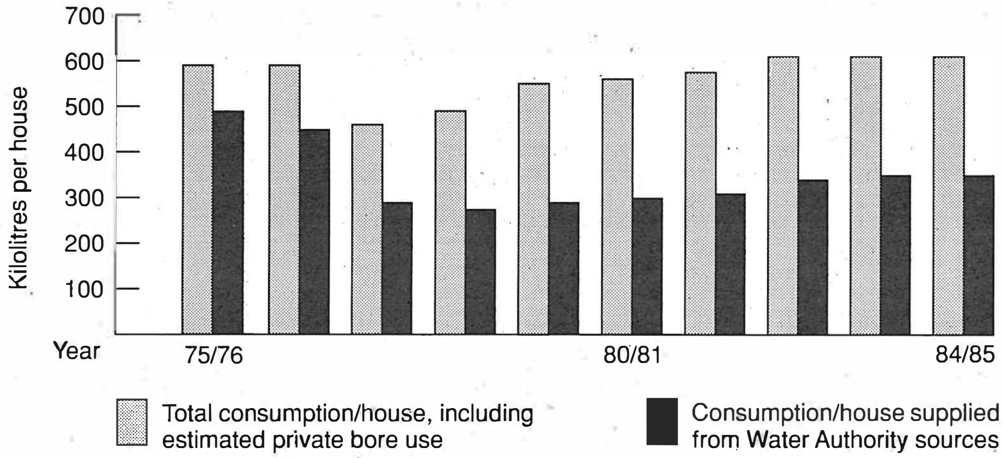


TABLE 6. AVERAGE HOUSE LOT APPLICATION RATES IN PERTH L/day/m² (MWA,1985)

Irrigated Area (m^3)	SCHEME WATER All Users	Bore Users	BORE WATER Non Bore Users	Bore
200	3.85	*	4.04	14.5
200-300	2.60	0.40	3.31	23.8
300-400	1.97	0.59	2.73	12.4
400-500	1.33	0.28	2.30	12.6
500	0.84	0.19	1.58	10.5
Overall	2.01	0.31	3.16	12.7

** Insufficient houses for a reliable estimate.*

The distribution of private bore access is closely related to depth to groundwater (MWA, 1985). The distribution of bore ownership and depth to groundwater is shown in Figure 8.

Where groundwater is very shallow and drains have been constructed to minimise house flooding, use of private bores for irrigation may be desirable at a local and regional level. The reduction in evapotranspiration after clearing, often resulting in a rise in groundwater, would otherwise lead to loss of this water via intersecting drains to the river or ocean.

The enthusiasm of Perth's residents to become bore owners was identified in the Domestic Water Use Study (WAWA, 1987) and is shown in Figure 9.

Clearly the directing of this enthusiasm and tailoring of self supplied water abstraction to local water regions is required.

FIGURE 8. BORE OWNERSHIP BY DEPTH TO GROUNDWATER (WAWA, 1987)

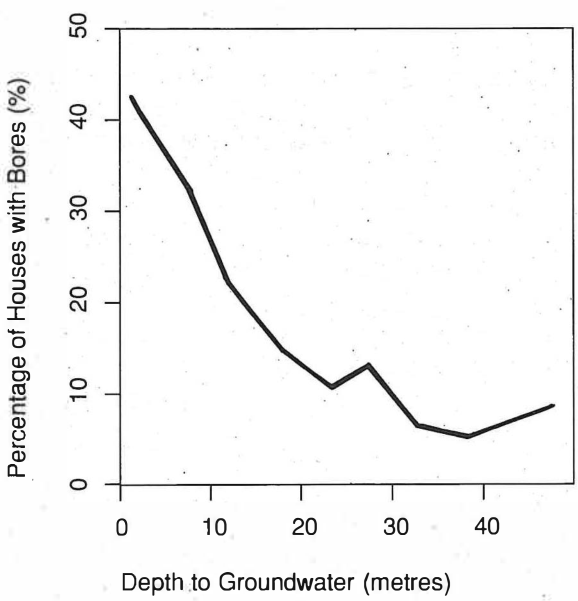
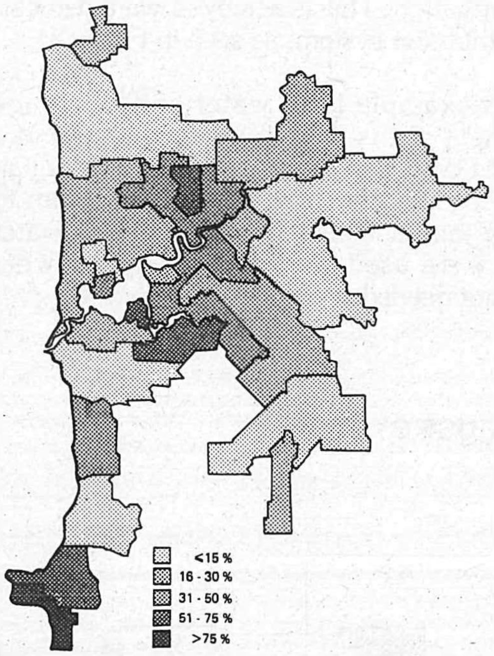
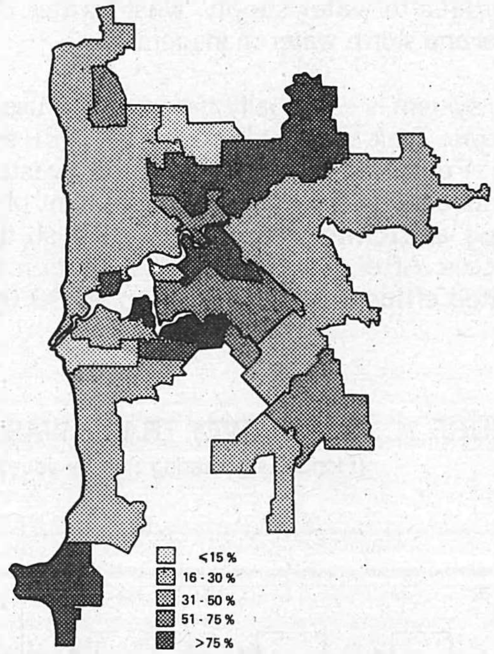


FIGURE 9. BORE OWNERSHIP AND INTENTION TO OWN (WAWA, 1987)



Percentage of households owning a bore in 1982 by primary sampling units.



Expected percentage of households owning a bore by 1987 by primary sampling units, on the basis of intentions expressed in the SEQ.

4.3 Water reuse

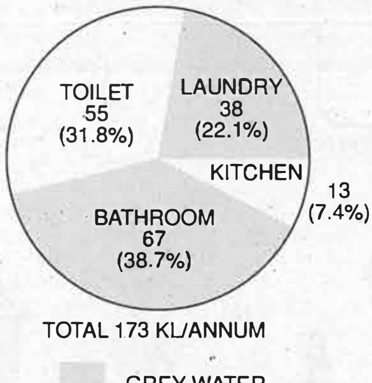
House lot irrigation water from private bores and scheme water can be supplemented by the use of grey water from showers, baths and the laundry (Figure 10). In general, grey water can be used to successfully augment scheme water irrigation on primary and secondary hydrozones at the house lot level. However some soaps and liquid detergents contain Boron which may in some instances be harmful to plants (and humans if used on vegetable gardens) (E&WSD, 1987:31), so this resource is most appropriately utilised on turf areas.

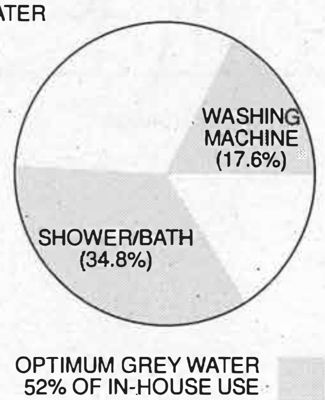
In the regional and local context, Western Australia has significant potential for innovation in the area of water reuse. Although statistically a national leader in this field (WAWRC, 1987:81), enthusiasm for and outstanding examples of the application of this technology are limited.

In contrast in 1988, a Florida engineering company Briley Wild and Associates recognised the potential for water reuse and won the American Consulting Engineers Council Engineering Excellence Award, for a residential development at Breakaway Trails near Ormond Beach in Florida (Lisk, 1988).

FIGURE 10. POTENTIAL FOR REUSE FROM IN-HOUSE USE
(MWA, 1985)

Components of In-House Use



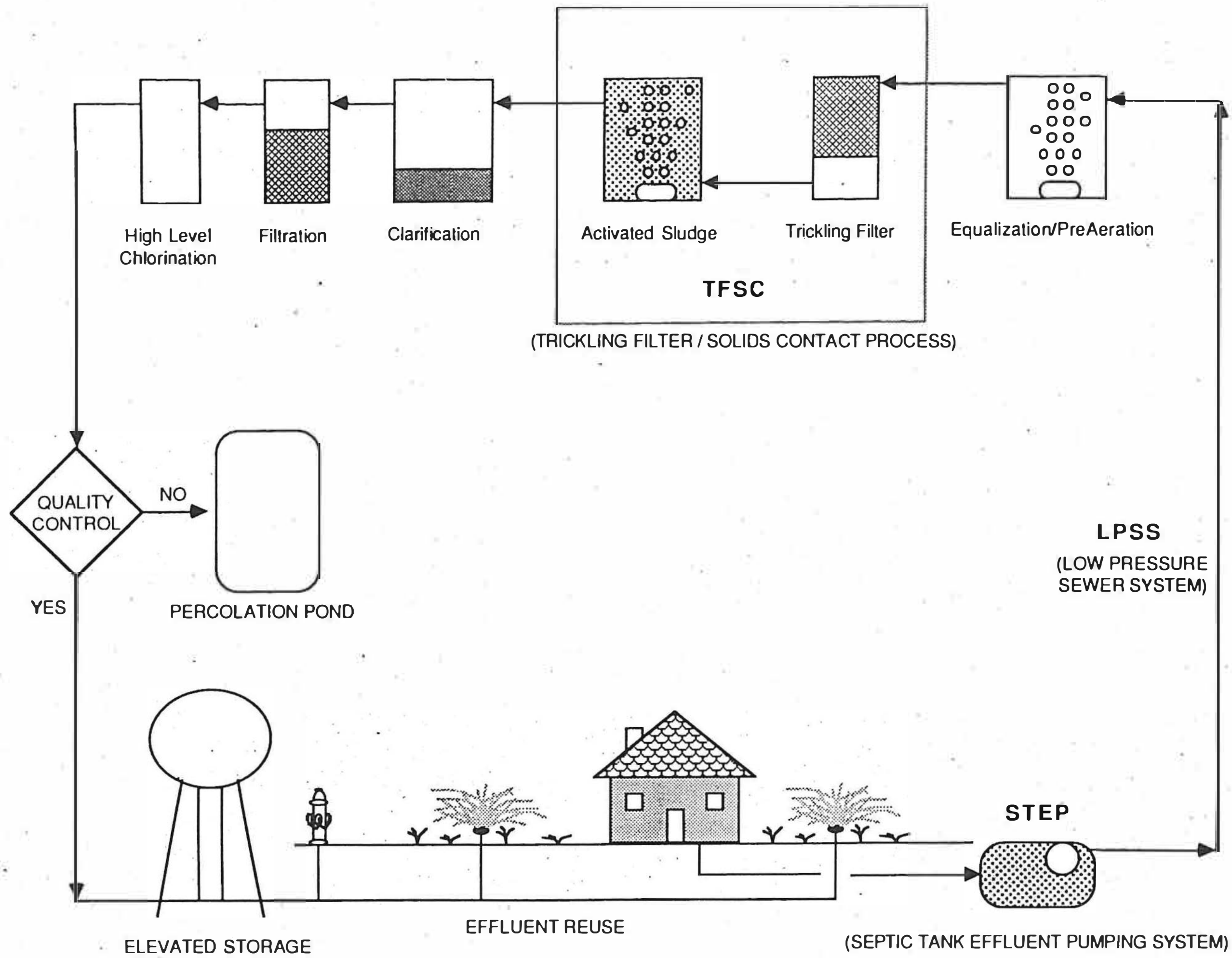


The design for a 715 acre community, housing 3 200 residents, involves an innovative approach to water supply, waste water disposal and storm water management.

The system is essentially based on the use of a Septic Tank Effluent Pumping or STEP system. Following primary treatment, waste is pumped at low pressure to a treatment plant using a trickling filter/activated sludge process. After filtration and disinfection the treated effluent is transferred to a 200 000 gallon elevated storage tank where it becomes the supply for fire protection and common area irrigation. This is achieved via a dedicated distribution system, as seen in Figure 11.

In this example both water and sewerage treatment plants were built smaller and at a reduced cost. The septic tank also substantially reduced organic load allowing the plant to be one third smaller. Smaller diameter water pipes were used, and deep gravity sewers were not needed.

FIGURE 11. BREAKAWAY TRAILS WASTE WATER REUSE SYSTEM
(Florida Engineering Society Journal, 1988).



5. DESIGN FOR WATER QUALITY MANAGEMENT

The Australian Environment Council (1987) suggested that reducing nutrient loads from diffuse sources requires consideration of land management practices within a total catchment framework. Controls suggested included avoidance of erosion prone areas, tree planting, streamside buffers, source detention, grassed waterways, and wet and dry detention basins.

Stormwater management at the residential development at Ormond Beach in Florida (Lisk, 1988) was based on the need to clean up stormwater before discharge, using wetlands, detention ponds and lakes. Similar use of artificial ponds for stormwater quality improvement and other beneficial uses including recreation has also been implemented in Canberra, Australia, by the National Capital Development Commission (Sanders and Toon, 1988; NCDC, undated).

Significant sized vegetated buffers adjacent to wetland basins and channels are an important tool for water quality management but also provide valuable wildlife habitat and recreational opportunities (Feilman Planning Consultants, 1987).

Identifying improved turf management as an avenue of reducing nutrient loss at its source has led to the initiation of studies by the Environmental Protection Authority and Local Authorities mentioned in Section 3.4.

HILL

Children playing in the vegetated buffer of Forrestdale Lake

6. DESIGN FOR WATER BALANCE MANAGEMENT

Understanding of Perth's water balance has significantly increased following a major study of groundwater management in Perth (Cargeeg *et al*, 1987; Figure 12). This significant study made 18 conclusions and 10 recommendations regarding the management of Perth's water balance, many of which are relevant to this report. The recommendations have been attached as Appendix A.

Previous papers on water conserving garden design have concentrated on understanding the water cycle at any particular site. The following examples of design approaches also incorporate an appreciation of water balance at the regional, local area and house lot level.

At the regional level Singleton (1989), in the review of Perth's Corridor Plan, discusses how the development of Perth must be shaped by an understanding of the regional water balance. Furthermore, traditional design was identified as contrary to long term responsible use of the region's water resources. Approaching issues at personal, residential and urban design level, Singleton noted the necessity for and the opportunity to implement innovative design based on water conservation.

The Environmental Protection Authority of Western Australia, in its response to the Corridor Plan Review, also endorsed this approach and proposed design criteria for water conservation as guidance towards required changes. This alternative approach to urban development includes the objectives of water conservation, wetland management and water balance issues (EPA, 1989). Houses distributed in clusters on high areas, not subject to inundation, and the judicial cutting and filling of low land to increase the area of high land, leads to benefits from the reduced risk of inundation and probable views over vegetated wetland areas. It has also been suggested that urban forestry, covering between 20% and 30% of low land including land alongside channels, might be used as a money making form of water quality and water balance control (Bartle J, 1989, pers comm).

FIGURE 12. SCHEMATIC DIAGRAM OF PERTH'S WATER CYCLE (Cargeeg *et al*, 1987)

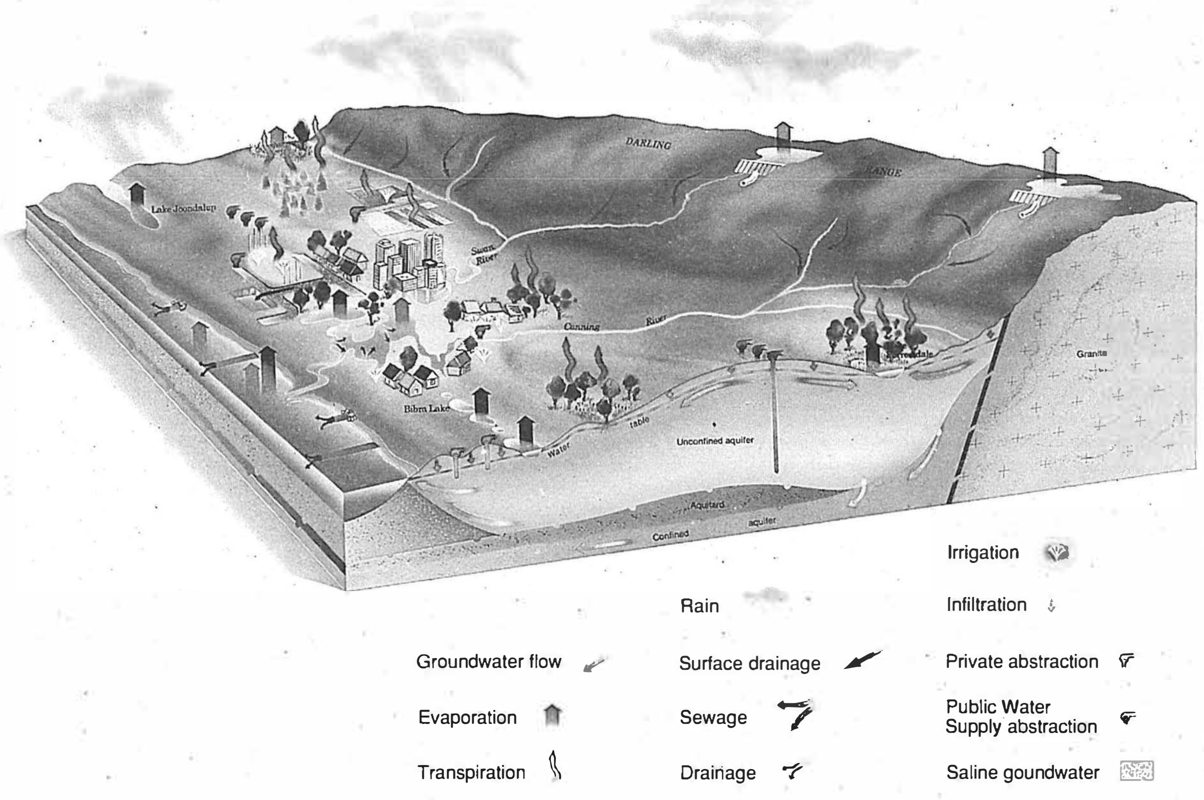
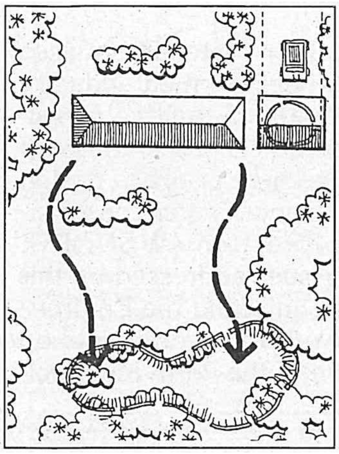


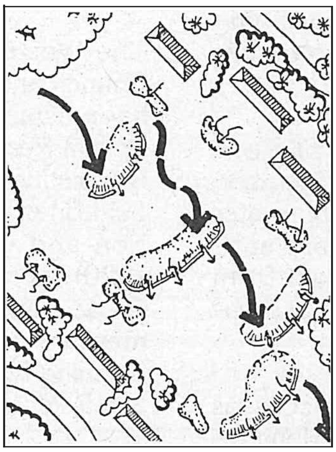
FIGURE 13. INNOVATIVE PROPOSAL FOR THREE TIERS OF RECHARGE AT BROOME

Tier One-Home or House Lot Recharge



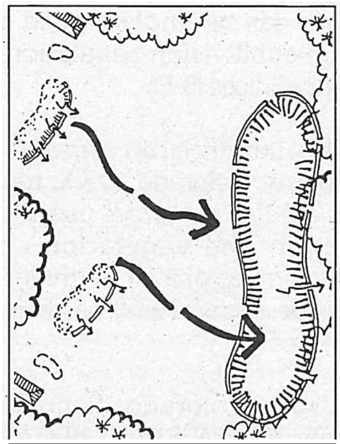
Tier One-*Water harvesting at the home is a starting point for design and layout. Water harvesting into recharge basins at the home reduces overall domestic water use and extends the capacity of the existing water supplies.*

Tier Two-Cluster or Local Area Recharge



Tier Two-*Recharge basins which service the home cluster (groups of single family homes or clusters of multi- density housing) constitute the second tier in the water management strategy. This design approach will help in moderating runoff peaks in minor storm events and have the effect of greening the suburbs.*

Tier Three-Neighbourhood Recharge



Tier Three-*Natural basins in low lying areas collect water from swales servicing the overflow from cluster of local recharge basins. They enable fresh water lenses to form below the basins in the Broome sandstone. The added groundwater resource, if properly managed, can be utilised for community purposes.*

A successful prototype design has been implemented to maintain the water balance at the local area level at Pretty Pool in Port Hedland. Located on porous coastal dune sand ideal for water harvesting and infiltration, the project has confirmed how difficult it is to manage large volumes of water once generated from large drainage catchments in a cyclone prone area.

Consulting engineer responsible for the innovative drainage in the subdivision, R. Wittenoom, concludes that as a general rule in normal rainfall events water should be kept where it falls at the house lot level (1989, pers comm). Furthermore, even with the particularly favourable soil conditions at Pretty Pool, treatment of the runoff from a catchment of larger than 20 house lots and associated roads became impractical and too expensive.

Diessner (1989) describes how an American city tackled urban stormwater to reduce flooding and revive polluted and degraded streams using the management objectives of water balance. The City of Bellevue in Washington manages the quality and quantity of water runoff at the individual lot level. A rating system based on generation of runoff and development regulations on landuse and construction achieve this, with floodplains, wetlands and steep slopes protected against development. This containment shows how water harvesting and water balance at the house lot level can be realised.

Another example of this approach is given by a Royal Melbourne Institute of Technology Landscape Architecture Group led by Jim Sinatra (RMIT, 1989). In a draft report titled *Broome Western Australia: A Case Study in Water Conservation Through Good Design,* a three tier water harvesting strategy (Figure 13) was proposed as a design tool to return regional water balance to pre-development conditions.

It was proposed that infiltration from linked and vegetated water harvesting basins at the regional, local area and house lot level would contribute to overcoming Broome peninsula's water balance and saline intrusion problems. This would also maintain the water regime of existing seasonally inundated areas and vegetation and reduce sediment transport.

7. TOWN PLANNING REGULATION AND WATER CONSERVATION

Four examples of how water conserving design can be implemented by town planning and subdivision regulations are attached as Appendices B-D.

The subdivision regulations of El Paso County, Colorado, USA, require consideration of aquifer recharge, use of non potable water supply and vegetation cover before subdivision approval is given. An extract from Sanders *et al* (1982) has been attached as Appendix B.

Also in Colorado, Sanders (Ibid) discusses how Aurora's town planning regulations require soil amendment before lawn development and places restrictions on the absolute size of lawn areas.

Recent reviews of major urban development projects proposed on Perth's groundwater mounds and their probable effects on wetlands and future water supplies has led to the pulling together of these design techniques into proposals for town planning policies and designs (Hedgcock and Moritz, 1988).

The Western Australian Water Resources Council and the urban development industry have established a Water Sensitive Urban Design Research Group. This Research Group is assisting the development of urban design guidelines for water balance, water conservation and wetland protection (WSUDRG, 1990). Some of the issues addressed by this Group have been recognised in the Environmental Protection Authority comments on planning for the future of the Perth Metropolitan Region (EPA, 1989; Appendix C).

An interim statutory town planning policy has been framed by the Department of Planning and Urban Development of Western Australia (formerly the State Planning Commission) to ensure that future rezoning of land for urban development and subsequent subdivision, particularly in water sensitive areas of Perth, incorporate such design principles (SPC, 1989). A copy of this policy has been attached as Appendix D.

Low water garden landscaping utilising local native plants.

8. DESIGN FOR THE FUTURE: THE LOW WATER GARDEN

In this report it has been proposed that water conserving design needs to be applied in both home gardens and suburban open space. Although a new field, it is developing rapidly because it offers considerable immediate and long term economic and environmental benefits from its implementation.

The promotion of water conserving design is an essential part of the Water Authority of Western Australia's water conservation programme. The full potential for water conservation at the house lot will not be achieved unless subdivisions are designed with a clear understanding of the site's water cycle and water balance. To implement water conserving design within the house lot, local area and region, practitioners require and must seek pertinent site information on soils, species selection, opportunities for irrigation replacement and reduction, other aspects of turf management including nutrient runoff and problems of water balance.

In Western Australia these issues have been incorporated into an interim town planning policy to direct town planning structure plans and subdivision designs in water sensitive areas. This statutory approach is being combined with design guidelines for future developments to address water conservation, water balance and wetland protection.

All of these issues can be brought together in the concept of the Low Water Garden.

The Macquarie Dictionary gives three apt definitions of a garden:

- 'A plot of ground devoted to the cultivation of useful or ornamental plants'. All plants are useful or ornamental in one way or another, even if only to take carbon and give oxygen.

- 'A piece of ground, or other space, commonly with ornamental plants, trees, etc., used as a place of recreation'. All plants are recreational, even if only to rest the eye against the hardness of the built environment. Turf is especially recreational.

- 'A fertile and delightful spot or region'. If only all urban areas were so! We believe they could be, if water conserving design using the principles, approaches and techniques described in this paper were used throughout the built environment.

The term Low Water Garden was applied to a home garden designed for Karratha in an urban water conservation programme (see cover illustration, this report). This programme aimed to protect the town's source of water, the Millstream aquifer whose springs supply an oasis on the Fortescue River, in the Millstream-Chichester National Park.

The detailed features of the Low Water Garden are outlined in Edgecombe (1983), Nicholson and Edgecombe (1986), Forests Department (1983) and WAWRC (1987).

The principles and techniques employed in the Low Water Garden apply equally to all three levels of water conserving design; the house lot, the local area (see illustration opposite page) and the region. Their relevance at all levels and across the State has been stressed throughout this paper. We believe this approach, summarised in Table 7, will make our urban areas sustainable gardens in each sense of the Macquarie definition.

Due to our geographical and climatic conditions, technical expertise and historical traditions of innovation, Australian practitioners are well positioned to develop and become leaders in this field of design and technology. Water managers, environmental planners, landscape architects, urban developers, town planners and engineering consultants are strongly encouraged to consider site specific and innovative water conserving designs when urban areas are being planned. Water sensitive design and reduction of water demand in our cities and towns, suburbs and homes will then set the foundations for a water balanced future.

TABLE 7. THE LOW WATER GARDEN: DESIGN RESPONSE TO WATER CONSERVATION

DESIGN RESPONSE	HOUSE LOT	LOCAL AREA	REGION
Patterns of housing	• Smaller blocks as private open space becomes local area and regional space.	• Houses within remnant vegetation or clusters of houses or units on high ground overlooking wetlands in green belt.	• Structure plans topographically determined and compatible with regional water balance objectives.
Patterns of open space	• Local area open space, more important for recreation than on conventional house lot. • Paving or turf used in high use areas. • Infiltration areas on house lot linked to local area drains.	• Drains creeks, floodplains and other wetlands in local open space. • Remnant vegetation protected. • Local parks part of linked open space system.	• Open space used to satisfy regional user needs, resource management and landscape integrity. • Conservation corridors linking island reserves.
Areas zoned by intensity of human use: To conserve water 'areas are downzoned' towards elemental zone Primary Hydrozone Secondary Hydrozone Minimal Hydrozone Elemental Hydrozone	 • Lawn and vegetable garden. • Exotics garden. • Native garden. • Remnant vegetation.	 • Park areas and civic flowerbeds. • Shrubberies. • Limited irrigation 'dry' parks. • Remnant vegetation, conservation corridors.	 • Ovals, major parks. • Horticultural areas. • Grazing areas. • Remnant vegetation, conservation corridors.
Soil amendment need for surface protection, water infiltration and storage.	• Improve soil for lawn, vegetable and exotic garden areas.	• Improve soil for park, flowerbeds and shrubberies.	• Improve soil for ovals and horticultural areas.
Turf Management well designed turf areas have efficient management of water and fertilizer.	• Water efficient species. • Good irrigation and fertilizer practice.	• Water effecient species. • Good irrigation and fertilizer practice.	• Water efficient species. • Good irrigation and fertilizer practice.
Local native plants retention or restoration of remnant vegetation where possible, replacement with local native vegetation adapted to soils and climate when landscaping.	• Front garden and wind break.	• Dry parks. • Conservation corridors, road verges, drainage lines, other utility corridors.	• Bush reserves, wetlands, drainage lines, conservation corridors.

Windbreaks reducing wind speed and evapotranspiration.	• Around house lot.	• Around parks.	• Around city (e.g. Broken Hill).
Water harvesting rain replaces irrigation.	• Off roof, paving onto turf, vegetable and exotics garden.	• Off roads, landscaped swales, compensating basins in parks.	• Runoff regime allows infiltration and maintains contribution to regional water balance.
Private water supply irrigation replacing high quality scheme water.	• Increased number of houses owning or sharing backyard bores, but with lower application rates.	• Increased number of parks irrigated by private bore.	• Ovals, parks and horticultural areas.
Waste water irrigation replacing high quality rainwater.	• Irrigate lawn and garden with grey water.	• Innovative reclaimation at a suburb scale e.g. Ormond Beach, Florida U.S.A., irrigated local area open space from local treatment plant.	• Innovative water reclaimation for irrigation of ovals and horticultural land from water treatment plant.
Water quality management reduce nutrients and sediment transport.	• Dished grass basins for infiltration in backyard, linked with vegetated local area swales.	• Vegetated swales linked to artificial basins acting as detention basins and pollution control ponds. • Prepare nutrient and irrigation management plan for parks.	• Wetlands including streams and drains to be incorporated in vegetated open space (conservation corridors) acting as biological filters and pollution control ponds. Prepare nutrient and irrigation management plan for ovals and horticultural properties.
Water balance management maintain acceptable water regimes, maintaining wetland ecosystems.	• Infiltration in dished areas on house lots with overflow linked to swales. • Trees and bores used as part of water balance management effort to part compensate for decreased evopotranspiration.	• Houses located on high ground. • Wetlands water table rise allowed for in open space. • Trees and irrigation from bores used as part of water balance management effort to part compensate for changes in water balance as recommended in local water resource management strategies.	• Wetlands including streams and drains to be incorporated in vegetated open space, conservation corridors detaining water and increasing infiltration. • Maintain water storage for possible public or private use.
Town planning regulation and water sensitive design.	• Water sensitive building codes.	• Incorporated in development control policies and reflected in structure plans of State and Local Authority Town Planning.	• Urban expansion and development control policies compatible with maintenance of wetlands and efficient management of water resources.

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10. APPENDICES

APPENDIX A.

Recommendations of the Perth Urban Water Balance Study.

An Extract from Cargeeg *et al*, 1987.

The Steering Committee makes the following recommendations.

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

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

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

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

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

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

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

8. Further investigation should be undertaken by the Water Authority, in conjunction with the Geological Survey, the Department of Conservation and Land Management the Environmental Protection Authority and relevant local government authorities, to determine the need for local management strategies in risk areas specifically investigated during this Study.

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

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

APPENDIX B.

Examples of how conserving design can be implimented by town planning and subdivision regulation, from Sanders et al, (1982:12).

El Paso, Colorado - Water Conservation through Town Planning Regulations.

An example of how town planning regulations were used in El Paso County, Colorado to influence design. Their ordinance states:

'All subdivision design shall take into consideration the importance of water usage for the well-being of the region and the development of effective aquifer recharge capabilities. Planners and subdividers shall consider the applicability of nonpotable water as an irrigation source, the development of ponds and catchment basins, and the effect of groundcover modification on aquifer recharge capability.

1. Use of large areas of artificial groundcover or groundcover not indigenous to the region shall be discouraged, except in cases where a plan is submitted to use non-potable water as a primary irrigation source or in cases where such groundcover can be proven to be suited to the pre-existing natural conditions.

2. Subdivision design, lot design, and site design shall incorporate, whenever possible, the use of vegetation suited to the natural climatological and soil conditions of the area in which the subdivision is located.'

Aurora, Colorado - Soil Amendment for Turf through Town Planning Regulations.

Aurora, Colorado, has taken another approach with town planning regulations to ensure that soil is amended before installing or enlarging turf.

'It shall be unlawful for any person, firm, public entity, or corporation, either for profit or nonprofit, using water supplied by the Aurora water supply delivery system to install or develop any lawn, turf, or sodded area, without first having conducted soil preparation and obtained a permit from the Director of Utilities of the city of Aurora, for such installation or enlargement as is provided herein.

The ordinance defines soil preparation as, 'the introduction of organic matter, humus, or other similar materials to native soil to increase the water-holding capabilities of such soil'. The city also offers suggestions on how the various types of soils in the area may be prepared for planting. This information is available along with an explanation of the ordinance's requirements.'

The absolute size of lawn areas are also restricted:

'For areas covered by planned unit developments, where the underlying zone is not R-A, R-E, R-O, R-1, or R-1A, and for all planned community zone districts residential planning areas designated by the General Development Plan to have 6.0 units per acre or more; such development may devote up to fifty percent (50%) of the required forty-five percent (45%) open space within the development to lawn, turf or sodded area.

For all other residential zone districts, including planned community zone district planning areas with less than 6.0 units per acre; for lots with lot areas up to and including 7 000 square feet, 2 000 square feet plus thirty percent (30%) of the increment of the area which exceeds 2 000 square feet may be devoted to lawn, turf, or sodded areas; for lots with areas exceeding 7 000 square feet, but having no more than 17 000 square feet, 3 500 square feet plus fifteen percent (15%) of the increment of the area which exceeds 7 000 square feet, may be devoted to lawn, turf, or sodded areas, up to a maximum of 5 000 square feet; for lots with area exceeding 17 000 square feet, fifty percent (50%) of the lot area not used for structures or parking may be devoted to lawns, turf, or sodded areas.

APPENDIX C.

Urban Design Considerations For Water Conservation.

Extract from EPA (1989) 'Comments on the Planning of The Future of the Perth Metropolitan Region, Appendix B'.

URBAN DESIGN CONSIDERATIONS FOR WATER CONSERVATION
(NOTE: Partly derived from a draft policy for water sensitive residential design - Urban Design for Water Conservation Research Group)

- BROAD OBJECTIVES FOR WATER CONSERVATION IN REGIONAL URBAN DESIGN

- ensure that the necessary environmental information is obtained and analysed by developers, in order to achieve integration of land and water planning;
- ensure that adequate plans are prepared showing appropriate urban form, density, landscaping and infrastructure necessary to achieve water sensitive design;
and
- ensure that developers adequately consider the future management responsibilities, strategies and implications for water sensitive design features.

- ENVIRONMENTAL INFORMATION NEEDS FOR ACHIEVING WATER CONSERVATION OBJECTIVES IN URBAN DESIGN

The following information should be seen as part of the site evaluation process and will enable design options to be identified on the basis of ongoing water management requirements.

Proponents should be required to identify:

- the water balance of the locality and its relationship to the regional water body;
- the expected groundwater rise associated with clearing and urbanisation both on and off the subject site;
- the principal landscape components occurring on the site including:
  (i) wetlands, sump lands, damp lands and associated vegetation;
  (ii) streams, gullies and drainage lines;
  (iii) existing or proposed conservation reserves;
  and
  (iv) areas of remnant vegetation
- the significance of these components for conservation and recreation and/or drainage and the establishment of criteria to protect their integrity;
- groundwater availability on the site and the present water quality characteristics including nutrient levels. The distribution of soil types and their infiltration characteristics; and
- the extent of buffer zones around wetlands to accommodate flood storage, nutrient stripping, conservation and recreation.

- DESIGN CONSIDERATIONS TOWARDS ACHIEVING WATER CONSERVATION

The following design principles are intended to assist the development of design solutions associated with determining an appropriate urban form, density, landscape and infrastructure. The application of these principles will be site specific and will be guided by the evaluation of the environmental information obtained for the site.

- Maximise *in situ* recharge in situations where run off is unpolluted and soil capacity permits.
- Stormwater drainage systems to be designed in a manner that enhances the environmental quality of the site.
- No direct drainage or stormwater discharge to natural wetland systems. Associated sedimentation traps and vegetation buffers to be designed to achieve nutrient stripping.
- Minimise the negative impact of possible nutrient enrichment.
- Where appropriate public open space should be designed, developed and managed using Xeric landscape principles.
- The boundaries of public open space areas incorporating wetlands to be planned to incorporate vegetation nutrient stripping buffers.
- Urban form and density to be designed in a manner that reduces private open space water demands.

- SPECIFIC DESIGN FEATURES RELEVANT TO WATER CONSERVATION AND WATER HARVESTING PRACTICE (examples only)

- Use of porous pavements for roads and carparks to retain water for slow discharge, and the use of other techniques for water retention.
  Identification of soil types and infiltration characteristics.
  Use of flush edge kerbing on appropriate soil types.
- Use of grassed or vegetated swale drains on the side of the road.
- Increase of unit density by:
  1. Reduction of block size to (say) 500m³
  2. Medium density home units.
- Reduction of frontage width to reduce area of road and verge.
- Retention of native vegetation where possible and use of local or water efficient species for landscaping. Zonation of species in the garden by water requirements.
- Identification of volume of recharge basin required on different soils to retain and recharge 80% (say) of all rainfall events for:
  (i) one house and associated impervious areas (e.g. drives);
  (ii) ten houses and associated impervious areas (including roads);
  (iii) one hundred houses and associated urban areas;
  and
  (iv) whole drain catchment.
- Restriction of the area of impermeable surfaces on house blocks to allow for required on site recharge.
- Redirection of all runoff from paved areas into lower garden beds.
- Location of local recharge basi in cul-de-sac ends, roundabouts, local open space. Design of shallow sloped multiple use recharge basins with volume calculations incorporating infiltration ability (e.g. if grassed x cubic metres volume, if totally landscaped y cubic metres volume). Basins planted with local species to minimise maintenance costs and water requirements.
- Linkage of local recharge basins with grassed or vegetated swale drains. Inclusion in public open space. Integration of drains to carry out drainage functions in very wet years.

- When piped stormwater drains are required use 'leaky pipe' system or alternatively use gully sumps with unsealed base below drain invert level to allow recharge from a significant number (say) 80% of rainfall events.
- For nutrient management of surface runoff, consideration of the opportunities for using nutrient stripping wetlands prior to discharge of stormwater into significant water bodies.

- In Perth, climate amelioration should be considered as an essential part of planning the built environment and can significantly influence water demand and water usage patterns. Some techniques which may be applied include the following:

- Appropriate siting;
  Correct orientation; Canopy amelioration (reduction of glare and radiant heat by tree planting);
- Shadow effects;
  Night cooling (by means of designed planting and microjet irrigation);
- Wind channelling;
- Transpirational cooling of air;
  Consideration of the heat-sinks and reflective qualities of paved surfaces and appropriate shading;
- Dust control through planting.

APPENDIX D.

Planning Considerations in the Metropolitan Region for Sources of Public Water Supply and Sensitive Water Resource Areas.

Extracted from State Planning Commission (1989), Policy No. DC 6.3.

BACKGROUND NOTES

1. This Policy Statement reflects the growing awareness within the community that water is a scarce resource and needs to be managed with care. It also recognises the fact that Perth's fresh water sources are extensively used for public and private water supplies and support the natural environment including many wetlands and river systems.

2. Some land uses can result in changes in local hydrology, the pollution of surface and groundwater resources, or excessive water abstraction resulting in:

   - reduced water for public and private water supply;
   - wetlands drying up, overfilling or becoming polluted;
   - increased groundwater salinity adjacent to the ocean and river;
   and
   - increased costs of public and private water supplies.

   While the risks are greater from industrial uses, waste disposal and unsewered development, any intensification of land use can impact on water resources. Through rezoning, subdivision and development approval procedures, there is an opportunity to consider and take account of water conservation in regional planning and local design.

3. A 'Draft Policy for Water Sensitive Residential Development' was recently prepared for the Western Australian Water Resources Council by a working group convened by the Council. Following Council considerations the Minister for Water Resources requested the Minister for Planning to refer the Draft Policy to the State Planning Commission with a suggestion that the policy be considered as an interim policy for adoption by the Commission. The following policy is based on the broad principles foreshadowed in the draft policy and addresses those matters within the purview of the Commission.

1. INTRODUCTION

1.1 The climate of southwest Western Australia is characterised by mild wet winters and hot dry summers. This climate, coupled with a moderate rainfall has resulted in few perennial rivers. Further, widespread clearing of land for agriculture in the hinterland has caused an increase in the salinity of larger river systems. Only the shorter rivers and streams of the mainly forested Darling Ranges can be used for water supply without costly treatment. However, the sandy coastal plain contains substantial reserves of shallow unconfined groundwater and these are extensively used for both public and private supplies. These reserves also support a variety of natural environments, including many wetlands of great significance to the preservation of the region's flora and fauna.

1.2 The protection and conservation of the region's water resources are therefore important considerations in planning for future land use. The Commission will accordingly take into account the impact of proposed land use changes on water resources and on wetland systems in assessing development proposals and planning schemes.

2. APPLICATION OF POLICY

2.1 This policy applies to proclaimed and proposed Catchment Areas and Water Reserves, Public Water Supply Areas and Undergroung Water Pollution Control Areas wholly or partly in the Metropolitan Region (as shown on Figure 1). The policy may also be applied, as required:

- to other areas having particular water resource management problems;
- where a proposal is of a scale likely in the opinion of the Commission to impact on environmentally significant surface or groundwater features such as wetlands and rivers.

2.2 In determining the relevance of water issues the Commission will have regard to the Water Authority of Western Australia's policies for water resource protection and management and allocations to beneficial uses as set down in strategic water plans published by the Authority.

2.3 In making decisions the Commission shall have regard to advice from:

- the Water Authority in respect to the need to apply the policy, on the proposed or existing arterial drainage system as determined in consultation with local authorities, on the desirability of such drainage systems and their impact on the water balance of wetlands, and on the likely impact of land use proposals on the quality and quantity of water resources;

- the Environmental Protection Authority, CALM and the Waterways Commission in respect to the need to apply the policy, the identification of important wetlands and river systems and provisions to minimise their nutrient enrichment, and any additional environmental assessment requirements;

- the appropriate local authority to ensure that proposals for the design and development of open space within subdivisions adequately take account of water resource management considerations such as minimising water usage, preserving and enhancing natural wetland values and facilitating the conservation of stormwater.

2.4 The Commission will apply this policy when considering regional or district planning schemes or their amendment and in determining and imposing conditions on subdivision applications. The Commission may require the provision of information such as a water resource management plan, incorporating consideration of drainage and to satisfy the Commission in respect of the water resource protection impact of planned development on water resources.

3. POLICY OBJECTIVES

- To heighten awareness amounst planners, developers and public authorities of the need to plan for water conservation;
- To avoid development that will unacceptably diminish the quality and quantity of water resources and unacceptably modify the ecosystem;
  To ensure that subdivisional designs and servicing arrangements:
  - make provision for water conservation;
  - avoid pollution of resources;
  - minimise adverse alteration to the water balance;
  and
  - minimise the destruction by draining or filling of existing wetlands.

4. POLICY MEASURES

4.1 The Commission will not support the zoning of land or subdivision applications where in its opinion:

- there is an unacceptable risk of pollution to surface or groundwater;
- the water balance is modified to the detriment of the environment;
- water resources are likely to be diminished to the detriment of public water supplies;
  and
- the proposal is inconsistent with land and water management plans and policies for the area.

4.2 In considering proposals for the zoning of land the Commission shall take into account the impact the proposed land change will have on the water regime of the area,
and in particular:

- the quality and quantity of groundwater;
- any permanent or seasonal wetland or sensitive environmetal area;
- any natural water course or drain.

4.3 In considering proposals for the zoning of land the Commission shall take account of and may require that evidence, such as a water resource management plan and a structure plan for the locality, is available to demonstrate:

- the identification of valuable ecosystems and the management measures proposed which will conserve them;
- the extent to which the design of open space, lots and the road and drainage systems shown on an accompanying structure plan will minimise any adverse effects to the required local and regional water balance;
- the extent to which town planning provisions or environmental controls will be available to control detrimental impacts on water resources.

4.4 In its assessment of subdivision proposals the Commission shall have regard to the extent to which private open space water demands are likely to be managed by:

- the urban form and density proposed;
  the design of stormwater drainage systems;
- *in situ* recharge.

4.5 In approving subdivision applications the Commission will seek to ensure that resulting development will not prejudice the integrity of the water resource and will aim to secure within public open space areas:

- compensating basins for flood storage and dispersion suitably designed to provide environmental benefits as artificial wetlands or recreational areas;
- nutrient stripping buffers adjacent to wetlands;
- remnant vegetation and areas which can be developed using dry landscape principles;
- wetlands which have been identified as being worthy of conservation in as near to their natural state as possible;
  and
- adequate floodways, water courses or swales for containing extreme flood events without property damage.

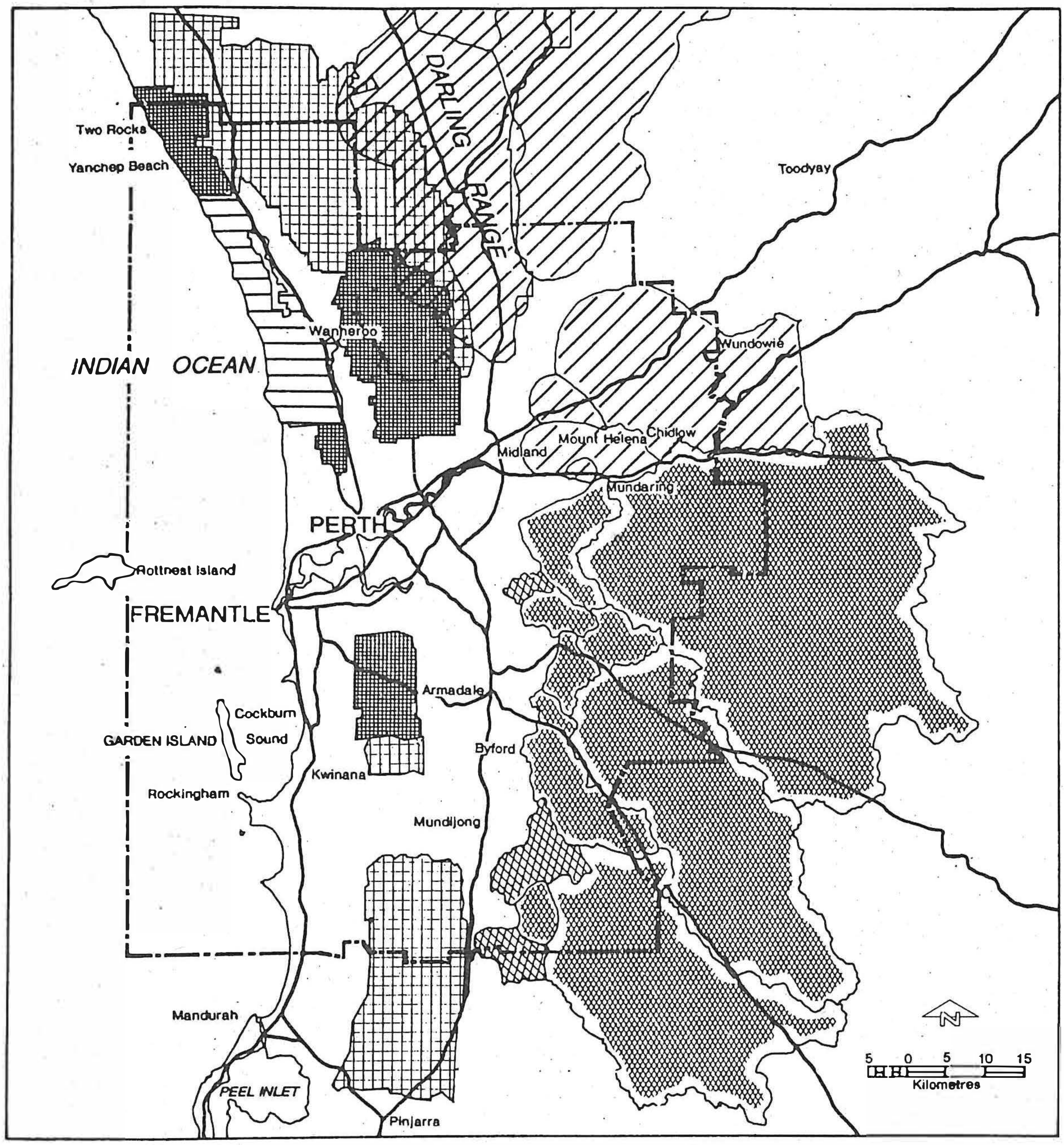

Figure 1 PUBLIC WATER SUPPLY AREAS*

SURFACE WATER

- Proclaimed and used for public water supply
- Proclaimed with plans for future public water supply
- Potential for public water supply but not proclaimed
- Areas not currently identified as having potential for public water supply
- MAJOR ROAD

GROUND WATER

- Proclaimed and used for public water supply
- Proposed to be proclaimed for public water supply
- Potential for public water supply but not proclaimed
- Areas not currently identified as having potential for public water supply
- METROPOLITAN REGION BOUNDARY

**Figure as published by State Planning Commission in 1989. New Boundaries now apply.*