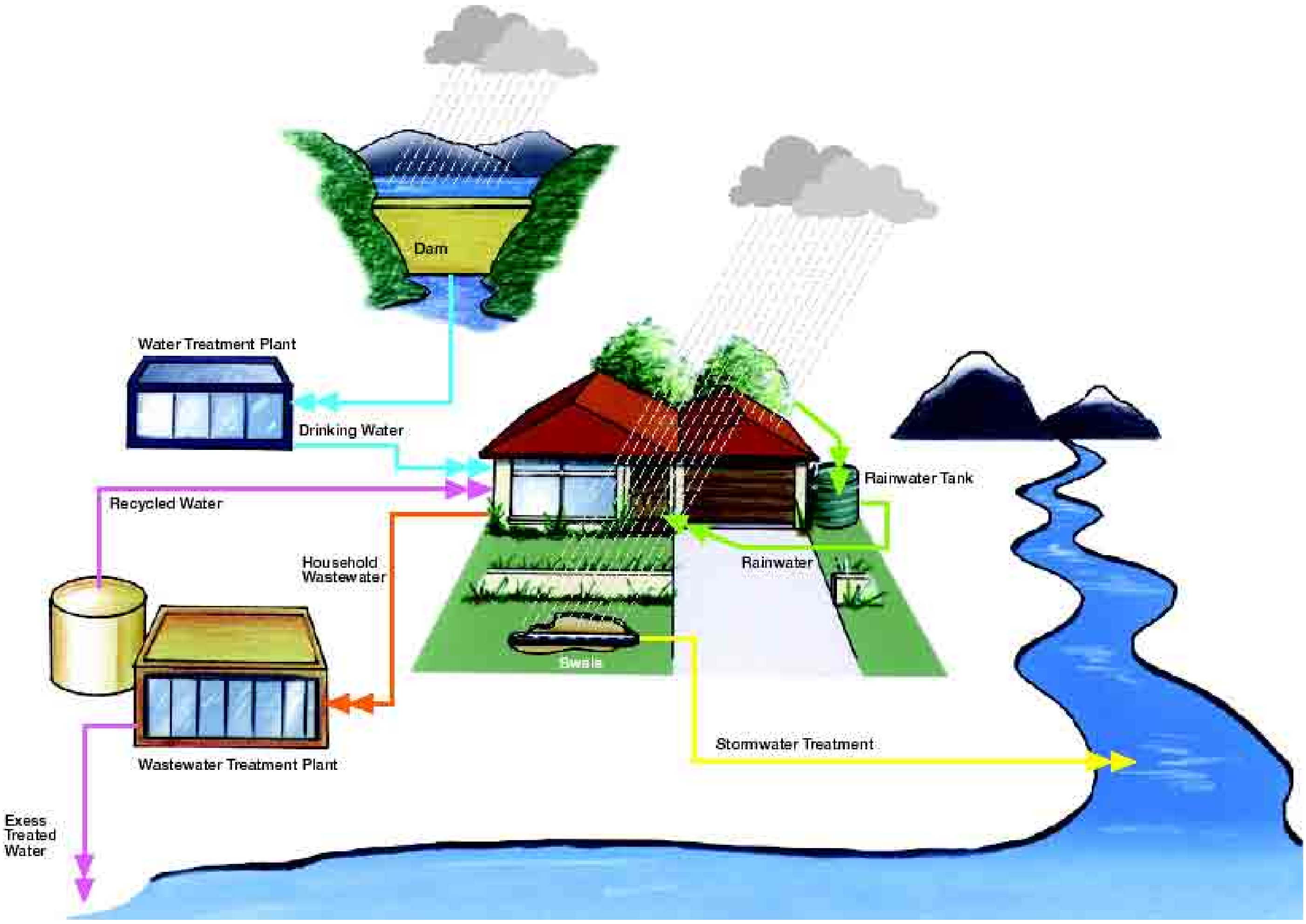
WATER RECYCLING

IN

AUSTRALIA



A review undertaken by the Australian Academy of Technological Sciences and Engineering

2004

Water Recycling in Australia

ISBN 1875618 80 5.

Publisher:

Australian Academy of Technological Sciences and Engineering
Ian McLennan House
197 Royal Parade,
Parkville, Victoria 3052
(PO Box 355, Parkville Victoria 3052)

ph: +61 3 9347 0622
fax: +61 3 9347 8237
www.atse.org.au

This report is also available as a PDF document on the website of ATSE, www.atse.org.au

Authorship:

The Study Director and author of this report was
Dr John C Radcliffe AM FTSE

Production:

BPA Print Group,
11 Evans Street
Burwood, Victoria 3125

Cover: - Integrated water cycle management of water in the home, encompassing reticulated drinking water from local catchment, harvested rainwater from the roof, effluent treated for recycling back to the home for non-drinking water purposes and environmentally sensitive stormwater management. – Illustration courtesy of Gold Coast Water

FOREWORD

The Australian Academy of Technological Sciences and Engineering is one of the four national learned academies. Membership is by nomination and its Fellows have achieved distinction in their fields. The Academy provides a forum for study and discussion, explores policy issues relating to advancing technologies, formulates comment and advice to government and to the community on technological and engineering matters, and encourages research, education and the pursuit of excellence.

The drought from 2001 to 2003 focussed the thinking of much of the Australian community towards our dependence on the nation's limited water resources. In consequence, the Australian Academy of Technological Sciences and Engineering sought and received funding from the Australian Research Council to gather and analyse information and to prepare this report, ***Water Recycling in Australia***

The report outlines the current extent of water recycling in Australia, encompassing rainwater and stormwater, but with the main emphasis on the extent of treatment and recycling of domestic and industrial wastewater. It discusses a range of issues arising from both international and Australian experience. Suggestions and recommendations are made for the future management and use of recycled water.

Australian's land management has progressively been adapting to our environment as our understanding of it increases and we recognise the need to better manage our natural resources and what we take from and return to them. In the early 1990s, the Australian states began to develop their own environment protection agencies / authorities and to establish policies on, monitor and licence waste management including wastewater discharges from sewage treatment plants. This interest has intensified in the first years of the new millennium.

Most rain in Australia soaks into the ground. Little more than one-tenth of Australia's rainfall runs into rivers and much of that is in rivers remote from population centres. We use about 20% of the water that could be taken from our rivers and groundwater sources but there is great variation in the distribution of use. Some areas of the country such as the northern coastline have little use of divertible water resources. Other areas have significant use, notably the Murray Darling Basin, which has more than 50% use and where provision of adequate water for the environment has become an important policy issue.

The recent National Land and Water Resources Audit established that half of the profit at full equity in Australian agriculture in 1996/7 came from irrigated production systems, occupying only 0.5% of the surface area of Australia. Its mean annual water use in 1996/97 was about 19 000 GL of surface water and 5 000 GL of ground water. There had been approximately a 26% increase in the area irrigated since the 1980s.

Yet, five years later, Australia was in widespread drought. Water restrictions in most capital cities brought home to the urban population that water is a limited resource. It was realised that whilst some of our treated sewage effluent was being recycled for agriculture, that had not of itself reduce the demand for mains (drinking) water. Most of the water used for agriculture and around half of the water being used for industrial and domestic purposes does not need to be water of drinking quality. Increasingly, wastewater, stormwater and rainwater are being seen as recyclable resources rather than as disposal problems.

The purpose of the study has been to generate a succinct update for policy-makers, and to make available a detailed account of developments and arising issues in water recycling for readers seeking information about the current position in Australia.

The study was overseen on behalf of the Academy by a steering committee comprising Dr Tom Connor FTSE (Director, Engineering Excellence and Technology, KBR, Brisbane) as Chairman, Dr Graeme Allison FTSE (formerly Chief, CSIRO Water Resources), Mr John Anderson (NSW Department of Commerce), Mr Don Blackmore FTSE (CEO Murray Darling Commission), Dr Mick Bourke, (Chairman, Victorian EPA), Professor Paul Greenfield FTSE (Senior Deputy Vice Chancellor, University of Queensland), Dr John Langford FTSE (former Director, Water Services Association of Australia), Professor Tom McMahon FTSE (Professor of Environmental Hydrology, University of Melbourne), Professor Ian Rae FTSE (Technical Director of the Australian Academy of Technological Sciences and Engineering) and Dr Geoff Syme (Director, Water Security and Sustainable Communities, CSIRO, Perth).

The project was managed and the report prepared by Dr John Radcliffe AM FTSE (formerly South Australian Director-General of Agriculture and subsequently Deputy Chief Executive [Environment and Natural Resources], CSIRO Australia).

Officers of Commonwealth and State agencies provided valuable assistance. Particular recognition is given for help by staff of the Australian Department of Agriculture Fisheries and Forestry, the Australian Department of Environment and Heritage, state water resources, environment protection and water/ wastewater service agencies, and the Water Services Association of Australia, which is the national peak body for the water agencies serving the 22 largest cities in Australia. A detailed list of contributors is included in the Acknowledgements section.

The preparation and publication of the study was made possible by a Linkage – Learned Academies Special Projects Grant, managed through the Australian Research Council.

SUMMARY

Australia is a large continent with only a small population to husband its land and water resources. Most of its rainfall soaks into the ground. Only 12% of its rainfall runs off and is collected in rivers. Much of this is in tropical monsoon areas with sparse communities and little development. The National Land and Water Resources Audit showed in 2002 that water resources from 26% of Australia's surface management areas and 31% of its groundwater management units were fully or over-allocated. In 1996-7, Australia used 26,000 GL of water, 75% for irrigation, 20% for urban and industrial purposes and 5% for stock and domestic use. Water is a valuable resource in Australia, but in short supply. There is scope to make better use of recycled water, stormwater and rainwater as additional water resources.

This report addresses current trends, particularly since 1999, in the processing, use and methods of application of recycled water internationally and in the Australian States and Territories. It explores a range of water recycling policy issues which include the impact of recycled water on society; the need for the continued assurance of public and environmental health; current regulatory processes and their accessibility to public scrutiny in Australia; the impact and potential impact of the greater substitution of recycled effluent water, storm water and rainwater for drinking water throughout the community and the need for continued investment in innovative research and developmental projects. The report provides observations and recommendations from the issues explored.

Background
An Australia-wide study commissioned in 1977 (GHD 1977) and another in Victoria (GHD 1978) concluded that representative studies of the economics of reclaimed water projects should be undertaken, and some pilot applications and full scale projects developed, and that water deficits would become a problem in Victoria by 2000. These studies seem to have had little impact in the capital cities where most of the domestic and industrial water consumption was occurring.

Meanwhile, sewage treatment systems were coming to Australian small country towns. Many of these, particularly in dry inland areas, recognised that the effluent from their plants could be usefully applied to amenity areas and recreational facilities such as golf courses and sports ovals. However, this represented recycling of only a small proportion of the nation's effluent

At about the same time as publication of the *Ecologically Sustainable Development Report* in 1991, the Australia states began establishing environment protection agencies and authorities. The potential damage caused by inadequately treated sewage effluent being discharged to oceans, rivers and estuaries was recognised. Regulations were brought in setting standards for discharges. Sewage Treatment Plant operators were increasingly required to come up with environmental management strategies for their discharges.

A number of major projects were initiated in the 1990s, including the development of the *National Water Quality Management Strategy Guidelines*, the NSW *Guidelines for Urban and Residential Use of Reclaimed Water*, the planning for reticulation of

both drinking water and recycled water in the new Rouse Hill (Sydney) subdivision, initiation of an integrated approach to sewage effluent and stormwater management at the site chosen for Sydney’s 2000 Olympic Games, the upgrading and provision of recycled water from Adelaide’s Bolivar STP for vegetable growing on the Northern Adelaide Plains and the building of a microfiltration - reverse osmosis water recycling plant at Luggage Point in Brisbane to produce very high quality water for industrial use. Other plants, particularly in Tasmania, were upgraded to improve the quality of discharges to water bodies. Many of these projects were supported, at least in part, by the Commonwealth Natural Heritage Trust programs, particularly that for Coasts and Clean Seas.

The drought that afflicted much of Australia in 2001-3 resulted in water restrictions being imposed in Sydney, Melbourne, Canberra, Perth and the Queensland Gold Coast. A re-evaluation of the use of rainwater tanks in urban areas began to occur, with some governments introducing subsidy schemes to encourage their installation. Several projects for harvesting urban stormwater for integration into the water supply and management system, notably at Olympic Park (Sydney) and Salisbury (Adelaide) began to attract attention. The drought also focussed increased attention on the water needs of the environment and the consequences of excessive water harvesting from natural water flows and a likely need to reduce reservoir catchment volumes. Opportunities for water harvesting in some catchments were reducing due to long-term climate and ecological changes.

Many of the recycling projects then being implemented or planned were oriented to the application of recycled effluent to land, either for amenity use or for new economic developments in agriculture, but did little to reduce the current consumption of water. Indeed, experience showed that at Rouse Hill, the community actually used more water from all sources than would have occurred in a conventional subdivision provided only with a single drinking water supply.

Many water authorities had successfully introduced water demand management systems, particularly through pricing mechanisms. They now face increasing difficulty in maintaining total urban potable water demands static in the face of continued population growth. Attention has turned to the potential of water recycling as an additional and substitutable water resource for our cities. Specific recycling targets have been established for Sydney, Canberra, Melbourne and Perth.

Over five hundred sewage treatment plants (STPs) across Australia now engage in the recycling of at least part of their treated effluent. Between 150 GL and 200 GL of effluent are now being recycled each year. Details are summarised in Appendix 1. Many of the major recycling projects are described in detail in the text. From a consideration of Australia’s experience with water recycling, it has been possible to draw a number of conclusions and make recommendations.

Observations and Recommendations

Governments and water agencies must come to recognise that in a dry country, wastewater effluent, stormwater and rainwater are complementary additional water resources rather than disposal problems.

The maintenance of confidence and trust between water agencies and their consumers is essential. The community has high expectations for the security and safety of its water supplies and is extremely sensitive to any health risks.

'Drinking water' should be the term adopted in Australia to describe 'potable water' and that 'water recycling' be adopted as the preferred term for generic water reclamation and reuse in view of the acceptance and success of other urban recycling programs.

Policy-makers, developers and the entire community should develop a wider appreciation of the complete hydrologic (water) cycle. There should be a convergence in the use by planners and water resource managers of the expressions *Water Sensitive Urban Design* (WSUD) and *Integrated Water Cycle Management.* Both have arisen to describe similar concepts encompassing an awareness of the urban hydrologic cycle and effectively harnessing its characteristics in maximising the efficient and sustainable use of our water resources.

Water resource managers should consider defining, with community assistance, areas of limited water resources as 'Water Resource Caution Areas'.

Wider use of recycled water should be undertaken where water of drinking water quality is not required. In some areas, mandating its use may be appropriate. There may be scope for greater use of indirect potable water recycling, but its introduction should only be progressed after community acceptance of its necessity.

National water policies should be extended to encompass entitlements to recycled water. Australia has made considerable strides in recent years under the CoAG Water Reform Agenda towards better defining water rights and their tradability, but they do not yet appear to encompass recycled water.

The *National Water Quality Management Strategy Guidelines* should be reviewed and revised, with the current revisions of the *National Guidelines on Water Recycling*, based on Hazard Analysis and Critical Control Point (HACCP) principles, being progressed as rapidly as possible to make them appropriate for the management of recycled water used in the urban domestic environment rather than being mainly oriented to land application. Recent experience with recycling has exposed the limitations of some of the existing *National Water Quality Management Strategy Guidelines*.

The current *Australian Guidelines for Urban Stormwater Management* should be revised as they do not give adequate consideration to the harvesting and use of urban stormwater as an additional water resource.

A revision of the National Environmental Health Forum's monograph *Guidance on the Use of Rainwater Tanks* should be encompassed in the *National Water Quality Management Strategy Guidelines* series.

The States and Territories should review and amend their plumbing and drainage regulations to achieve standardised outcomes. There remains considerable variability among the states in the infrastructure standards currently in use.

Much improved awareness must be developed in the plumbing industry and among customers of the essentiality of maintaining complete separation of drinking water and recycled water supply systems to ensure public confidence in recycled water. Experience with the frequency of cross connections found in the implementation of recycled water at Rouse Hill has highlighted this need.

Planning approval systems for water supply and effluent treatment provisions in new subdivisions should be streamlined. Many of the existing approval processes are cumbersome and some have potential conflicts between and within arms of government that serve to inhibit innovation.

“Headworks charges” by water utilities should be reviewed and made more equitable to reflect recognition of the extent of drinking water savings from the introduction of recycled water in new developments. The current charging regimes act as a disincentive to introducing water recycling to save drinking water.

Greater attention should be given to the costs and benefits of locating new developments close to newly-established small disaggregated STPs. Such plants may achieve energy and greenhouse gas savings compared with connection to distant but already operating large STPs.

Legislative or regulatory changes should be made where necessary to facilitate the right of recycled water providers and users to lay infrastructure to deliver recycled water. There are areas where these rights are not currently available.

Incentives should be introduced to encourage installation of ‘in-house’ recycling systems in new high-rise office and apartment buildings and the establishment of a service industry to manage such systems, particularly where there are hydraulic conductivity limits in existing water and sewer infrastructure.

A national approach to addressing the costs and prices of drinking water and recycled water and the processes of deriving them should be developed. Currently they are not transparent and do not adequately recognise the cost of externalities as required under the CoAG water reform principles and some contain perverse incentives to water consumption. There is considerable variability between the States in their water regulation economics. Some States have none.

Future water recycling projects should clearly define the probable market demand before commencement. There is considerable evidence from overseas and some evidence from Australia that projects have been initiated without establishing the market for recycled water.

Any residual liabilities to the water supply authorities within the *Trade Practises Act 1974 (Cwlth)* should be clarified, along with the necessity for any additional legislation that might be needed with the intent of protecting water utilities from lawsuits if they are in compliance with Australian and State legislation.

Agencies responsible for industry development attraction should recognise the benefits of being able to locate those requiring large amounts of process water that does not need to be of drinking water standard, close to existing or proposed sewage treatment plants.

There is scope for greater use of wetlands for water quality remediation, particularly stormwater, but installed systems must receive adequate maintenance. There is evidence that this has not been provided to some recently installed projects.

The potential role of effluent treatment facilities in biodiversity conservation should be recognised.

Further research should be encouraged into treatment processes that will lead to progressive improvement in costs and efficiency of advanced wastewater treatment and the more effective integration of all forms of water conservation and reuse, including recycled water, stormwater and rainwater. Consideration should be given to the suggestions made in the November 28 2003 Working Party presentation to the Prime Minister's Science, Engineering and Innovation Council (discussed in section 4.1.2).

Investment in innovative community scale water recycling projects should be stimulated.

Any separation of responsibilities for the ultimate management of water and wastewater resources as has developed in USA, should be discouraged in Australia.

Governments must resolve at whole-of-government level the conflicts of interest that can be and are evident between portfolio agencies responsible for environmental management, water resource provision, revenue generation and price determinations.

Ensuring public participating in decision making, and gaining public confidence and trust in future water recycling initiatives is absolutely essential to the greater use of water recycling in Australia as a strategy to better share the country's limited water resources and maintain the integrity of its environment.

TABLE OF CONTENTS

LIST OF TABLES

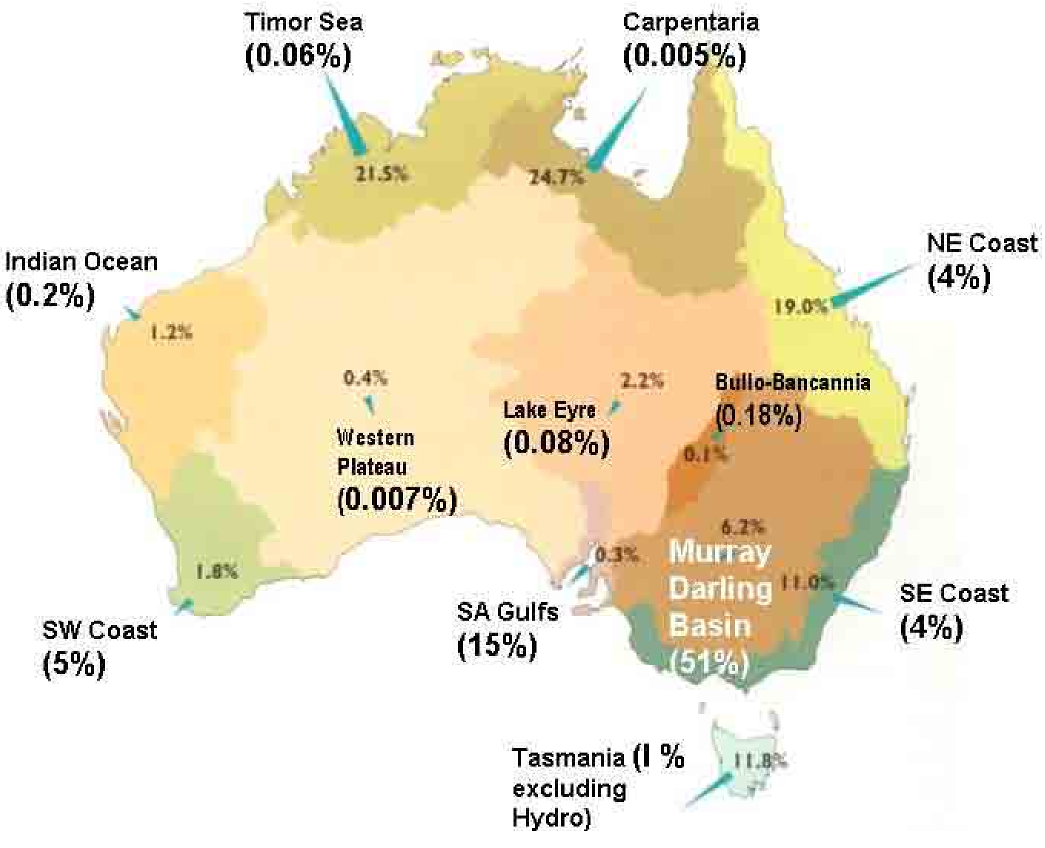
LIST OF FIGURES

1 INTRODUCTION

1.1 Australia's Water Resources

Australia is a very large continent, with a total surface area of 7.6 million km², surrounded by an ocean territory of 16.1 million km² including its Exclusive Economic Zone (EEZ) and claimable continental shelf. It is a very old continent geologically. Australia is the driest of the world's inhabited continents, with lowest percentage of rainfall as run-off, the lowest amount of water in rivers and the smallest area of permanent wetland. On average, only 12 % of Australia's rainfall runs off and is collected in rivers. In five of Australia's drainage divisions, run-off is less than 2%. In only two drainage divisions, being the tropical monsoonal divisions of the Timor Sea and Gulf of Carpentaria, does runoff exceed 20%. The remaining 88% of rainfall is accounted for by evaporation, water used by vegetation and water held in storages including natural lakes, wetlands and groundwater aquifers (Figure 1)

Figure 1 The percentage of rainfall that runs off Australian drainage divisions (small numerals), and the percentage of that run-off currently used for agricultural, domestic or agricultural purposes (large numerals) (NLWRA 2002).



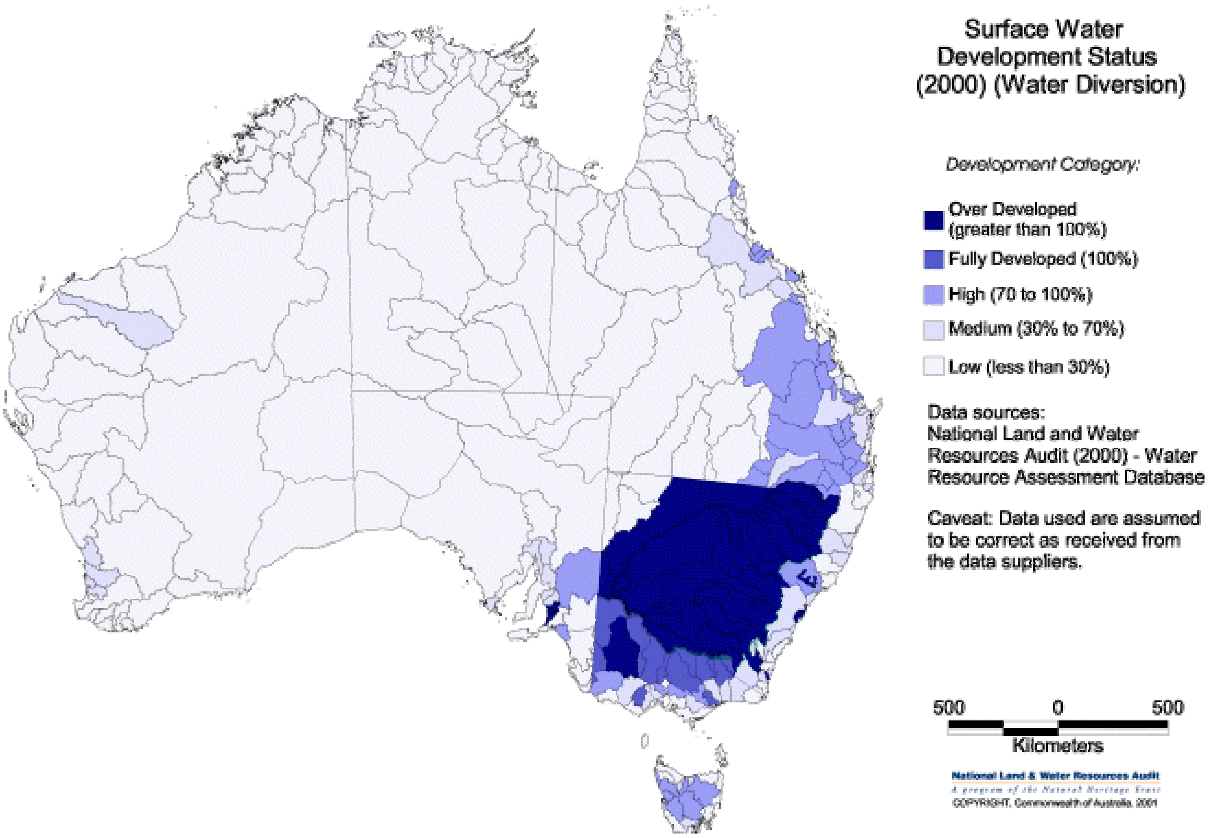
It will be noted that the drainage division with the largest agricultural development is the Murray Darling basin, which has a relatively low run-off, but already a high consumptive use.

Since the early 1990s, there has been a considerable change in thinking about the value and management of Australia's natural resources, including its water.

The *Ecologically Sustainable Development Report* (ESD 1991) noted the growing demand for water for conservation, recreation, irrigation, industry and domestic use. There was a concern about the capacity of existing supplies to meet future demands. The need for an integrated catchment-wide approach to water and land resource management was recognised. In 1994, the Council of Australian Governments adopted a strategic framework for the reform of the Australian water industry. An integrated approach that addresses the environmental, economic and social issues associated with water use through the provision of water and wastewater services was agreed (NCC 1998). A State of Environment report (SoE 1996) noted that sewage disposal was inadequate. Management of nutrient loadings to coastal environments required reducing the flow of land-based effluents or removing their nutrients.

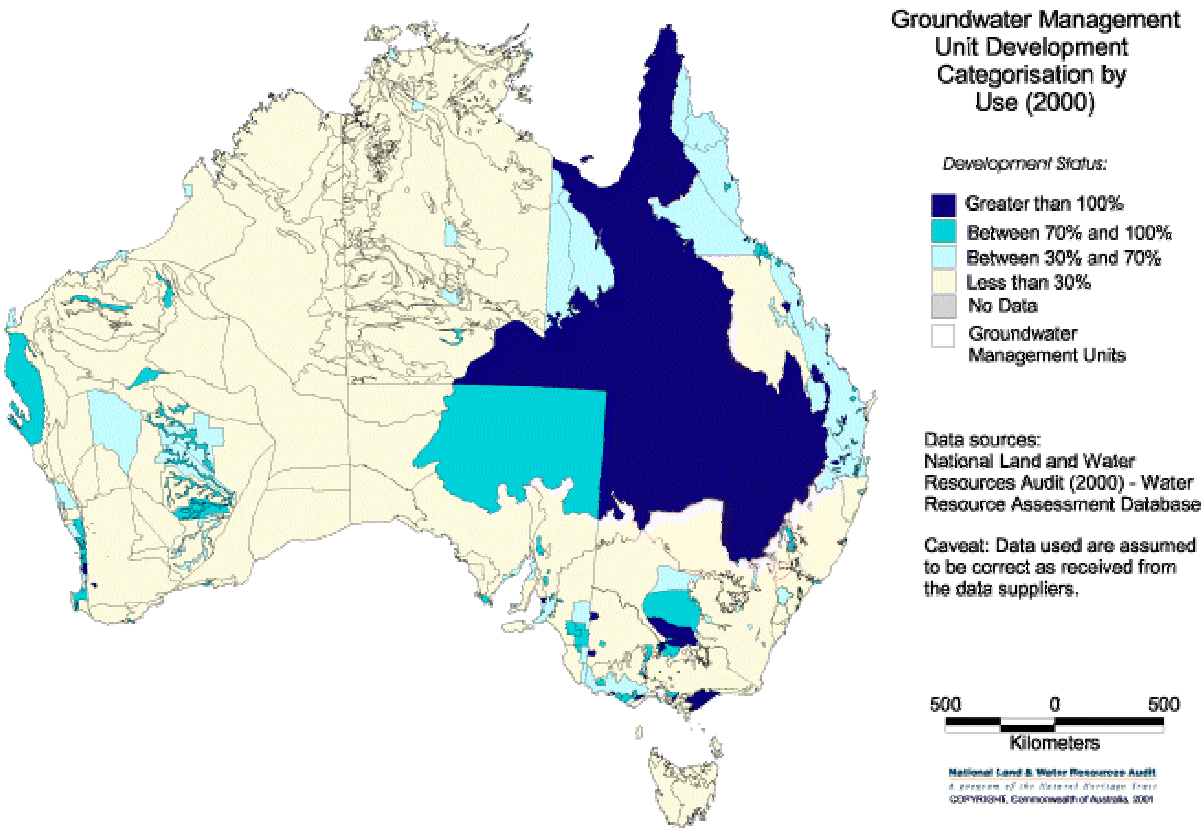
The National Land and Water Resources Audit (NLWRA 2002) showed that 26 percent of Australia's surface water management areas are either close to or overused compared with their sustainable flow regimes (figure 2). The Audit defines the Sydney-Georges River area, Newcastle's Hunter River and Adelaide's Gawler, Little Para, Myponga, Onkaparinga and Torrens Rivers as over-allocated, and Melbourne's Thomson-McAlister, Werribee and Yarra Rivers as close to or at their extraction limits. The greatest extent of over-allocation occurs within the Murray Darling Basin drainage division – in essence where Australia already appropriates the highest proportion of rainfall run-off.

Figure 2 Water development of Australian surface water management areas – the darkest colour represents over 100% of annual flow having been allocated (NLWRA 2002).



The same report also established that water from 168 of Australia's 538 groundwater management units is either fully or over-allocated (Figure 3).

Figure 3 Water development of Australia's groundwater management units – darkest colour represents over 100% of estimated annual groundwater recharge (NLWRA 2002).



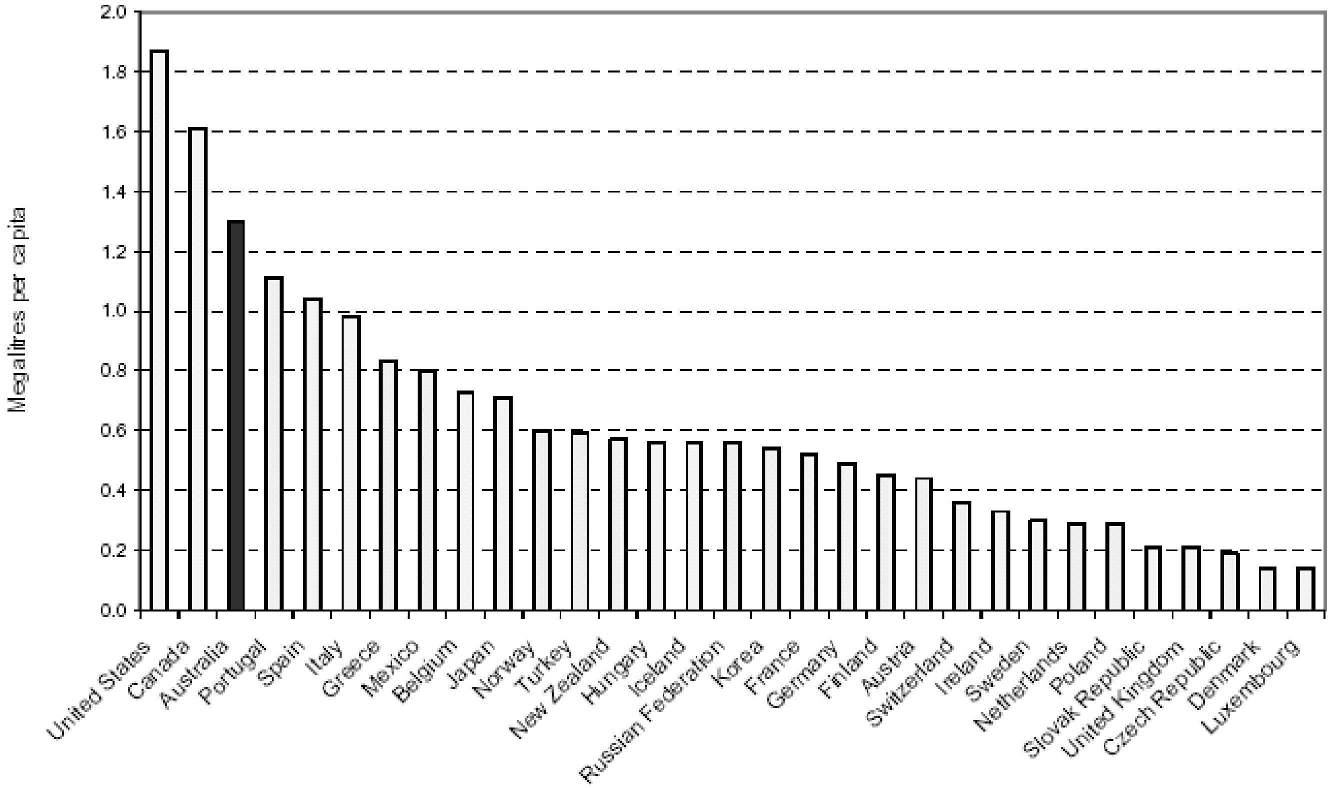
Although groundwater represents only 17% of the water used in Australia, it is of especial value for agriculture in many areas, is crucial for stock and domestic supplies in most of inland Australia, and is a major component of the domestic and industrial water supply for Perth, where several Swan Coastal Plain groundwater management units are at their extraction limits.

1.2 Water Use

In 1996-7, Australia used 24 000GL of water, 75% being used for irrigation, 20% for urban domestic and industrial use, and 5% for rural stock and domestic use. Over the period 1983-4 to 1996-7, irrigation use increased by 76%, urban domestic and industrial use increased by 55%, while rural stock and domestic use fell by 2% (NLWRA 2001).

Australian has the third-highest *per capita* consumption of water after the USA and Canada among OECD countries (Figure 4) (Productivity Commission 2003).

Figure 4 Water extraction per capita, OECD Countries, 1999 (Productivity Commission 2003).



Australian cities consume as much water per hectare as do irrigation areas, and Australian per capita domestic water use (320 litre per person per day) is second highest in the world after USA (Price, 2002). Although the introduction of demand management pricing has temporarily slowed the increasing trend of domestic consumption in the major cities, these trends are likely to continue as urban populations continue to grow.

The drought of 2001-3 saw water rationing in most Australian capital cities, and brought home to the urban public that there are limits to accessible sources of drinking water. These constraints have become especially evident in Sydney, Melbourne, the Gold Coast and Perth.

The use of water in the average Australian city is shown in Table 1. Households use about 59% of urban water; of that, 54% of the water used in the average Australian household is used for flushing toilets and watering gardens. Such uses do not require high quality drinking water. The remaining water is used in industry and local government. The numbers in this table refer to the total for Australia’s 22 largest cities with a combined population of 13.4 million people, and are from the Water Services Association of Australia (WSAA 2001).

Table 1 Water Use in Australia's 22 largest Cities (Rathjen *et al*. 2003).

Component of Water Use	Volume ML	Percentage of Total Consumption	Percentage of Residential Consumption
Residential Gardens	414,000	20.1%	34%
Toilet Flushing	244,000	11.8%	20%
Laundry	183,000	8.9%	15%
Bathroom	317,000	15.3%	26%
Kitchen	61,000	3.0%	5%
Total Residential	1,219,000	59.0%	100%
Industrial and commercial	437,000	21.2%	
Local government, parks, fire fighting	139,000	6.7%	
System losses	221,000	10.7%	
Customer meter errors	49,000	2.4%	
TOTAL	2,065,000	100%	

1.3 Wastewater / Sewerage services

The identification of pollution of water from sewage (Snow 1855) and the provision of reticulation systems to supply clean water and effective sewerage systems for domestic sanitation with the consequent effluent treatment and discharge being separated from the water supply system, are generally recognised to have been among the greatest advances in protecting public health. The reduction in the incidence of water-borne diseases was the dramatic success story of the 19th and early 20th centuries.

Many early sewerage systems discharged raw sewage to rivers and oceans. Overseas, this practice can still be observed.

Figure 5 Discharge to ocean, Stanley, Falkland Islands. Skuas are perusing the arriving effluent with interest. There is little local interest in sea bathing due to cold water temperature, incessant winds with a high chill factor, and because many of the local beaches are still mined.

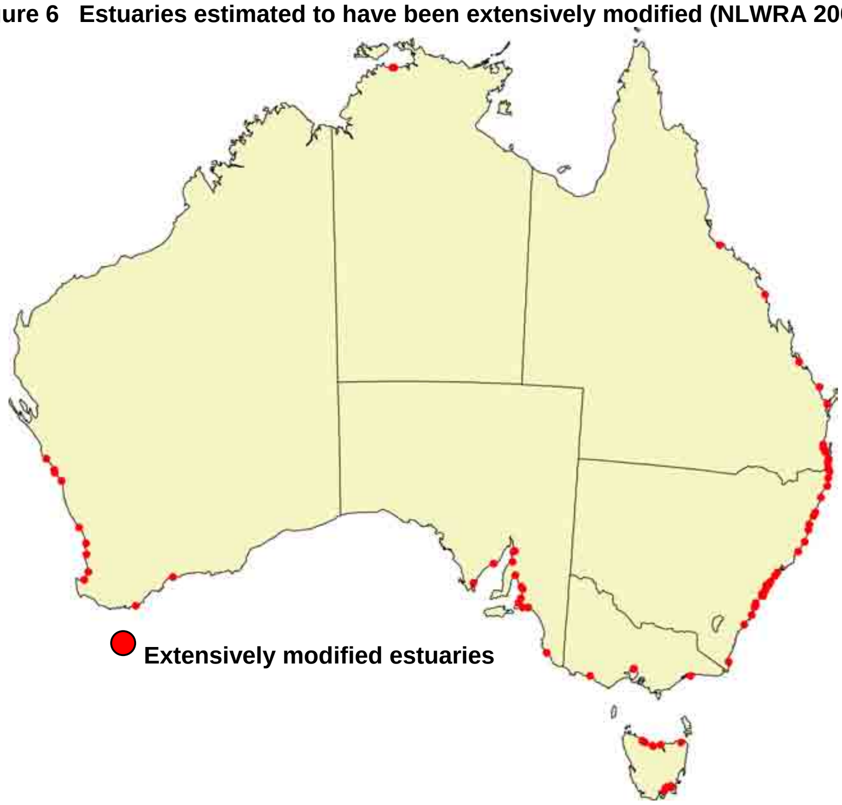
Barbara Radcliffe

Land application of effluent, initially serving as the treatment process, had its origins in Germany around 1550 and in Britain about 1700 (Asano 1998). The practice commenced in Australia at Islington, South Australia in 1881 (Burgess 1907) and resulted in a decline in deaths in Adelaide from 23.5/thousand in 1880 to 14.3/thousand in 1886 (E&WS 1986). The Islington Farm was replaced with the Bolivar Wastewater Treatment Plant by 1969. A much larger land-based plant was developed at Melbourne's Werribee sewage farm from 1892, operating on a land and later a grass filtration system (KBR 2003) which progressively expanded to reach its present size of 10 850 hectares, but is to be discontinued in 2005 (Melbourne Water 2002a).

Now to discharge to rivers and oceans, environmental protection regulations require treatment standards to be achieved to comply with discharge licences. Discharge of treated effluent to ocean, bay or estuary is still a primary disposal route, Luggage Point (Brisbane), Malabar (Sydney), Carrum-Boags Rocks (Melbourne), Bolivar (Adelaide) and Woodman Point (Perth) being among the largest Australian examples. Even though standards have been considerably enhanced over the past decade, these discharges can still have significant nutrients in them, and have been shown to have significant impact on aquatic ecosystems.

The National Land and Water Resources Audit (NLWRA 2002) established the extent of degradation in Australia's rivers, bays and estuaries. It will be seen from Figure 6 that the greatest modification to the nation's estuaries has taken place adjacent to the areas of highest population. Whilst a considerable proportion of this degradation has been attributed to agricultural pursuits, individual studies of the impact of effluents from sewage treatment plants have shown that they can have considerable local impact on coastal ecosystems.

Figure 6 Estuaries estimated to have been extensively modified (NLWRA 2002).



Similarly, a review of pollution in the Murray Darling Basin (GHD 1992) established that significant point pollution was emanating from effluent discharges from towns along the Basin's rivers, amounting to 500 tonnes of phosphorus and 2790 tonnes of nitrogen each year.

In 1997-8, Australia's major cities processed 1350GL of sewage effluent, the majority of which was being discharged to water bodies (WSAA 2001). Appropriately treated, this effluent represents a valuable resource. Although there have been increases in the reuse of treated effluent since then, the proportion being recycled remains small.

Table 2 Annual water reuse from water utility STPs in Australia, 1996-9 and 2001-2 (Radcliffe 2003).

Region	1996-9			2001-2		
	Effluent, GL/yr	Reuse, GL/yr	%	Effluent, GL/yr	Reuse, GL/yr	%
QLD	328*	38*	11.6	339‡	38‡	11.2
NSW	548†	40.1†	7.3	694	61.5	8.9
ACT	31*	0.25*	0.8	30	1.7	5.6
VIC	367	16.9	4.6	448	30.1	6.7
TAS	43	1	2.3	65	6.2	9.5
SA	91*	9*	9.9	101	15.2	15.1
WA	109	5.5	6.1	126	12.7	10.0
NT	21*	1*	4.8	21	1.1	5.2
Aust.	1538	112.9	7.3	1824	166.5	9.1

†1996 *1998 ‡Subject to revision

Recycling of effluent is more common in rural areas, especially away from the coast. When the proportion of effluent recycled in the capital cities is examined, it is found to be much lower than the respective state figures incorporating the country towns (Table 3).

Table 3 Recycled water use in State capital cities expressed as a percentage of sewage effluent treated, 2001-2

State Capital	% recycled water use
SYDNEY	2.3
MELBOURNE	2.0
BRISBANE	6.0
ADELAIDE	11.1
PERTH	3.3
HOBART	0.1

1.4 Rainwater and Stormwater

Rainfall run-off collected in household tanks ('rainwater') or from the urban stormwater drainage system ('stormwater') is an additional water resource that can add to our conventional catchment-based water resources. These resources can be regarded as resources for recycling but have been inconsistently dealt with historically.

The extent of recycling within the States and territories is discussed further in Chapter 4. The issues affecting the management and use of recycled water, rainwater and stormwater are discussed in Chapter 5.

1.5 Future water resource management

A Senate inquiry into Australia's management of urban water recommended the establishment of a National Water Policy including State and local targets with timeframes for effluent reuse, stormwater retention and pollution removal, decentralised, small scale sewage treatment and reduced effluent to ocean outfalls (Allison 2002).

The Council of Australian Governments, comprising the Prime Minister, State Premiers, Territory Chief Ministers and the Australian Local Government Association agreed at their meeting on 29 August 2003 to establish a National Water Initiative that, among other aspects, will encourage water conservation in the cities including better use of stormwater and recycled water (CoAG 2003).

A presentation to the Prime Minister's Science, Engineering and Innovation Council on 28 November 2003, recommended that investment in water recycling projects should be stimulated (Rathjen *et al* 2003).

The development of these policy issues is further discussed in Chapters 4 and 5.

- **The circumstances are right to encourage Australians to better manage their water resources. The adoption of opportunities to make better use of recycling should be encouraged.**

2 WASTEWATER TECHNOLOGIES AND USES

2.1 Definitions

There is a wide variety of terms used to describe forms of water and wastewater and their subsequent use. The principal terms are: -

Potable water:
Water suitable for human consumption without deleterious health risks.

- **The term ‘drinking water’ is recommended as a preferable term better understood by the community at large.**

Non-potable water:
Water which does not meet drinking water standards, but which may be fit for other specifically defined purposes.

Water reclamation:
The treatment of wastewater to make it reusable for one or more applications. The process produces reclaimed water.

Water Reuse:
Beneficial use of reclaimed or treated water for specific purposes such as irrigation, industrial or environmental uses.

Water recycling:
In most literature (eg Asano 1998; Mantovani *et al.* 2001), the term ‘wastewater reclamation and reuse’ was used for municipal wastewater . Water recycling is defined as reclamation of effluent generated by a given user for on-site use by the same user, such as in industry. However, in recent years, there are other more general definitions in use, such as in the California Water Code (State of California 2003a), where it is defined to mean ‘water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur’. The Australian community has come to realise that environmental resources are not infinite, and widely accepts recycling at a household scale.

- **The term ‘water recycling’ is therefore suggested as the preferred term to be adopted for generic water reclamation and reuse in Australia.**

Direct reuse:
This describes the beneficial use of reclaimed water (recycled water) that has been contained during direct transfer from the treatment plant to the reuse site via conveyance facilities.

Direct potable reuse:
This encompasses water that has been highly treated to make it suitable for human drinking water use, and is conveyed directly from the treatment plant to the water supply system. The best-known example is in Windhoek, Namibia (see Section 5).

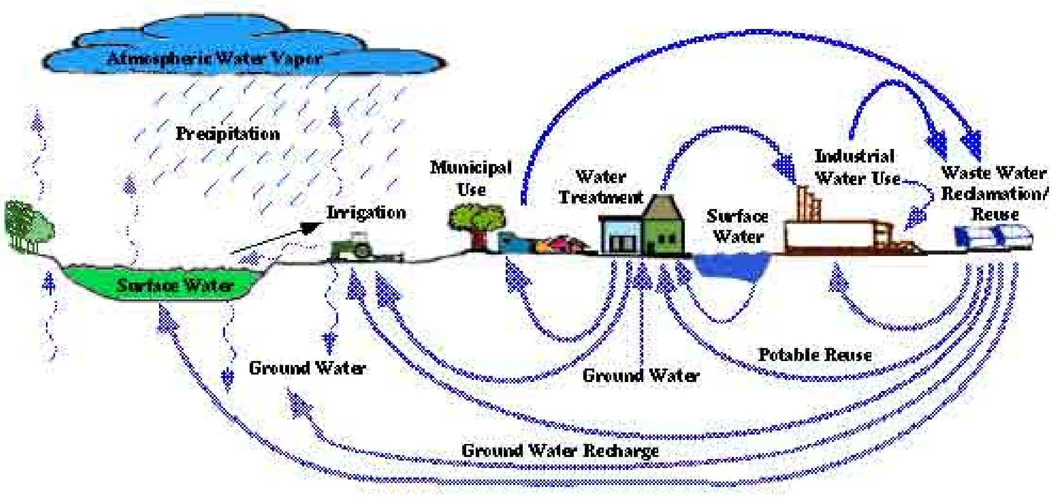
Indirect reuse:
This describes the subsequent beneficial use of water after it has been discharged from the treatment plant into a natural surface water or groundwater body, from which further water is taken, sometimes in an unplanned manner. See below for unplanned or incidental potable reuse now occurring in various parts of the world.

Unplanned or Incidental Indirect Potable Reuse:
This describes the subsequent use of reclaimed water (recycled water) after it has been treated and then discharged into surface waters or groundwaters from which further water is taken for human 'drinking water' supplies. This is a major health and aesthetic concern because our drinking water should come from wholesome and unpolluted sources. There are many examples of this, particularly in cities and towns at the end of major rivers. These include New Orleans (Mississippi River), London (River Thames), the numerous towns of the Rhine River Valley in Germany and Osaka, (downstream from Kyoto which discharges its treated effluent into the Yodo River) (Asano 1998). Adelaide, which takes 35% to 85% of its water from the River Murray, is an Australian example, being downstream from many towns discharging into the Murrumbidgee/Murray river system including from Canberra's main Sewage Treatment Plant (STP), the Lower Molonglo Water Quality Control Centre.

2.2 The Hydrologic Cycle

The hydrologic cycle refers to the continuous transport of water in the environment, involving evaporation from the surfaces of biota, land and water bodies to form clouds, its movement through the climate system and its subsequent precipitation as rain or snow. Man has learned to intervene in this cycle by developing water storages, and reticulation systems to facilitate the use of water, its subsequent treatment for reuse and/or discharge back into the environment. The components of the hydrological cycle have been elegantly illustrated by Asano (1998) and are shown in figure 7.

Figure 7 The role of engineered treatment, reclamation and reuse facilities in the cycling of water through the hydrologic cycle (Asano 1998).



2.3 Water Sensitive Urban Design – Integrated Water Cycle Management

Water Sensitive Urban Design (WSUD) is the integration of urban planning and development with the management, protection and conservation of water within a consideration of the water cycle as a whole (WSUD 2003).

Some consider that the principles of WSUD primarily revolve around stormwater management, with emphasis on

- protecting and enhancing natural water systems within urban developments by using stormwater in the landscape through incorporating multiple use corridors that maximise the visual and recreational amenity of developments;
- improving the quality of water draining from urban developments into receiving environments;
- reducing peak flows from urban development by local detention measures and minimising impervious areas while also minimising the cost of developing drainage infrastructure.

However, there are other aspects. These can include

- rainwater tanks, using stormwater as a resource to substitute for potable supply for gardening, car washing, toilet flushing, etc,
- reuse of ‘greywater’ collected from household kitchens, showers, baths and laundries, given primary treatment on site and then available for reuse for external irrigation or internal toilet flushing, and
- on-site treatment of all household wastewater for disposal or reuse

The WSUD framework should make provision of incorporating off-site wastewater treatment and the subsequent incorporation of recycled water as well as stormwater and rainwater into the urban planning environment.

Integrated water cycle management (IWCM) is an innovative way of managing urban water supply, sewerage and drainage systems, linked to local catchment considerations and water resources. Project experience has shown that the IWCM approach results in better environmental outcomes at lower costs than the traditionally separated approaches to water, sewerage and drainage service provision. The concept is similar to, though with perhaps a broader compass than WSUD (AWA 2004).

Desalination of brackish water or seawater also has potential to be incorporated into the planning of urban water supplies and is receiving some consideration in Perth. This resource is already used in a number of overseas locations, including 16 facilities in coastal California generating approximately 5.6 GL of desalinated water per year (Keene 2003). A small plant has operated at Penneshaw, South Australia since 1999 (SA Water 2003). Whilst desalination will not be considered in detail in this review, major policy issues include the energy requirements, greenhouse gas emissions and the impact of withdrawal of seawater, and subsequent discharges of brine on the marine environment. Since seawater is a common property resource, the basis of access and entitlements to seawater for desalination needs to be resolved.

- **An understanding of the entire hydrologic cycle, with a convergence of understanding of the expressions *Water Sensitive Urban Design* (WSUD) and *Integrated Water Cycle Management,* should form the basis of future water resource planning and management in Australia.**

2.4 Water recycling

Water recycling may encompass

- collection, storage and, if necessary, treatment of rain falling on structures in the built environment - rainwater;
- collection, storage and treatment of rain falling on hard surfaces and running off the built environment – stormwater; and
- recycling or wastewater from previous uses. This generally means the reclamation for reuse of domestic sewage effluents or municipal wastewater, preferably from which industrial effluents containing processing chemicals have been segregated. The recycled water may be reclaimed from bathroom and laundry effluents (greywater), or from the entire domestic sewage stream (black water) or municipal wastewater.
- Recycling of effluents of industrial processes including intensive rural industry effluents.

The stream of recycled water may be comprised of any or all of these waters, and where used in combination, managed in an integrated way.

Rainwater (sometimes called tankwater) is the traditional form of conservation for reuse in areas without reticulated water supply, and in areas where the quality of reticulated water has not been good (for example due to high turbidity or high total soluble salts, often deriving from the nature of the catchment from whence the reticulated supply has been harvested). In some cities, its use has not been encouraged due to perceived health risks. Owners usually have a poor record of maintaining the condition of their rainwater tank and its contents. Nevertheless, rainwater is an additional urban water resource, and rainwater tanks can reduce the impact of storm events. Natural biological processes in them tend to reduce any potential risks over time from pathogenic organisms.

Several states, in the face of recent water shortages, have been subsidising the installation of rainwater tanks for various uses.

Stormwater has traditionally been seen as a cost due to structures needed to achieve safe disposal, and as a potential hazard in the form of flooding with abnormal peak flows following storm events, rather than being seen as a valuable resource.

The incidence of run-off has been increased in the urban environment as larger and larger areas of ground surface have been sealed for roads, footpaths, hard stands for domestic, community, retail, commercial and industrial parking and also for the management of some industrial processes. Uncollected run-off from buildings adds to the stormwater flow.

Every effort is made to separate stormwater from sewage flows in most Australian cities, though storm events inevitably increase sewage flows – sometimes by up to 100%.

Recycled water can be produced at a several different scales, viz

- Area scale
- Locational scale
- Site scale

Recycled water can be generated at the **area scale** by collecting sewage (or municipal wastewater) via the sewerage system for appropriate treatment in a Sewage Treatment Works (STP), sometimes called a Waste Water Treatment Works, where the solids (sludge) and liquids (effluent) are separated, and biodegradable organics are stabilized and removed.

The quality of the treated effluent required from the processing will be determined by its ultimate disposition, namely whether it is immediately returned to the environment, in which case environmental standards will need to be met, or if it is to be recycled, the purposes for which it is to be used. Often this involves constructing a water reclamation plant to improve the quality of the STP effluent so that it is 'fit for purpose'.

The nature of the country to be traversed and the cost of transporting the effluent for treatment will usually determine the distribution of such plants in an urban setting. Siting has traditionally been influenced by decisions influenced by elevation of the site (to maximise the use of gravity flows), on the ease of discharge of the effluent (location close to a river, estuary or the ocean has been common), access to power sources, and community acceptance.

Supply of the recycled water usually requires pumping to a higher elevation to supply customers, and pumping costs may be a major operational cost (See Chapter 5).

Recycled water can also be obtained at a **locational scale** by the process of **Sewer Mining**, whereby the sewage flow in a main trunk sewer is accessed, and the sewage effluent separated and treated, with the solids returned to the sewer main for treatment at the end-point STP. These are also termed satellite water reclamation plants.

Recycled water can also be produced at the **site scale**. Packaged units are available for use on high-rise office buildings and apartments, and installations have been developed for use at the scale of the urban house-block containing a single-family dwelling. However, there are limits in the use of on-site treatment systems. Owners have a poor record in achieving effective maintenance, and the average domestic building block is generally regarded as too small for their use (EPA Victoria 2001).

2.5 Sewage / Wastewater Treatment Processes

The treatment of Sewage or Wastewater conventionally involves a series of physical, chemical and/or biological processes to remove solids, organic matter, pathogens, metals and often the added nutrients (Asano 1998). The components of wastewater treatment are generally described as the preliminary, primary, secondary and tertiary stages, with advanced treatment being added to the third stage when the effluent is to be returned to potable or near potable standard, the extent of treatment being determined by what is necessary to reliably reclaim the effluent to make it suitable for its eventual use or discharge.

The preliminary stage involves physical screening of the arriving influent to remove coarse particles such as small stones, sand and gravel.

The primary stage involves the removal of the most of the remaining particulate matter, involving comminution if necessary, followed by coagulation and/or flocculation before sedimentation. Alternatively, filtration can be applied after sedimentation. This processing will remove about half the suspended solids and reduce the biological oxygen demand (BOD), and will also remove about 10% of the nitrogen and phosphorus. If the primary effluent is to be discharged, it is likely to be disinfected. However, processing to only the primary stage is not now perceived adequate to meet current-day discharge standards.

The options for **the secondary stage** usually involve a range of aerobic biological processes aiming to microbially metabolise the dissolved or suspended organic matter. These may involve using either slow rate suspended growth processes such as aerated lagoons and stabilisation ponds or faster processes such as activated sludge technologies. Alternatively, fixed film processes may be adopted such as the use of trickling filters.

Some of the organic matter in the wastewater provides energy and nutrients for the microbial populations, the remainder being oxidised to carbon dioxide, water and other end products. A secondary sedimentation follows to remove the biomass produced. The biomass may then be treated by aerobic or anaerobic digestion, by composting or by other technologies.

These processes remove up to half the nitrogen and convert the phosphorus to phosphates. There may be a further filtration of the effluent stream, which is then disinfected. About 80-95% of the BOD and suspended solids are removed in the secondary treatment.

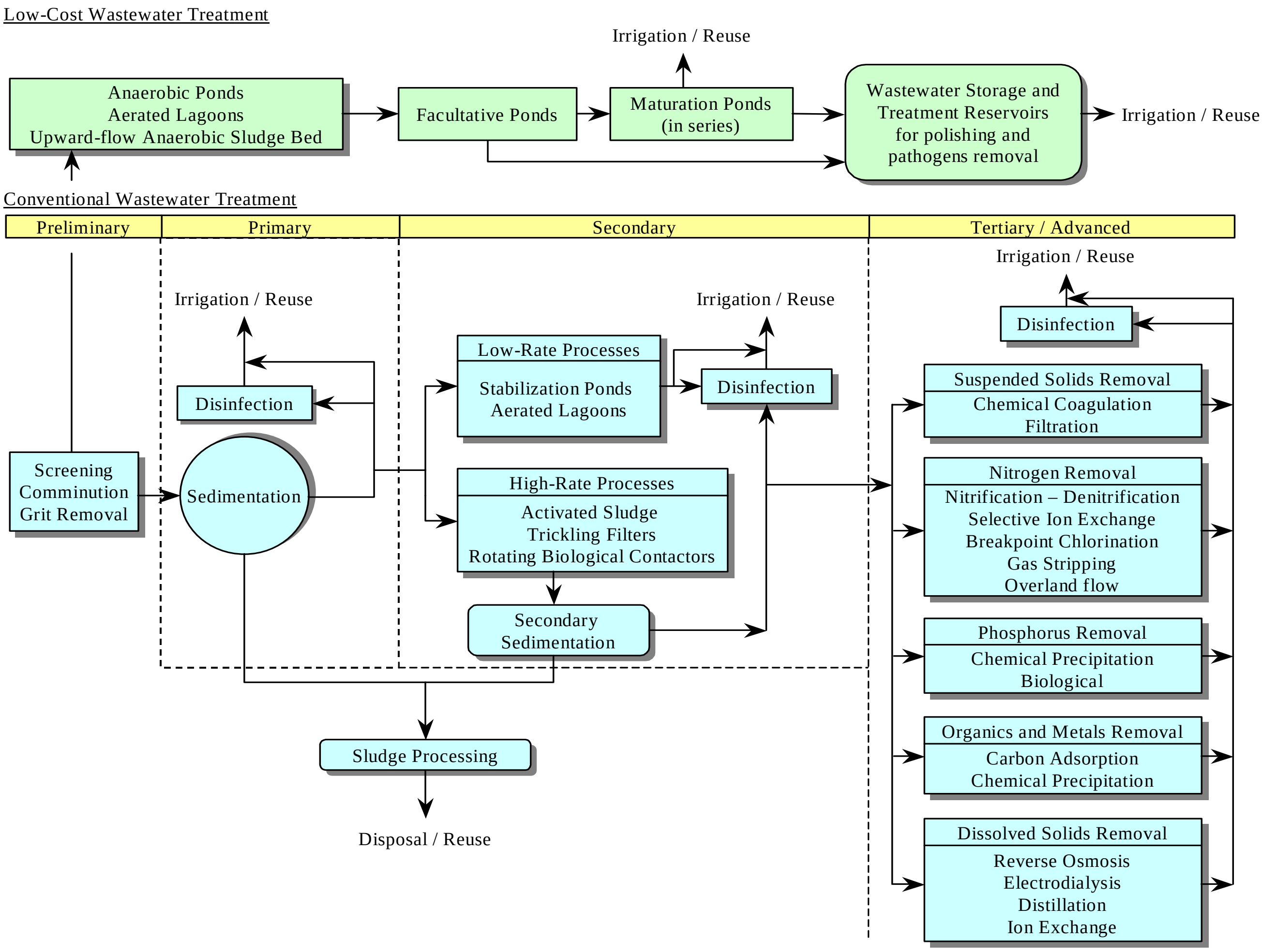
Tertiary treatment is usually the minimum for discharge to water bodies, particularly inland. Its processes involve further removal of colloidal and suspended solids by chemical coagulation and filtration, with the removal of specific metals, pathogens, and nutrients.

Activated carbon can be used to adsorb hydrophobic organic compounds and lime can precipitate various cations and metals at high pH.

Membrane processes including microfiltration and reverse osmosis are increasingly being adopted for the most advanced tertiary treatment processes beyond conventional filtration due to their ability to remove very fine particles from the effluent stream. In essence, the pores in the membrane are large enough to allow water molecules to pass through, but too small to permit the passage of salt, other minerals and large organic molecules.

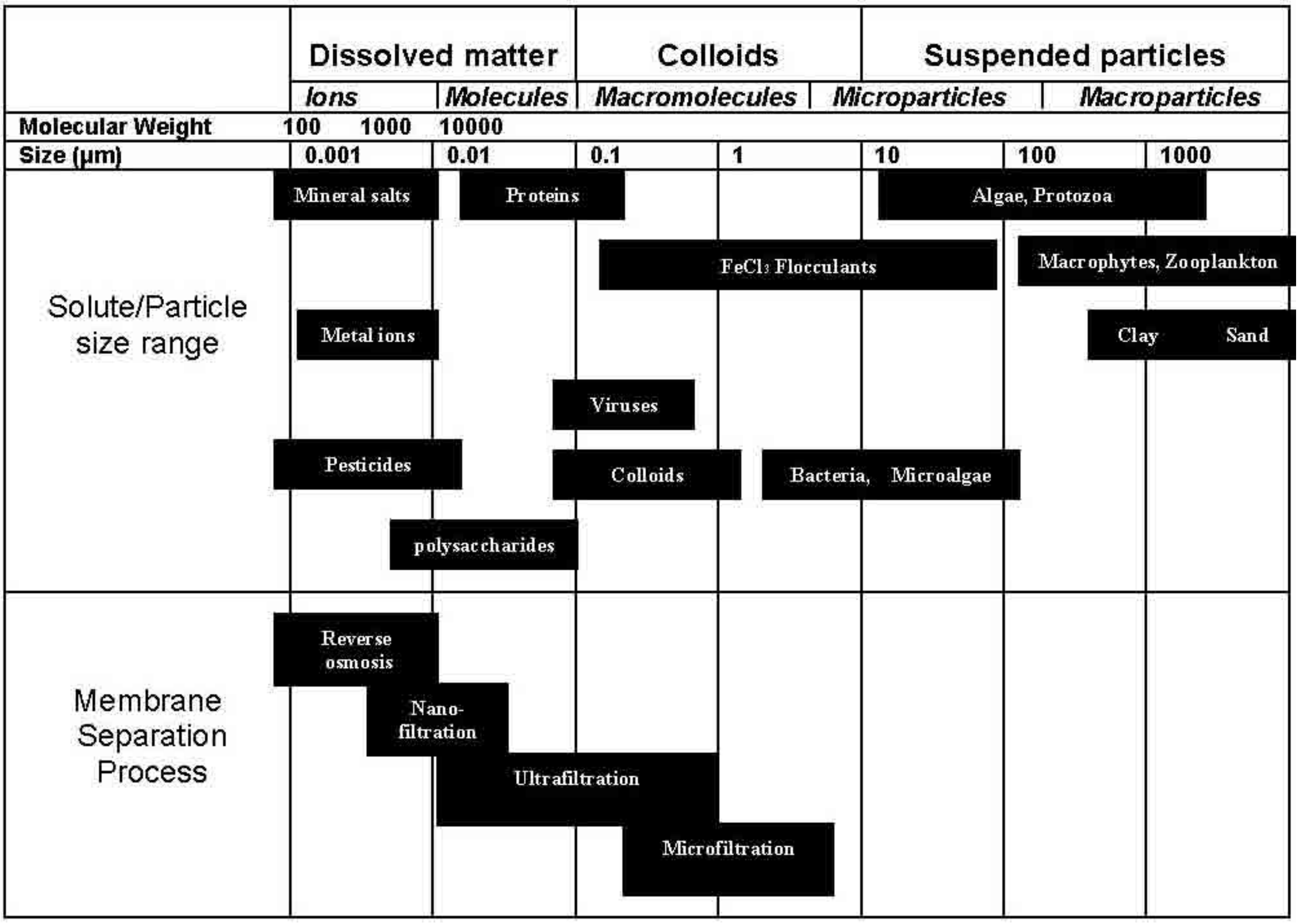
Options for components of the wastewater treatment process have been summarised by Asano (1999), and are reproduced in Figure 8.

Figure 8 Generalised wastewater treatment processes and operations, and effluent reuse schemes (Asano 1999, adapted from Asano, Smith and Tchobanoglous 1985).



Membrane technologies have advanced rapidly over the past decade, and choice of membrane will be determined by the filtration separation requirements. The particle size distribution effects of microfiltration, ultrafiltration, nanofiltration and reverese osmosis membrane technologies are shown in Figure 9. More efficient membrane technologies are reducing the energy costs of reverse osmosis to the point that there are now significant reductions in processing costs, leading even to the routine desalination of seawater as an economically feasible alternative source of large-scale water supply, though flash distillation may be used in the energy-rich water-poor countries of the Middle East.

Figure 9 Distribution of particle sizes showing the functional ranges of membrane technologies.



A major cost of water supply operations is the energy requirement for pumping. For example, it has been recently reported that the cost of seawater desalination in coastal Southern Californian cities would be no more than 30% greater than the current pumping cost of the existing inter-basin supply systems (Keene 2003). Nevertheless, successful membrane processing is highly dependent on pre-treatment technologies, and removal of any remaining sediments. It is preferable to divert industrial and potentially toxic trade-waste streams to alternative processing. In addition, the reject stream, which contains almost all the mineral and organic constituents of the original effluent, has potential to damage marine ecosystems unless mitigation is achieved through appropriate plant design (CCC 2003).

2.6 The National Water Quality Management Strategy

The National Water Quality Management Strategy, jointly developed between the former Agricultural and Natural Resource Management Council of Australia and New Zealand and the former Australian and New Zealand Environment and Conservation Council (but since June 2002, the responsibility of the Natural Resources Management Ministerial Council), contains twenty-one “Guideline” documents. Two of the Guidelines, no. 11 *Guidelines for Sewerage Systems – Effluent Management* (ARMCANZ/ANZECC 1997) and no. 14 *Guidelines for Sewage Systems – Reclaimed Water* (ARMCANZ/ANZECC 2000a), deal specifically with effluent discharges and subsequent alternatives uses. Stormwater is encompassed in Guideline no. 10, *Australian Guidelines for Urban Stormwater Management* (ARMCANZ/ANZECC 2000b).

2.6.1 Australian Guidelines for Sewerage Systems - Effluent Management

The *Effluent Management* Guideline covers, in general terms, the management of effluents and the extent to which they can be applied to land or can be discharged to coastal waters or inland waters depending on the treatment level applied. Sampling and monitoring guidance is also provided.

2.6.2 Australian Guidelines for Sewerage Systems – Reclaimed Water

The Guideline *Use of Reclaimed Water* sets out the quality required of reclaimed water and extent of monitoring that might be anticipated for secondary and tertiary treated effluents for various potential uses. These include indirect potable, urban (non-potable), agricultural, aquacultural, recreational impoundment, environmental and industrial uses. No guidance is provided on direct potable use. Guideline values are suggested for various use applications, primarily for how reclaimed/recycled waters may be incorporated into irrigation programs. Although there are references to turbidity (to some extent an aesthetic consideration), and to pH, the suggested parameters are primarily expressed in terms of thermotolerant coliforms (also known as faecal coliforms). The coliform values are given in table 4.

Table 4 Thermotolerant coliform standards for various recycled water use applications.

2.6.2.1.1 Recycled Water use application	Thermotolerant coliforms per 100 ml (median)
Non-human food chain	<10 000
Low contact, eg. Irrigation of open spaces with controlled public access	<1 000
Medium contact, eg. drinking water for stock (except pigs)	<100
High contact, eg. urban residential garden watering	<10

No guidance is given on protozoa in reclaimed water, and virus limits are not recommended. A risk management approach is missing from the document and its strong orientation towards land application for agricultural production provides only limited guidance for use of recycled water in the urban environment, and that primarily for amenity horticulture. Recycled water standards and progress in their review, recently initiated by the Natural Resources Management Ministerial Council and Environment Protection and Heritage Council, are further discussed in Chapter 5.

2.6.3 Australian Guidelines for Urban Stormwater Management

The current National Water Quality Management Strategy Guideline series also includes *Australian Guidelines for Urban Stormwater Management*. These encompass a multiple objective approach encompassing ecosystems, flooding and drainage control, public health and safety, economic considerations, recreational opportunities, social considerations and aesthetic values. These objectives are built around the principles of Integrated Catchment Management (ICM), taking a holistic approach to natural resource management within catchments, marine environments and aquifers, with linkages between water resources, vegetation, land use and other natural resource issues. The Guidelines seek to integrate social, economic and environmental issues. They encourage the coordination of all agencies of government and interest groups, and highlight community consultation and participating in the development of stormwater management. The need to tailor planning to each individual catchment is recognised.

The important issues are ecosystem health, achieving better water quality objectives, ensuring water for the environment and recognising the need for natural groundwater recharge to be maintained – the latter being of particular importance in Perth.

However, the thrust of the document is towards ensuring the conservation of natural ecosystems in the urban environment. Although the document recognises stormwater as a resource, it does not implicitly recognise that the human population is part of the urban ecosystem, and does not go as far as providing guidance on opportunities to integrate stormwater into the overall provision of water resources for community use. This issue is further discussed in Chapter 5.

2.6.4 Guidance on the use of rainwater tanks

Rainwater tanks have been used for many years in rural Australia and in Adelaide. A 1994 survey by the Australian Bureau of Statistics showed that 13% of all Australian households used a tank as a source of drinking water, the mean across all capitals being only 6.5%, while 30.5% of rural households had one (ABS 1994). The highest use was in South Australia with 37% of households having tanks, with 82% of the South Australian rural population having rainwater as their primary source of drinking water compared to 28% in Metropolitan Adelaide (Heyworth *et al.* 1998).

The use of rainwater is not without health risks. Coliforms including thermotolerant coliforms can be detected, and *Campylobacter*, commonly excreted by birds, has been recorded from rainwater. The use of rainwater tanks was not actively encouraged in some capital cities such as Melbourne and Sydney until quite recently, the likely reasons being slight health risks, the disinclination of urban residents to maintain their tanks in a clean condition, and potential competition with government-owned water supply authorities. Some metropolitan water boards in the past banned the domestic collection and use of rainwater (Workman, Herbert and Tink 2003).

Under the auspices of the National Environmental Health Forum, a joint venture between the Directors of Environmental Health from each State and Territory and the Commonwealth, Cunliffe (1998) prepared a monograph *Guidance on the use of rainwater tanks*, and a revised edition is nearing publication (Cunliffe 2004). It provides a valuable applied discussion of water quality and pollutants, tank construction, the size of tanks in relation to roof catchment area and rainfall, appropriate installation and maintenance, means of disinfection, mosquito control and the use of alternative sources if augmentation is required. It should be encompassed in the National Water Quality Management Strategy Guideline series.

2.7 The Uses of Recycled Water

There is a wide range of potential uses for recycled water, the actual use being a function of the standard to which the water has been reclaimed. In practice, the treatment is usually oriented to a commonly acceptable standard, but industrial users may be encouraged to further treat the water at the point of receival to meet their own particular needs.

The breadth of uses at different treatment levels can be illustrated from the experience in California where water reclamation and reuse has be practiced more than 50 years A range from their experience is given in table 5. The majority of water reuse is in agricultural irrigation (63 %) followed by landscape irrigation (13 %). At present, groundwater recharge is about 14 %, but may increase in the future (see Chapter 3.)

Table 5 Examples of Recycled water uses and the minimum treatment levels required to protect public health (California DWR 2003).

Types of Use	***Treatment level***		
	Disinfected Tertiary	**Disinfected Secondary**	**Undisinfected Secondary**
Urban uses and Landscape Irrigation			
Fire protection	√		
Toilet & Urinal flushing	√		
Irrigation of Parks, Schoolyards, Residential Landscaping	√		
Irrigation of cemeteries, Highway landscaping		√	
Irrigation of Nurseries		√	
Landscape impoundment	√	√*	
Agricultural Irrigation			
Pasture for milking animals		√	
Fodder and Fibre Crops			√
Orchards (no contact between fruit and recycled water)			√
Vineyards (no contact between fruit and recycled water)	√		√
Non food-bearing trees			√
Food crops eaten after processing		√	
Food crops eaten raw	√		
Commercial and Industrial uses			
Cooling & Air Conditioning with cooling towers	√	√*	
Structural fire-fighting	√		
Commercial Car Washes	√		
Commercial Laundries	√		
Artificial Snow Making	√		
Soil Compaction, Concrete Mixing		√	
Environmental and other uses			
Recreational Pools with Body contact (Swimming)	√		
Wildlife Habitat - Wetland		√	
Aquaculture	√	√*	
Groundwater Recharge			
Seawater Intrusion Barrier	√*		
Replenishment of potable aquifers	√*		
		** Restrictions may apply*	

Most of these uses are represented in Australia, and will be further discussed in Section 4, which deals with the current position of water recycling in each of the States and Territories.

Where the recycled water is being supplied through a pipeline system to users, such as for urban domestic, commercial or industrial use, or in agricultural areas which also have a reticulated potable water, the recycled supply system is usually described as a **third pipe** system (comprising a piped recycled water in addition to a piped potable supply and a piped sewage disposal [sewerage] system), or may be described as a component of a **dual reticulation** system. Some authors have suggested that the recycled water should be described as in a "fourth pipe" system, the first three being the systems for potable water, sewage, and stormwater (Marks 2004). The Australian use of dual reticulation systems in several locations is described in Section 4.

3 WATER RECYCLING OVERSEAS

There is evidence that wastewater was reused as a source of irrigation for agricultural crops more than 5000 years ago. Piping of sewage through sewerage systems became common in the 19th Century, but the inadvertent mixing of effluent into the water supply system led to major outbreaks of water-borne disease.

Disease transmission mechanisms and risks were recognised after the British and European epidemics of the 1850s, and separated sewage disposal became more common, discharging as raw sewage to water bodies, then later also after treatment.

Many of the world's cities remain without any sewage treatment system, discharging the raw sewage directly to land or water. This may pose serious health risks if the locations are immediately accessed for agriculture, aquaculture or direct human contact. Sewage being directly applied to food production systems is still common in developing countries. For example, in Hanoi City, greywater receives no treatment and runs down to wastewater ditches whereas urine and faeces are being used as organic nutrients. The urine may be separated, with the human and animal faeces stored together in underground tanks until used, then carried by bicycle to the field for application to agricultural fields and aquaculture ponds without adequate digestion. Vegetables are washed in these ponds; children swim in them. Though the fish from them are usually cooked before consumption, the vegetables are often served without cooking on top of noodles or in raw spring rolls. Only in Central Hanoi, sewage passes into an underground sewerage system, but then into ponds and open sewers (Takizawa 2002).

To protect farmers' and consumers' health, the World Health Organisation (WHO) published guidelines for the safe use of water in agriculture. They were developed on the premise that hygiene standards applied to wastes reuse in the past, based solely on potential pathogen survival, have been stricter than necessary. A meeting of sanitary engineers, epidemiologists and social scientists, convened by the World Health Organization, the World Bank and the International Reference Centre for Waste Disposal and held in Engelberg, Switzerland, in 1985, proposed a more realistic approach to the use of treated wastewater and excreta, based on the best and most recent epidemiological evidence. (WHO 1989).

Williams (1996) reviewed many overseas recycling projects and concluded that worldwide, water reuse was becoming an increasingly common component of water resource planning as opportunities for conventional water supply development dwindle and the costs of wastewater disposal climb. The greatest water recycling occurs in world regions suffering water scarcity, such as the Middle East, Australia or the US south-west, or in regions with severe restrictions on disposal of treated wastewater effluents, such as Florida, coastal or inland areas of France and Italy, and densely populated European countries such as England and Germany (Marsalek *et al.* 2002). Although Japan has a mean annual precipitation of 1714mm, population density is very high in the settled areas, some regions can suffer from water shortages, and urban wastewater reuse has become common (Ogoshi *et al.* 2001).

Examples of experience with water recycling in a number of countries follow.

3.1 United States of America

The United States Environment Protection Guidelines for Water Reuse (US EPA 1992) are currently being revised. These Guidelines were not produced as a standard to be applied in the United States, but rather to convey information to utilities and state regulatory agencies when standards do not exist or are being revised or expanded. The guidelines aimed to provide a comprehensive review of technical information (treatment processes, pathogenic organisms, storage requirements, types of recycling applications (industrial, urban, agricultural, environmental), and an inventory of the then existing state legislation, legal issues, funding alternatives, and public information programs. Details of water reuse programs in some other countries are given, though not about those in Australia. They note that for large systems, high level treatment and broad-scale indirect potable reuse is less expensive than implementing a dual reticulation system (Williams 1996).

The US EPA Guidelines are generally accepted to be more stringent than the WHO guidelines.

The USA National Research Council determined in 1998 that planned indirect potable reuse is a viable application of reclaimed water, but only when there is a careful, thorough, project-specific assessment that includes contaminant monitoring, health and safety testing and system reliability evaluation.

Indirect potable reuse is an option of last resort. It should be adopted only if other measures – including other water sources, non-potable reuse and water conservation – have been evaluated and rejected as technically or economically infeasible (NRC 1998).

An impediment to greater recycling of water in the United States of America has been the separation of water and sewerage service functions between separate agencies. In consequence, the responsible agencies may sometimes cover different geographical areas, making it difficult to achieve coordination for the most efficient use of water resources. This may be exacerbated by each of the organisations having different goals. A consequence is that the public and administrations have not recognised the potential benefits of water recycling, particularly the economic and environmental benefits of not unnecessarily expanding the potable water supply system.

An alternative difficulty can arise when there is considerable interest shown in direct and indirect potable recycling options without adequately evaluating non-potable recycling as a means of reducing the demand for the existing drinking water supply (Williams 1996).

Although wastewater recycling in the USA is predominantly oriented to disposal on land, there are now a number of schemes in place that in effect generate indirect potable supply. The principal ones are shown in Figure 10

Figure 10 Indirect potable water recycling facilities and the direct potable water recycling research facility in the United States of America (Ong Choon Nam *et al.* 2002).

3.1.1 California

The use of reclaimed wastewater for the irrigation of corn, barley, lucerne, cotton and pastures began in Bakersfield, California in 1912. California introduced its first regulations through its State Board of Public Health in 1918. Formal irrigation projects based on recycled water began from the 1920s, and by 1970, the California State Water Code stated (Asano 1998):

> *It is the intention of the Legislature that the State undertake all possible steps to encourage development of water reclamation facilities so that reclaimed water is available to help meet the growing water requirements of the State.*

In 1972, the US Congress passed the *Water Pollution Control Act of 1972* (PL92-500), to restore and maintain the chemical, physical and biological integrity of the Nation's water, with an ultimate objective of zero discharge into navigable, 'fishable and swimmable' waters.

California has progressively developed a set of Public Health laws related to recycled water that are summarised from the Health and Safety Code, the Water Code, and Titles 22 and 17 of the California Code of Regulations (State of California 2001) in a publication known as the *Purple Book* (DHS 2001). These have been widely adopted elsewhere as *de facto* standards, or have formed the basis of standards developed by other states and countries.

Among other aspects, the *Purple Book* provides that

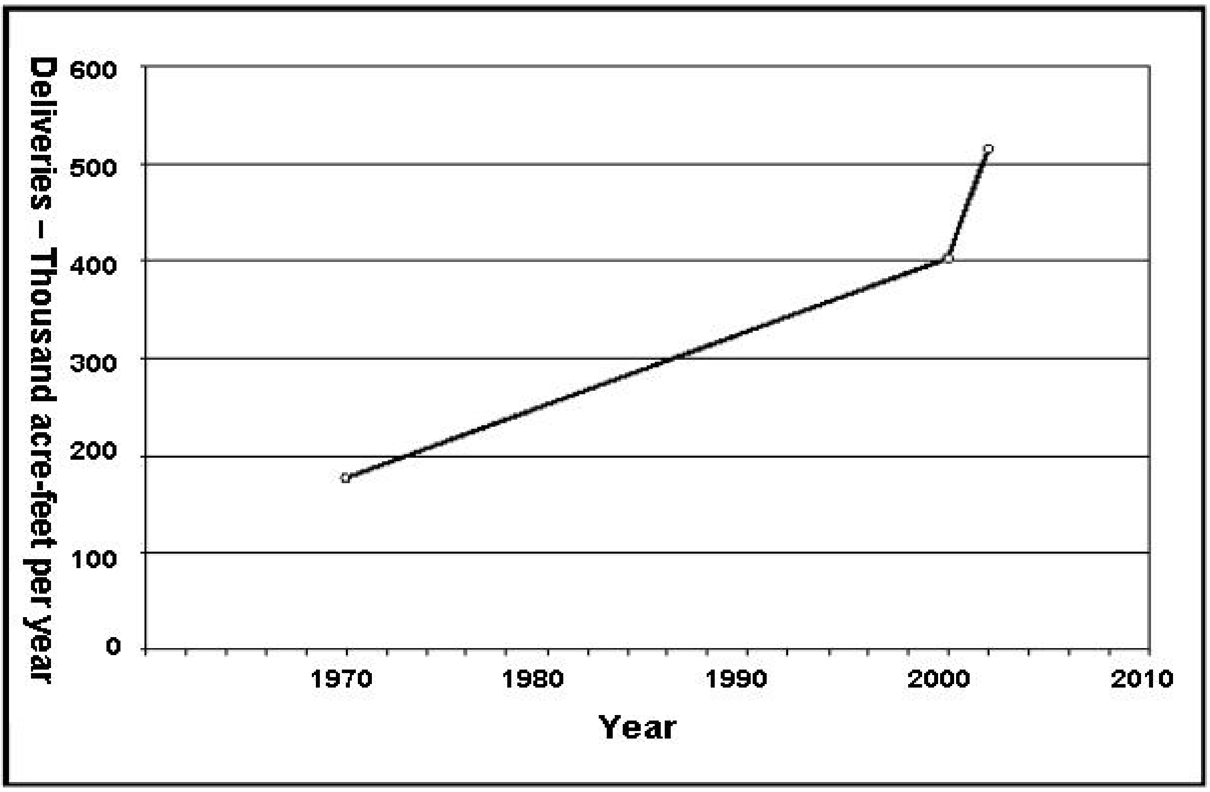
- Three public hearings are to be held for any recycling proposal.
- Wastewater treatment facilities shall provide for emergency storage capacity for 24 hours flow of untreated or partially treated wastewater, and a back-up power supply.
- There is to be no provision to by-pass the plant to the point of use.
- Multiple primary and secondary treatment units shall be fitted such that the plant can operate with one unit not in operation.
- Standards of water quality are set for various approved uses.
- Standards for disinfected secondary-treated water provide that the median concentration of total coliform bacteria does not exceed a most probable number (MPN) of 2.2 per 100ml over a seven-day analytical period, and that not more than one sample exceeds an MPN of 23 per 100ml in 30 days (a slightly lower standard is set for some non-contact uses).
- Standards for disinfected tertiary-treated water include chlorine residual standards, or with filtration processes, virus testing standards and that the median concentration of total coliform bacteria does not exceed an MPN of 2.2 per 100ml over a seven day analytical period, that not more than one sample exceeds an MPN of 23 per 100ml in 30 days and that no sample exceeds an MPN of 240 per 100ml.
- Turbidity standards must achieve an average of not more than 2 nephelometric turbidity units (NTU) for filter bed installations, (not more than 5% >2NTU for microfiltration/reverse osmosis systems) over a 24-hour period, and never exceeding 10 NTU (5NTU for microfiltration/reverse osmosis systems).
- Recycled water shall be in purple pipes or pipes wrapped with purple tape.
- Standards are set for dual potable/recycled reticulation systems.
- Backflow prevention devices shall be installed to protect the public water supply, the type to be a function of the assessed hazard.
- Systems shall be tested for any cross-connections every four years. Twenty cross connection incidents have been reported to California State Health since 1991(Safewaterreuse 2003).
- State, City or County agencies can require the use of recycled water for various purposes where it is available, does not cause any loss of water right and the connections comply with approved standards, (including use for domestic toilet and urinal flushing except in mental hospitals).
- There shall be no recycled water spray irrigation other than disinfected tertiary recycled water within 100 feet (30 m) of a residence or a place where public exposure could be similar to that of a park, playground or school yard.
- All areas where recycled water is used that are accessible to the public shall be signed “RECYCLED WATER – DO NOT DRINK”.
- The price of recycled water shall be equal to or less than the retail price of potable water.

The use of recycled primary effluent has been prohibited since 2000.

There has been a steady increase in the amount of wastewater recycled in California. In 2000, with a population of 35 million, approximately 600 GL of recycled water is being used across over 4800 locations from 234 wastewater treatment plants.

The trend of increasing use of recycled wastewater is shown in Figure 11.

Figure 11 Recycled water use in California, 1970-2002 (DWR 2003)



A range of different technologies and policies has been adopted by Californian communities within the framework of the Californian Codes. Much of the initial recycling has been based on groundwater augmentation (Asano 1998).

During 2002, the California State Water Resources Control Board conducted a survey of the extent and distribution of water recycling in California. The results of this survey show the variation in distribution across different regions of the state, but indicate widespread adoption of recycling except in the northern region of the Central Valley (Table 6).

Los Angeles County has been surface-spreading reclaimed secondary water, which has been passed through a dual media filtration system and then chlorinated, into the Whittier Narrows Groundwater basin since 1962. Potable water is subsequently withdrawn. It has been estimated that up to 23% of the potable water is indirectly recycled water.

The **West Basin Municipal Water District** has substituted reverse osmosis-treated secondary effluent for the potable water it has been using since the 1950s to inject into the coastal South Bay aquifers to mitigate salt water intrusion. The net effect of injecting the recycled water, which is of higher quality than the local water previously used, will be to improve water quality in the groundwater basin.

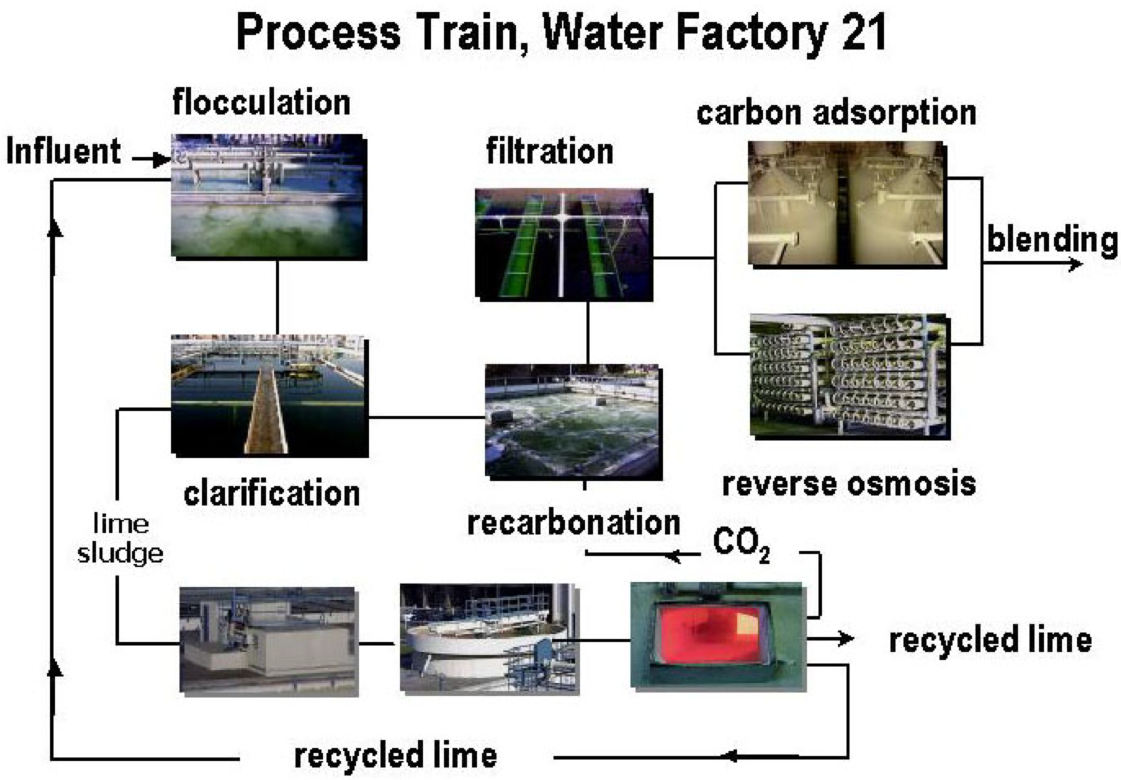
Table 6   Recycled Water Use in California (DWR 2003).

Types of Reuse	Volume of Recycled Water use within Regions*, Acre-Feet/year											
	1	2	3	4	5F	5R	5S	6	7	8	9	Total
Agricultural irrigation	12,694	8,318	22,110	3,752	110,046	1,314	35,349	8,588	2,951	30,795	5,033	**240,951**
Landscape irrigation	2,675	10,114	3,152	26,229	80	51	1,431	8,418	6,624	28,135	24,191	**111,100**
Industrial use	0	4.865	26	22,376	0	61	264	65	0	199	0	**27,857**
Groundwater recharge	0	0	0	46,247	0	0	2,500	0	0	0	286	**49,033**
Seawater barrier	0	0	0	10.651	0	0	0	0	0	15,000	0	**25,651**
Recreational impoundment	0	0	0	24,429	111	0	0	7,347	0	0	1,216	**33,103**
Wildlife habitat, miscellaneous.	1,977	6,198	5	6,437	0	0	1,009	0	172	4,361	41	**20,200**
Geysers/Energy Production	0	0	0	2,198	0	0	0	0	0	0	0	**2,198**
Other or mixed type	0	25	0	9,997	0	0	0	0	0	5,l59	188	**15,369**
TOTAL	**17,346**	**29,519**	**25,295**	**152,316**	**110,238**	**1,427**	**40,552**	**24,418**	**9,747**	**83,650**	**30,955**	**525,462**

***California Water Resources Control Board Regions** – 1. North Coast; 2. San Francisco Bay; 3. Central Coast; 4. Los Angeles; 5. Central Valley; (5F. Fresno Office; 5R Redding Office; 5S Sacramento Office): 6 Lahontan; 7. Colorado River Basin; 8. Santa Anna; 9. San Diego.

Orange County Water District has operated its **Water Factory 21** since 1976, using lime clarification, air stripping, and recarbonation, filtration, carbon adsorption, reverse osmosis and disinfection of unchlorinated secondary effluent (Figure 12).

Figure 12 Process train, Water Factory 21. The process stream divides into Carbon Adsorption and Reverse Osmosis in final stage (Mills, 2003).



The recycled water from Water Factory 21 is used for a groundwater replenishment scheme, being injected into the groundwater basin to prevent salt-water intrusion and maintain a freshwater aquifer. This was the first use of reverse osmosis for water treatment (Law 2003). Up to 5% of this water may return to the potable supply from the basin. There has been no evidence of any significant risks from this practice.

As a result of the success of Water Factory 21, the California Department of Health Services proposed regulations to govern future indirect potable reuse projects involving groundwater recharge. Aspects included that no more than 20% of injected water or 50% of surface spread water should return to the potable system over 5 years, that reclaimed water shall remain underground for 12 months (direct injection) or 6 months (surface spreading), and that in effect, carbon adsorption or reverse osmosis were likely to be the only feasible reclamation processes.

The **Irwin Ranch Water District**, which serves southern Orange County, has maintained separate water lines to provide both raw water and reclaimed water for irrigation uses since the late 1960s. In 1991, it began the supply of recycled water in the first of a group of six high-rise office building fitted with dual plumbing, the recycled water being provided for non-potable purposes, notably toilet flushing. The water meets the advanced tertiary standards of California's Title 22, the plumbing is located within the central core of the towers, the maintenance of services is contracted, and the office workers who constitute the regular users of the buildings, are familiar with the recycled water and its use.

Irwin Ranch has now mandated recycled water for high-rise buildings. Possible cross connections are checked for once a year, or whenever there is a change of tenancy.

Figure 13 High-rise office buildings, Irvine Ranch Water District
US EPA, District 9

Williams (1996) quoted potable water as then being priced at US 33c/kL, while recycled water was charged for at US 30c/kL, with approximately 20% of the water supply to the Irvine Ranch Water District then being reclaimed water. The cost of dual plumbing systems has been estimated to increase plumbing capital costs in buildings over seven stories by only 9% (US EPA 2002). The requirement for reuse has in part been driven by the high cost of purchasing water from the Metropolitan

Water Districts of Southern California and it became economical to retrofit recycled water pipelines to older parts of the city (Williams 1996).

The supply system is interconnected with that of the Orange County Water District to provide the opportunity for shut-down for maintenance, the arrangement being covered by a MoU between the agencies. (Mantovani *et al.* 2000)

A major groundwater replenishment scheme, costing $US450 million, is currently being built in Orange County. This will be based on 160ML/day of recycled water, which meets Federal drinking water standards and will be on-line in 2007. The scheme will combat possible future water shortages that would otherwise require rationing or permanent water restrictions (GRS 2003).

San Diego established a water recovery demonstration facility in 1983. This involved secondary treatment using a water hyacinth aquaculture system, coagulation, clarification, filtration, ultraviolet disinfection, reverse osmosis, aeration, carbon adsorption and disinfection to compare the recovered water with the city's raw water source. The plant demonstrated that from a health perspective, the outcomes of its use were as good or better than obtained from the raw water system.

The Californian Department of Health Services subsequently approved in concept the addition of recycled water to drinking water supplies held in local reservoirs.

However, when San Diego later tried to establish an 80 ML/day reverse osmosis/groundwater recharge recycling plant, with the water subsequently to be brought back for indirect potable consumption, a vocal fraction of San Diego citizens opposed it. Opposition even took on racial overtones when it was pointed out— falsely— that treated wastewater from wealthy northern neighbourhoods would be distributed to poorer urban communities, which would be forced to drink 'the effluent of the affluent'. The opponents of the repurified water project brought large display boards to public meetings showing directly piped connections between the toilet and the kitchen faucet ('toilet to tap'), implying that no treatment was applied to the wastewater. The plan was shelved (Sheikh 2003).

However, the California Legislature passed Assembly Bill 331 in 2001 establishing the creation of a 2002 Recycled Water Task Force to identify constraints, impediments and opportunities for the increased use of recycled water and report to the Legislature by July 1 2003.

The Report (California DWR 2003) noted that in general, the public has accepted Department of Health Services Regulations for various uses of recycled water, but in some cases the public has not been receptive to using recycled water to recharge groundwater basins that serve as drinking water supply sources. It noted that some reuse proposals have been mischaracterised by images of recycled water being fed directly into drinking water pipeline systems. The Task Force found that the public needed to be involved much earlier in the decision-making processes for new projects, and to be provided with facts early in project planning. Other issues included lack of local funding for infrastructure, research on emerging contaminants and public health concerns. A total of 26 recommendations were made encompassing community decision-making, leadership, education, uniform plumbing codes, clarified cross-connection control, the need for bans on or more stringent controls on domestic water softeners and additional state-sponsored research and university education programs. It suggested that the Department of Housing and Community Development should remove the requirement for 'skull and crossbones' from the California Plumbing Code. Taking into account a projected 17 million increase in the Californian population by 2030, the Task Force suggested that expanded recycling could substitute for enough fresh water to meet 30-50% of the total household water demand.

Incentives for Californian urban areas to recycle water, possibly in combination with support programmes, are (California SWRCB 2003):

- Water Recycling Facilities Planning Grant Program, which provides grants up to $75,000 to local public agencies to investigate the feasibility of water recycling and to prepare a facilities plan documenting the analyses and conclusions of the investigation.

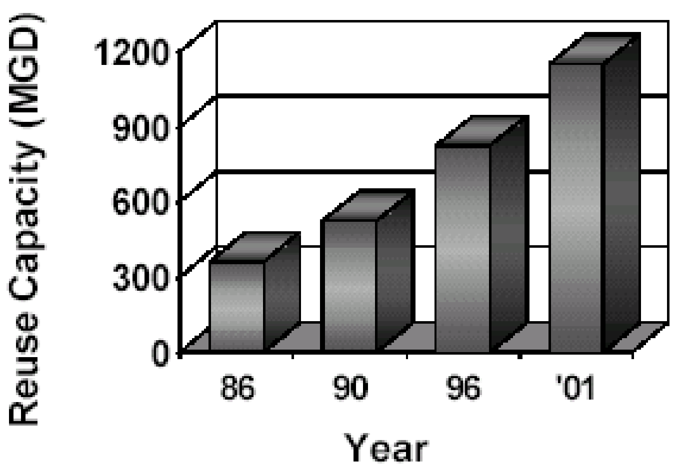
- Water Recycling Construction Program, which provides low-interest loans and grants to local public agencies for the design and construction of water recycling facilities. The types of facilities include wastewater treatment, re-cycled water storage facilities, pump stations, and recycled water distribution pipelines. A funding application must include a facilities plan to document the need for the project, the alternatives that were analysed, and the engineering, economic, financial, and institutional feasibility of the proposal.

3.1.2 Florida

Florida, with a population of 16 million, is the fourth most populous state in the US, and the second-largest user of recycled water after California. Use has increased rapidly since 1986 (Figure 13).

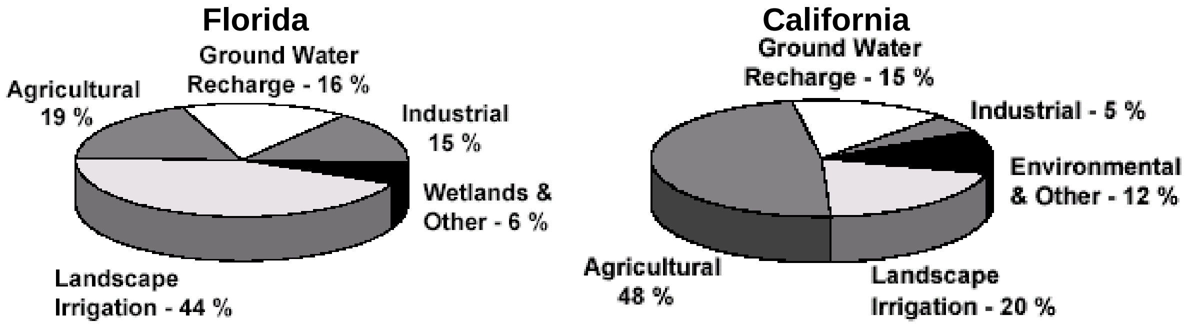
In 1995, Florida secured 60% of all its freshwater, and 90% of its public water supply from groundwater.

Figure 14 Increase in recycled water capacity, Florida, since 1986 in million gallons per day (MGD) (Florida Reuse Committee 2003).



The use of Florida's recycled water differs from that of California, with landscape irrigation being much more important and agricultural use much less important in Florida than California (Figure 14).

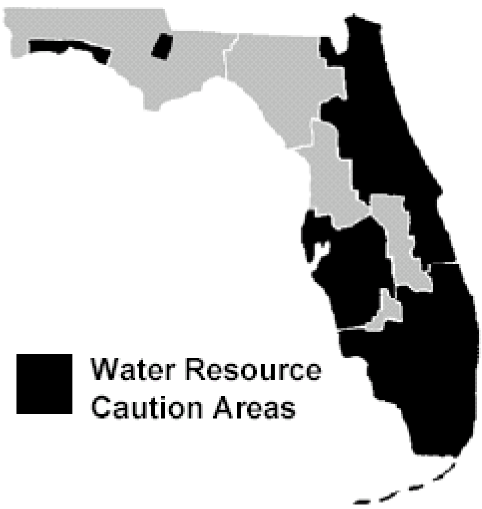
Figure 15 Percentage uses of recycled water production in Florida and California (Florida Reuse Committee 2003)



Florida's water consumption is distributed between agriculture (46%), public domestic supply (34%) and the industrial, commercial, electricity generation, recreation, irrigation and domestic self-supply sectors. Reuse is perceived to provide an environmentally sound means for managing wastewater, dramatically reduces environmental impacts of discharge and provides an alternative supply for many uses not requiring drinking water standards. Reuse can also be used to recharge and augment existing available water supplies.

Many of the state's counties have been designated "water resource caution areas" (Figure 12) with current or likely future critical water supply problems. However, there are wide variations in the extent made of water recycling in Florida's 64 counties. Ten counties have between 80 and 100% reuse.

Figure 16 Florida Water Resource Caution Areas (Florida Reuse Committee 2003).



The State average reuse is 39%, but many counties have very little reuse. Maimi-Dade and Brownard Counties, which between them represent 24% of Florida's population and generate 33% of the wastewater, manage only 5-6% reuse. (Florida Reuse Committee 2003)

Florida has a mandated reuse program, which is actively enforced, particularly in the "water resource caution areas" (Crook 1998). All automatic sprinkler systems installed after May 1991 must have a rain sensor fitted or a rain shut-off device to prevent waste of water and excessive run-off.

Examples of recycled water use in Florida include:

- The **St Petersburg** dual distribution system, which uses highly treated recycled water for irrigating 8000 homes, 46 schools, 66 parks and 6 golf courses, is one of the most widely known reuse systems. It has been operating since 1977. The scheme prohibited the use of hose connections until 1995, previously garden irrigation being limited to in-ground sprinkler systems (Mantovani *et al.* 2001).
- The **CONSERV II** project, which depends on the recycled water rapidly infiltrating a network of basins to recharge groundwater for both **Orange County FL** and **Orlando**, and is then used to irrigate 11500 acres of citrus, eight nurseries, a tree farm and a fernery.
- Using recycled water from the Ironbridge STP, **Orlando** created a 1240 acre wetland that is the centrepiece of a park and nature reserve featuring hiking, jogging and biking, using about 5.1 mgd.
- **Gainesville** uses recycled water from its Kanapaha STP with 7.1 mgd recharging the Floridian Aquifer through deep wells, with 0.3mgd being used for irrigation and the Botanical Gardens.
- **Walt Disney World Resort Complex,** using recycled water from Reedy Creek Utilities for five golf courses, highway medians, a water park and a 110 acre tree farm growing horticultural produce for the Complex (Florida DEP 1996).
- **Curtis Stanton Energy Center** for cooling coal-fired boilers.
- **Tampa's McKay Bay Refuse-to-Energy Centre** for non-contact cooling water.

Tallahassee began land application of recycled water in 1966, and by 1992, about 70ML/day was being applied to a 700Ha farm. Subsequently, a 30ML/day biological nutrient plant was installed, decreasing the nutrients going to the farm and reducing the economics of the operation, with the result that the contracted farmer declined to renew his previous contract (Williams 1996).

The **City of Altamonte Springs** instituted its **Project Apricot**, an acronym for 'A Prototype Realistic Innovative Community of Today'. This name was supposedly chosen to upstage the nearby Disney World City EPCOT – 'Environmentally Planned City of Tomorrow' (Williams 1996). Altamonte Springs' recycling is based on an activated sludge, highly chlorinated, secondary treatment scheme with nitrogen removal. A dual water supply system has been built throughout the city with recycled water being used for household irrigation and car washing. It can be used for vegetable growing provided the produce is peeled, cooked or thermally processed before consumption, or alternatively, a drip type irrigation system can be used. The water is also used for the fire mains, ornamental fountains and ponds and for toilet flushing in commercial buildings. Aboveground outside taps are prohibited to minimise misuse of the water. Belowground taps in lockable boxes are allowed, with any hoses being disconnected after use. All commercial and multi-family dwellings were required to connect to the system within 90 days of its establishment in 1989, and all new single houses constructed after January 1989 were required to connect to the system. The City engaged in a detailed communication program with its residents, making it clear that reclaimed water was not to be used for unapproved purposes such as drinking, swimming pools, hot tubs, wading pools and children's water toys Meters for recycled water were fitted to commercial buildings and multi-unit dwellings, but not to single family houses. Commercial users and condominiums were charged 82c/1000 gallons, while single dwellings paid a flat fee of $10.00 per month for recycled water service. (Altamonte Springs 1997). The scheme has led to a 30% reduction in potable demand, but with the reclaimed water priced at 40% of potable rates, shortages occur in hot weather. Sewage is imported from other utilities for treatment to meet the demand (Mantovani *et al.* 2001).

In contrast, the **City of Sanford** metered all properties in anticipation that the recycled water would become a valued resource (Marcous and Porter, 1997). New subscribers were presented with a list of 12 subscriber responsibilities including the necessity to inform renters of these responsibilities if the property were let out. Detailed sprinkler system requirements were defined. Subscribers are required to sign an agreement waiving liabilities from the city for any damages that may occur due to use of the recycled water (Marcous 2000).

Despite very strong US proscription against cross-connecting recycled and drinking water systems, such a connection was found in July 2003, inadvertently made to four houses by utility workers in **Cape Coral**, FL. One house had been so connected for three months and two others for one month. The lines were subsequently flushed and chlorinated, with the City agreeing to meet any medical bills (USA Today 2003).

3.1.3 Other States

Virginia's Upper Occoquan Sewage Authority (UOSA) began reclaiming wastewater for discharge as a source of indirect potable supply into the 40GL Occoquan Reservoir in 1978. This reservoir supplies up to one million people in Northern Virginia and in droughts, receives up to 90% of its water from the reclaimed supply, which typically represents 15% of the reservoir volume. The current technology involves secondary treatment followed by high lime treatment, clarification, recarbonation, sand filtration, granulated activated carbon (GAC), ion exchange and chlorination. Negative health effects have never been recorded. Ongoing quality monitoring is carried out by an independent panel of review (McEwen, 1998, Law 2003).

Colorado's Denver Water, the water supply agency of Metropolitan Denver, instituted an experimental plant in 1983 to examine alternative technologies for the production of recycled water suitable for direct potable reuse. After seven years, it instituted a lime clarification, recarbonation, filtration, ultraviolet light intermediate disinfection, carbon adsorption, reverse osmosis, air stripping, ozone primary disinfection and chloramine secondary disinfection treatment system and subjected it to comprehensive health effects testing. The results of this $US30 million program unequivocally verified the ability of advanced water treatment processes to reliably remove a broad spectrum of pollutants and render a product which satisfied every then known measure of drinking water safety (McEwen 1998). In 1990 a proposal by Denver Water to build the large Two Forks Dam was quashed by the US EPA. Denver Water had subsequently been intending to provide water services to Denver International Airport using recycled water for indirect potable supply, but in the mean time, the separate Denver Metro Wastewater Reclamation District had already expanded an existing plant to provide wastewater treatment for the Airport. This highlights institutional problems that can arise when different agencies are separately responsible for water and wastewater.

The **Las Vegas** Water District, Nevada, was operating near the limit of its entitlement of 360 GL of water per year from Lake Meed (Hoover Dam), but was able to secure increased water by return flow credits from discharges from its sewage treatment plant. Williams (1996) reported that it was returning about 180 GL/year back to Lake Meed. The system of giving credit for return flows has acted to ensure there is no incentive for moving to direct recycling.

The increasing interest in the United States is demonstrated by the recent passage of bill H.B. 2016 in **Louisiana** (Louisiana Legislature 2003) which mandates a reclaimed water program for the state and prohibits the use of potable water for irrigation at parks, cemeteries, golf courses and highway landscaped areas when recycled water is available. The water must be provided at or less than the cost of potable water.

3.2 Canada

On the whole, Canada has abundant supplies of water in most regions. Recycling is on a relatively small scale, involving agricultural and golf course irrigation in British Columbia, Alberta, Manitoba and Saskatchewan, and at isolated resorts and truck tops in British Columbia and Ontario. There are no Federal guidelines on water recycling, though Provincial guidelines have been developed in British Columbia and Alberta.

However, recognising increasing water demands on finite supplies, opportunities to save on future expansion of water supply infrastructure the need to eliminate effluent discharge to sensitive receiving waters, and scope to inexpensively provide water in isolated places, the Canadian Council of Minsters of the Environment sponsored a workshop in 2002 at which agency representatives and scientists discussed water quality issues relating to water reuse and recycling (Marsalek *et al.* 2002).

The workshop recognised the need for National Guidelines requiring Federal leadership; that Provincial quality standards would be required; noted the emergence of new contaminants of concern such as endocrine disruptors and pharmaceuticals, and foresaw the increasing use of reclaimed water for wetland preservation, stream flow augmentation and groundwater recharge.

The workshop identified the need for

- Performance criteria, validation protocols and technology demonstration, particularly for small scale decentralised treatment facilities.

- Policies that encouraged full-cost pricing of water resources.
- Design standards and a public education program for national and provincial reuse programs.
- Applied economic analysis and management systems to assess the feasibility of proposals.
- Effective public consultation and communication programs.
- Meeting additional research needs including for emerging health issues, long-term impacts, risk assessment methods, the development of well defined multiple barrier strategies, economic analyses capacity and the encouragement of improved collaboration.
- Creating a standing task force on water recycling, with periodic follow-up workshops and greater electronic networking.

3.3 Namibia

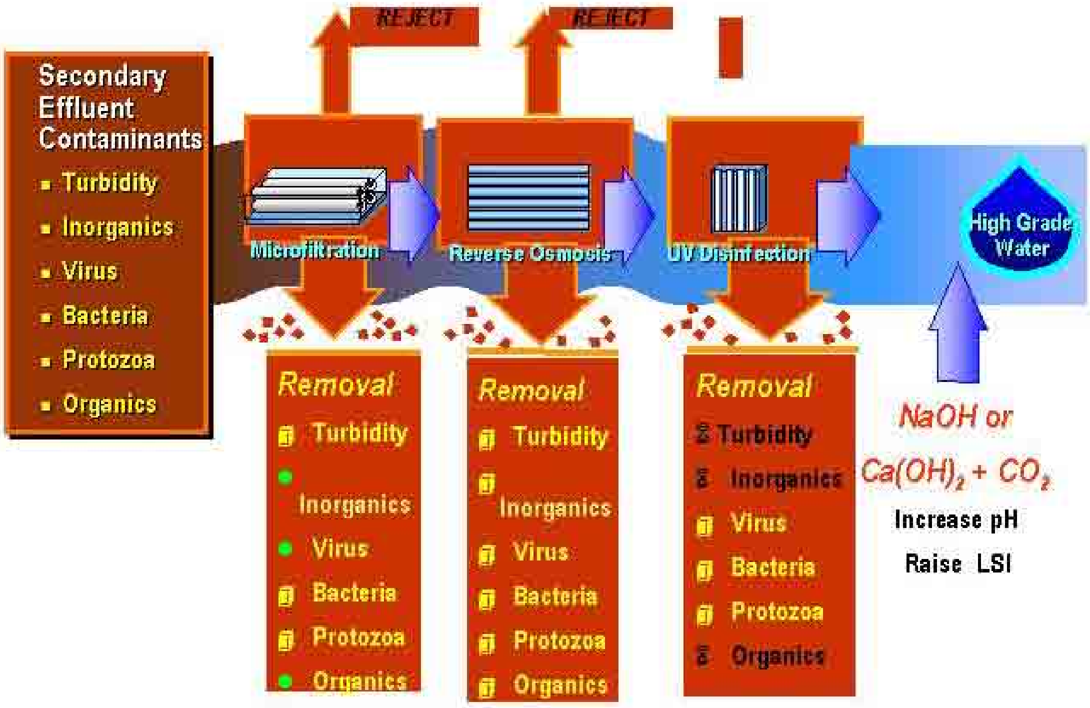
Windhoek, now the capital of Namibia, is in an area of low rainfall, high evaporation and limited catchment. It has exploited all surface water resources within 500km, maximum groundwater utilisation has been achieved, demand management policies are in place, and following establishment of the first experimental direct potable plant in 1969, now depends on direct recycled potable supply. The original plant was built with secondary treatment followed by algae floatation, foam fractionation, chemical clarification, sand filtration, GAC and chlorination. This would no longer be seen as an acceptable treatment production train and the plant has been upgraded four times. It currently comprises improved secondary treatment followed by pre-ozonation (for iron and manganese), dissolved air floatation, sand filtration, ozonation, GAC, ultrafiltration and chlorination. Epidemiological studies have shown no increased incidence of illness or disease associated with this water recovery and reuse practice (Odendaal *et al.* 1998, Law 2003).

3.4 Singapore

Singapore, being a small island, has a very limited catchment, and imports half of its water from Malaysia. The continuity of this supply is subject to periodic bilateral renegotiation, which leaves the country in a long-term insecure position. Singapore is examining the use of desalination as a future resource, but has already commissioned a demonstration water recycling plant in May 2000 to produce recycled ***NEWater*** at its Bedok STP, based on the recommendations of the National Research Council USA, (NRC 1998).

Water to the demonstration plant is a clarified secondary effluent from an activated sludge treatment process. The effluent is first microscreened, followed by microfiltration (MF) to remove suspended solids, prior to demineralisation with reverse osmosis (RO). As a last step, the RO permeate is disinfected by ultraviolet irradiation. Two parallel 5 ML/day reverse osmosis trains are provided, each fitted with thin film aromatic polyamide composite membranes configured for 80-85% recovery in a three-stage array, followed by three UV units in series. The general layout is shown in Figure 16.

Figure 17 Schematic overview of the Bedok water recycling process used for the production of *NEWater* (Leslie 2004).



The purpose for constructing and operating the demonstration plant was twofold - to establish performance and operational ranges for the dual-membrane and UV disinfection processes; and to assess the physical/chemical and microbial water quality of the high-grade reclaimed water through a rigorous 24-month sampling, analytical testing and monitoring programme. A number of lessons were learned. The extent of turbidity (>10 NTU) in the effluent from the secondary treatment has a deleterious impact on the performance of the microfiltration. Inflows of tidal seawater into the sewer system through leakage ultimately result in reduced performance of the reverse osmosis component of the plant. Biological fouling can develop on the membranes, reducing their effectiveness, but any free chlorine (>0.1mg.L) that is part of anti-fouling can damage the membranes. Other forms of fouling can also reduce the effectiveness of the reverse osmosis membranes, requiring increased operating pressures and frequency of cleaning (Law, Leslie and Poon 2003).

A review by an Expert Panel showed that the plant operated at 80-82% recovery, consumed power at 0.7-0.9 kWh/m^3, and inactivated micro-organisms at better than a 7-log (99.999999%) level. It was concluded that after two years, the *NEWater* Factory has demonstrated that *NEWater* can be produced consistently and reliably on a large scale, is safe for potable use, and the Singapore Government should consider the use of *NEWater* for indirect potable reuse as a safe supplement to the existing water supply (Ong Choon Nam *et al.* 2002).

Two full-scale plants became operational at Bedok and Kranji respectively in 2002, primarily serving high technology industries. The first water was delivered to Wafer Fab Parks at Tampines/Pasir Ris and Woodlands in Feb 2003. A small portion of the recycled water is being returned to a raw water reservoir from which it is subjected to the normal water supply treatment regime.

A major public communication program has accompanied the development of the NEWater plants, with visitors, particularly schoolchildren, being encouraged to inspect the plant so they are familiar with its operation and comfortable with using the water.

Figure 18 Visitors are encouraged to visit the NEWater plant in Singapore (Turner 2003).

3.5 Japan

The steep topography and very short rivers make stable water conservation difficult. Nearly 65% of the Japanese population has access to sewage services. Approximately 150 GL of water is recycled annually in Japan. Uses include environmental use (52%), snow melting (18%), agriculture (13%), Industry (5%), toilet flushing (5%) and use within plants (5%) (JSWA 2002). Primary interest is now oriented to urban recycling. In 1997, 163 publicly owned STPs provided water recycling in 192 use areas, and 1475 on-site individual building and block-wide water recycling systems provided toilet flushing water in commercial buildings and apartments as well as water for landscaping. Much of this is driven by the existing potable water infrastructure being unable to cope with the increasing building density. The toilet-flushing water criterion is 1000/100 mL faecal coliforms compared with that in California where the standard is 2.2/100 mL. There is an assumption that no cross connection will occur, so no annual cross connection inspections are required. Reclaimed water has been important in the restoration of aquatic environments. With the rapid growth of urban sprawl in many cities and the subsequent construction of sewers and flood control channels, many small urban streams have been neglected and their aquatic environments degraded. Agricultural use is much less important than in many other countries (Ogoshi *et al*. 2001).

Tokyo producing guidelines on the reuse of treated ‘miscellaneous-use’ water in 1984. Based on these guidelines, Tokyo directs the operators of large-scale buildings, with a floor area of more than 30,000 m^2 or that use a daily total volume of 100 m^2 of water for non-drinking water purposes ('miscellaneous-use') to use recycled water. Methods of recycling treatment to produce miscellaneous-use water include:

- **Individual water reuse systems** in which miscellaneous-use wastewater discharged by one building is treated in-house and reused in the same building;
- **District water reuse systems** in which miscellaneous-use wastewater from multiple buildings is collected in one building, treated, then supplied to the other buildings for reuse;
- **Wide-area water reuse systems** in which water treated by a sewage treatment plant is recycled to buildings for reuse; and
- **Industrial water use systems**, involving recycling within the industrial enterprise.

Whichever of the above methods most suits the actual situation is adopted in order to promote the reuse of treated water (Tokyo Metropolitan Government, 2001a).

The number of recycling schemes in the first three categories (above) is shown in table 7, and includes 50 housing complexes encompassing 39,170 households (Tokyo Metropolitan Government 2002).

Table 7 Number of in-building, district and wide area recycling schemes, Tokyo, March 2001 (Tokyo Metropolitan Government, 2001b)

区分 Category	件数（件） Number of systems	循環利用水量（m^3/日） Volume of treated water (m^2 per day)
個別循環 Individual water reuse	288	43,080
地区循環 District water reuse	162	18,857
広域循環 Wide-area water reuse	96	16,985

In addition, in 1998, the Tokyo Municipal Government established guidelines for the utilization of rainwater, which is an important water resource for cities, in order to promote the utilization and permeation of rainwater into soil and to ensure the recycling of rainwater. Guidance is being given to the owners of buildings measuring 10,000 square meters and over in floor space and the companies that carry out development projects covering land spaces measuring 3,000 square meters and over to promote the use and permeation of rainwater. Facilities for reusing rainwater are installed in government buildings, high schools, junior high schools, and sporting facilities such as the Ryogoku Sumo Stadium, and the Tokyo Dome.

In **Osaka**, the Osaka Prefecture has developed a 21st Century Master Plan for a new Osaka Prefectural Sewerage System and aims to develop 30% recycling by 2013 and 100% recycling by about 2030. By April 2002, the Nagisa plant of the left bank of the Yodo River regional sewerage system, using an activated sludge base system, was each day processing 115 ML of sewage, 10% of which is recycled, 4% being used within the plant. The remainder is used in Hirakata City for landscaping, as a heat exchange source for air-conditioning the City General Welfare Centre, for fire mains and for toilet flushing in the Keihan Hirakata city railway station. Water is also available at the plant without charge for users to tanker to industrial plants, for example, for concrete batching. Experimental rice production is also being trialled (Hattori 2003)

Figure 19 Civic water wall and planting, using recycled water, with interpretive sign, Hirakata Civic Centre

Figure 20 Fire hydrant using recycled water, Hirakatashi Railway Station

(John Radcliffe)

Fukuoka, located on the northwestern end of Kyushu, despite having an annual precipitation of 1,600 mm, has a watershed with only small rivers and dams, and suffered major water shortages in 1978 and 1994. In becoming much more water conscious, the city has promoted three different systems to reuse reclaimed water for toilet flushing. There is a wide area system covering 770 Ha in the centre of the city, including City Hall and the subway stations. A district circulation system serves several apartment complexes each equipped with their own treatment facilities that recirculate recycled water within the complexes. The third system is an individual facility circulation system that is provided to reclaim non-faecal water in buildings supplied with 50mm or larger pipes or buildings with a total floor area exceeding 5 000m². In 1996, 384 facilities, and 2 apartment complexes were using recycled water that amounted to 7ML/day. Using rainwater for toilet flushing is also being explored (Shinoda 1999). The price of recycled water in Fukuoka is 16% less than the price of domestic potable water (Mantovani *et al.* 2001).

Yokohama has a 70,000-seat International Stadium covering a site of about 142,000 m^2 with seven stories, making it the largest stadium in Japan. Under the stands can be found the Sports Community Plaza (a community leisure facility with swimming pools,) and the Yokohama Sports Medical Centre. Treated wastewater, initially 2.5 ML/day, but later 5 ML/day, after undergoing advanced wastewater treatment at the Kohoku STP, is supplied to the Stadium for use as a heat source for a heat pump, then for multiple purposes such as flushing toilets, for sprinklers, and for artificial streams in parks neighbouring the stadium (Takeishi 1999).

Sapporo, located on the northern island of Hokkaido where there is much snow, uses recycled water, which emerges at 13 degrees, for winter snow melting and also for restoration of environmental flows (SSB 2003, Funamizu *et al*. 2001).

Japanese toilets are often fitted with dual flush arrangements and the water that fills the cistern enters through a gooseneck spigot under which hands may be washed as the toilet is filling, representing itself a form of recycling in the toilet room.

Figure 21 Japanese toilets are often fitted with dual flush; the small lever is turned left or right according to the desired flush volume. Hands may be washed under the water subsequently filling the cistern. (John Radcliffe)

3.6 Europe

Renewable water resource exploitation rates in some European and Mediterranean countries are becoming quite high. When the exploitation rate begins to exceed 20%, water management becomes a vital element in the country's economy. Some current exploitation levels include Hungary 114%, Israel 109%, Belgium 106%, Tunisia 87% and Netherlands 78%. Exploitation in Germany is 48% of renewable resource yield, while the figures in France and Britain are 21% and 17% respectively (Lazarova *et al.* 2001).

The European Urban Waste Water Treatment Directive (91/271/EEC) defines standards for the collection, treatment and discharges of urban wastewater and wastewater from some industrial sectors. The Directives states that (with a few exceptions) all urban waste water discharges greater than 10,000 person equivalents to coastal waters and greater than 2,000 person equivalents to freshwater and estuaries will be subject to secondary treatment by the year 2005. Hence in Europe, the development of water reuse is being driven by the need for alternative resources together, in most cases, with the need to protect receiving water bodies by meeting increasingly stringent quality rules for discharging treated wastewater.

Belgium is experiencing water shortages through over-extraction of groundwater. Recycled water is being adopted for industrial and indirect potable purposes. At the Wulpen STP, over 2.5 GL of urban effluent is to be treated by microfiltration and reverse osmosis, stored for 1-2 months in an aquifer and then be used for water supply augmentation (Lazarova 2001). The direct recycling of treated effluent into agriculture, as distinct from indirect reuse, is not yet a common practice in Western Europe, though in the Mediterranean countries, some wastewater is reused to augment rainfall. In most of the Mediterranean countries, there is a water imbalance, especially during the summer months, *e.g.* Greece, Southern France, Italy and Spain, where intensive agriculture must be irrigated. Water demand for irrigation is rapidly increasing, and there is potential for further use of non-conventional water resources including recycled water. A careful focus is maintained on the reuse of treated wastewater, as there is concern to ensure that the reuse of wastewater will not impair acceptability of agricultural products. No projects are implemented before the environmental and sanitary risk associated with reuse are researched and tested in pilot operations.

In the **United Kingdom**, privatisation has ‘commoditised’ water to such an extent, that there are few demonstration projects and limited public policy towards recycling and reuse (Seaton *et al.* 1999). In England and Wales, there are ten large public limited companies and a further twenty small water supply only companies. There is a significant amount of indirect reuse with abstraction points having some proportion of treated wastewater. (Williams 1996). However, Essex and Suffolk Water formally implemented the Chelmer Augmentation Wastewater Reuse Scheme involving indirect potable recycling in 1997 after they had approval from the National Rivers Authority (later becoming the Environmental Agency) to discharge treated wastewater into the River Chelmer, from which it was subsequently taken for augmenting the Hanningfield reservoir in Essex (Lazarova *et al*. 2001).

The first, major, in-building recycling scheme using greywater to be undertaken in the UK has been at the Millennium Dome, on the bank of the River Thames at Greenwich. The recycling facility provides 500 m^3/d of reclaimed water. The water for treatment is from three sources, *viz* greywater (120 m^3/d) collected from the hand basins in the toilet blocks, rainwater (100 m^3/d) collected from the Dome roof, and groundwater pumped from a borehole on site. Reedbeds were the treatment choice for the rainwater as the runoff from the Dome roof was predicted to be of good quality. The total reedbed area is 500 m^2 and is a significant proportion of the landscaped meadow area. Following the various treatment trains the waters are mixed, chlorinated and then returned to the Dome in a distinctly identifiable reclaimed water distribution system and used to flush over 400 WCs and 150 urinals on site (Hills and English, 1999).

Anglian Water Services serves Eastern England and was formed from 200 sewage and water undertakings as well as five former river authorities. The company operates a wastewater innovation centre near Cambridge and has been developing a number of biological nutrient removal plants for a “standard population of 5,000”. These use a two stage activated sludge process. Prototype systems were also being developed for populations of 750 and 350 persons (Williams 1996).

Holland has had a recent experience of developing a ‘third pipe’ system, presenting a salutary lesson. In Utrecht, 4500 houses were provided with a dual reticulation system – one line for potable water and the other for ‘household water’, provided at a 25% discount, to be used for toilet flushing, clothes and car washing and gardening. Illnesses were recorded and it would appear that there was mixing in the supply systems of 950 houses, with undisinfected river water being provided in the potable supply lines. A second major cross connection incident and a number of cross connections within houses have been recorded. Although the incidents do not necessarily derive from the introduction of recycled water, the Netherlands government has banned the supply of non-potable water to laundries and external taps (Listowski 2003; CRCWQT 2003).

In **Scandinavia** and **Germany**, there have been small groups of individuals taking a more innovative and holistic approach to water management by forming cooperative-like structures (urban enclaves or ecological villages), and therefore having strong local social support as well as agreement by governing bodies. The objective in these “ecological villages” is to make these communities self-sufficient in water (and nutrients) by developing “closed cycle” systems by adopting ecological sanitation (EcoSan). This approach is being encapsulated within a new industry known as Ecological Engineering (Ashbolt 2003).

Italy, with legislative constraints, has restricted wastewater use to discharge onto soil for agricultural purposes, and is allowed only if wastewater addition can increase crop production. Total coliform standards are set very low at 2 MPN/100mL (Barbaballo *et al.* 2001).

Only a few of the ‘transition countries’ of Eastern Europe use wastewater for irrigation purposes, i.e. **Poland** and **Hungary**. In these countries, the amount of municipal wastewater used for irrigation is very small - only 4% of the total wastewater generated in the case of Hungary (UNEP-IETC 2000).

In **Israel**, 20% of the water supply in 1994 came from recycled water, but the country hopes to achieve recycling of most of its wastewater by 2010. In the Dan Region project, up to 95 GL/annum of secondary effluent from the 1.5 million inhabitants of Greater Tel Aviv goes to recharge the coastal aquifer for further treatment and storage. The recycled effluent, after two months’ transit and purification, is pumped over 100 km for irrigation use, while 32 GL/annum of secondary effluent from Haifa goes to the Kishon complex consisting of two deep stabilisation reservoirs and a lage for seasonal storage (Lazarova 2001).

3.7 The Developing World

3.7.1 Latin America

The Pan-American Health Organisation has shown that less than 14% of the wastewater in Latin America receives any sort of treatment before discharge to rivers or the sea. Only 6% receives acceptable treatment (Cavallini and Young 2002). Over 500,000 ha of agricultural land is irrigated with raw wastewater, and an even larger area is irrigated with surface water contaminated by sewage. The position across various countries is summarised in Table 8.

Table 8 Proportion or urban sewage treated before discharge, and the associated level of treatment per country in Latin America (UNEP-IETC 2000).

Country	Proportion of Urban Sewage Treated Before Discharge	Proportion of Treated Waste by Level		
		P*	S*	O*
Argentina	10	0	100	0
Bolivia	30	33	67	-
Brazil	20	10	68	22
Colombia	5	-	100	-
Costa Rica	3	33	67	-
Ecuador	-	-	-	-
El Salvador	1	-	-	-
Guatemala	9	46	54	-
Mexico	13	14	27	59
Nicaragua	21	46	54	-
Paraguay	1	-	100	-
Peru	-	-	-	-
Suriname	1	-	100	-
Uruguay	15	50	28	22
Venezuela	-	-	-	-

*** P = Primary Treatment**
S = Secondary Treatment
O = Others

Less than 30% of the sewage generated in **São Paulo** and **Rio de Janeiro**, the largest cities in **Brazil**, receive some sort of treatment before final destination. In **Bolivia** sewage treatment is virtually non-existent. In **Chile,** 97% of the wastewater is disposed of in waterways without prior treatment. In **Colombia**, only 154 out of 1068 municipal districts treat sewage before discharging it to a water body. In **Ecuador**, there are no sewage treatment systems currently available. In **Costa Rica**, it is estimated that a mere 3% of the liquid effluents of the population are treated before reaching final destination. In **Guatemala**, out of 27 treatment facilities there are 16 wastewater treatment plants in the metropolitan area, but only 4 of them are in full operation. Many treatment facilities are impaired due to poor design, lack of spares, and shortage of qualified operators. In **El Salvador**, sewage treatment is poorly available, with 31 small plants under operation, while only 11 of the 55 major sewerage systems of **Honduras** have wastewater treatment plants. In **Panama**, 6 sewer systems serve 95% of coastal population. 4 of these systems have primary treatment (10% of coastal population); 2 systems discharge raw sewage (85% of coastal population). In **Paraguay**, raw sewage from **Asunción**, the country's capital, is discharged from 5 outfalls to the Paraguay River. It is estimated that in **Peru**, 83% of the urban sewage discharges to water bodies, whether coastal areas, rivers, lakes, or even agriculture lands with no control or treatment whatsoever. In **Venezuela**, the percentage of treated wastes does not exceed 5%, with only 6% out of the 40 m^3/s of the sewage collected in the urban areas being treated. The majority of this treatment occurs on Margarita Island, a tourist destination. In the **Suriname** capital of

Paramaribo, 15% of the population still use pit latrines and 5% have no facilities at all. The level of sewage treatment is estimated at about 1% (UNEP-IETC 2000).

It must be concluded that this detailed summary suggests that the low level of any form of sewage treatment across a continent, even though it is perceived to be at a more advanced stage of economic development than some, militates against a rapid increase in the use of recycled water in the sense that the term is generally understood in the developed world

3.7.2 West Asia

The reuse potential in the countries of West Asia is very high due to extreme water scarcity. There are at least eight countries in the region that operate modern wastewater reuse facilities for agriculture production. About six countries are practicing reuse in unplanned uncontrolled and direct use for irrigation without restriction. However, in **Yemen, Syria, Lebanon, Palestine Territories, Egypt** and **Iran**, raw sewage is being used for agriculture production (UNEP-IETC 2000). **Egypt** produces an estimated 2.4 billion cubic metres of unutilised treated water annually, half of which is in **Greater Cairo.** The Ministry of Environmental affairs began a project in 1998 to irrigate 400 000 feddans (acres) of desert land with treated effluent from 72 STPs for forestry (Bakr 2003). The government of **Bahrain** is planning for full utilization of the treated sewage effluent for irrigation purposes by the year 2005 to reduce the pressure on their already mined groundwater resources. In **Jordan**, which is exploiting its water resources at 146% of their renewable rate (Lazarova *et al.* 2001), the volume of treated wastewater produced in 1998 reached 74 million m^3/year, of which about 95% is reused for irrigation. The reuse of treated wastewater in Jordan has reached one of the highest levels in the world. About 80% of the treated effluent is discharged to the Zerqa River, from where it is collected and stored downstream in King Talal Dam to be used for restricted irrigation in the southern part of the Jordan Valley. The remaining 20% not located within the Zerqa River watershed, is reused on-site. In **Kuwait**, about 25% of its agriculture and green areas are irrigated using 52 million m^3/year of treated wastewater. The rest is either used for artificial groundwater recharge through basin filtration or being discharged to the sea. In **Iran**, there is about 70 million m^3/year of primary treated effluent used for irrigation. There is considerable further scope for groundwater recharge in the region. The cities of **Ismailiyah** and **Suez** of **Egypt** and **Aqaba** of **Jordan** already use the effluent of their wastewater stabilization ponds for artificial recharge of groundwater via rapid infiltration basins. Using reclaimed wastewater in urban areas is not practiced so far, but it appears that reclaimed wastewater reuse in urban areas for toilet flushing and street cleaning has potential because the majority of countries in the West Asia region face an increasing growth of high-rise buildings (UNEP-IETC 2000).

3.7.3 Asia-Pacific

Most of the Asia Pacific countries are tropical countries and their water resources are not very limited. As a result, most of the developing countries do not reuse wastewater except **India, China** and **Vietnam** where wastewater is being used for irrigation.

In **India**, the utilisation of wastewater through reuse and recycling has become very important, being seen as a resource rather than a waste since it contains appreciable amounts of nitrogen, phosphorus and potash. Stabilisation ponds can be used for fish aquaculture and the effluent can be used for cultivation of short-term and long-term, ornamental, and commercial and fodder crops.

Wastewater has been adopted as one of the major water resources nationwide, especially in the northern area of coastal cities in **China**. However, in 1994, 85% of effluent then being used in agriculture did not meet recycling standards, most of it being raw sewage (He *et al.* 2001). Reuse has not only reduced the demand for fresh water but also improved environmental quality. The main potential applications for reuse of treated wastewater in **China** are in the following fields:

* Agricultural use through irrigation of crops as well as for improving river amenity;
* Industrial cooling especially in the large industrial enterprises;
* Reuse in municipal public areas such as watering lawns and trees;
* Flushing toilets in hotels and residential districts;
* Reuse of the treated wastewater for urban landscape purposes.

Many municipalities set wastewater reuse as a strategy to meet the increasing water demand. To identify the alternatives of wastewater reuse as well as their feasibility and implementation, some cities where water shortages and pollution are very serious, such **Beijing, Tianjin, Taiyuan, Dailian** and **Qingtao**, have been selected as pilot areas. In **Beijing**, the main purpose for reuse of treated wastewater is in agricultural production during the irrigation season and to improve river amenity. Some 487 m^3/d of treated wastewater that meets the standard will be available for reuse by 2005, replacing the existing untreated effluent, and providing the potential for reducing existing reliance on groundwater resources (UNEP-IETC 2000).

On Pacific islands that often have very limited catchments, tourism developments have made considerable use of effluent recycling technologies.

3.7.4 Africa

Except in **Namibia** (discussed earlier), **Zambia** and **South Africa**, which was already recycling 16% of its wastewater by 1988, treated wastewater reuse is still in its infancy in much of Africa. The problems of accomplishing adequate treatment and cultural bias have militated against its effective use, especially in the humid zones of the region (UNEP-IETC 2000).

Metropolitan **Tunis** was already recycling up to 75% of its urban wastewater in 1987. **Tunisia** was among the first of the Mediterranean countries to implement a national reuse policy (Decree 89-1047), and the outcome has been effective (Mantovani *et al.* 2001).

3.8 Insights into Water Recycling Programs

Mantovani *et al.* (2001) have published the results of a survey conducted of 65 non-potable water reuse projects, including 40 in the United States and two in Australia (Darwin, N.T. and Albany, WA), and of 20 regulatory agencies under the auspices of the Water Research Foundation and its subscribers. The analysed sample covered a wide range of system ages, types or recycling applications, system capacities and reclaimed water customers. Some aspects will be discussed further in this review, but some principal conclusions can be summarised as follows:

- Non-potable water reuse has an excellent and well-documented performance track record, which to date has featured no documented health problems, strong public acceptance and good regulatory compliance.

- Long-term sustainability of projects is challenged by difficulties of achieving cost-recovery and/or environment protection goals, frequently because of shortfalls in reclaimed water deliveries. Specific associated risks include the difficulties of revenue-raising inherent in a new customer base and determining appropriate pricing, the challenge of recovering the capital costs for reclaimed water dual distribution systems, and liabilities for potential public health risks or environmental impact associated with inadequate levels of treatment, unreliable treatment operations or inadvertent human exposure.

- Coordination between water and wastewater agencies as well as between local, and state agencies is paramount to ensuring optimal project planning and cost and benefit allocation. Integrated agencies (as are generally found in Australia) appear to have an inherent advantage in developing projects.

- The majority of projects at the time of the survey had not attained their planned levels of delivery, and accordingly fell short of their projected goals

- Project-specific political, institutional, environmental, economic and technical constraints typically dictate planning priorities and levels of effort, and significant diversity of planning sophistication was detected.

- While most applications screened alternative use options, few examined alternative sites, most projects being constrained as retrofits of pre-existing wastewater treatment plants.

- The permitting process may require the most time in water recycling planning processes.

- The majority of projects provided tertiary treatment followed by disinfection because that provided for the needs of any unrestricted urban use

- California's Wastewater Reclamation Criteria (Title 22) were the basis for many other sets of regulations.

- Intangible benefits including environmental benefits were almost systematically unaccounted for in the quantified economic analysis of surveyed projects

- Capital came from a wide diversity of sources including bonds, government loans and grants and capital contributions by stakeholders such as developers and industrial users.

- Water pricing for most projects was driven by the need to provide incentives for potential customers, with very few projects directing their pricing strategies at full capital, operational and maintenance cost-recovery. Most relied on intra- or interagency transfers for financial viability.

- Contractual arrangements are the primary means of limiting liabilities, and to date, the liabilities and risks associated with the production and use of reclaimed water had not manifested themselves.

- Public outreach and education programs are an essential component of planning a reclaimed water service, and their cost is minor in the overall project cost. Most retained outreach programs after project implementation.

- Most projects achieved customer participation voluntarily, with very few having an imposed political or regulatory mandate.

3.9 The realities of recycling in the Developing World

In many countries of the developing world, farmers use wastewater out of necessity and it is a reality that cannot be denied or effectively banned (Buechler *et al*. 2002). Highly specialised farmers use every free space with water access to cultivate cash crops. Although their plots are often small, irrigation (including with effluents, no matter what level of treatment, if any), allows these farmers to escape from poverty (Drechsel *et al.* 2002). Wastewater treatment, let alone to an advanced tertiary standard, is not possible due to low municipal/government resources, and small, old or non-extendable sewerage systems. The position is a far cry from that of irrigation farming, whether with direct access to water resources or from use of recycled water, by which Australia has been shown to be able to generate up to half the profit at full equity from its agriculture on less then 0.5% of its land (NLWRA 2002).

4 RECYCLING IN AUSTRALIA

Within Australia, constitutional responsibility for recycled water rests with the States and Territories.

4.1 Commonwealth of Australia

At the beginning of the 20th century at the drafting of Australia’s Constitution, there was no perception that the Federal Government had a role in the management of Australia’s water resources, although river basins, groundwater aquifers and biophysical regions ignore State and Territory boundaries.

However, the Federal Government, through its constitutional external powers, did acquire responsibilities for any water-related issues that arose by virtue of its signing of international treaties and undertaking negotiations with respect to international trade.

The treaty obligations of the Commonwealth now include a number of water-related binding international treaties and conventions. Some can directly and indirectly influence the operations of wastewater treatment policies and processes, usually by virtue of their impact on treatment plant locations and discharging arrangements. These treaties include:

- **Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention), 1971**: Aims to prevent loss of habitats through encouraging the wise use of all wetlands.

- **Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention), 1972**: The conservation of natural and cultural areas of outstanding universal value through their inclusion on a World Heritage List and a List of World Heritage in Danger.

- **The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1976**: To prevent over-exploitation of endangered species of flora and fauna by means of import and export permits for species identified in the appendices of the Convention.

- **Convention for the Conservation of Migratory Species of Wild Animals (Bonn Convention), 1979**: To protect species of wild animals that migrate across national boundaries by placing strict obligations on Parties that are range states.

- **Agreement between the Government of Australia and the Government of Japan for the protection of migratory birds and birds in danger of extinction and their environment (JAMBA), 1981**.

- **Agreement between the Government of Australia and the Government of the People's Republic of China for the protection of migratory birds and their environment (CAMBA), 1988**.

- **The Convention on Biological Diversity (CBD), 1993**: Aimed at the conservation of biological diversity to promote the sustainable use of its components. In 1995 the Jakarta Mandate specifically addressed the relationships between conservation and fishing activities and established coastal and marine diversity as one of the first substantive sectors to be considered by the Convention.

- **The Agreement for the implementation of the provisions of the United Nations Convention on the Law of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks** and

- **Highly Migratory Fish Stocks (UNFSA), 1995**: Provides for the conservation and management of straddling fish stocks and highly migratory fish stocks on the high seas.

The <u>non-binding</u> international treaties and conventions that can affect the possible adoption of water recycling initiatives or through having an influence on effluent discharge policies and standards are:

- **Agenda 21 (United Nations Conference on Environment and Development, 1992)**: requires the international community to address environmental issues. The adoption of the precautionary principle is one of the important aspects of Agenda 21.

- **The Kyoto Declaration, 1995**: Identified the critical link between food security and the environmental sustainability that contributes to the income, wealth and food security of all people.

The principal vehicles for Commonwealth interest are its responsibilities under the

- ***National Environmental Protection Council Act 1994***: Establishes the National Environmental Protection Council to develop national environment protection measures and review the implementation of these measures in the States and Territories.

- ***Environment Protection and Biodiversity Conservation Act 1999***: Provides for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance, promotes ecologically sustainable development through the conservation and ecologically sustainable use of natural resources and promotes the conservation of biodiversity.

However, during the 20th century the Federal Government began to play a significant leadership role in promoting regional development through the provision of financial assistance to the States for the provision of infrastructure, including rural water supply development in the States; flood mitigation; and sewerage services in cities and larger towns. The focus was on development with little consideration in the early years to the environmental impacts of those developments (Taylor and Dalton 2003).

4.1.1 Twenty-five years ago

A detailed consideration was given to the potential for recycled water use in Australia in a report entitled *Strategies towards the use of reclaimed water in Australia* prepared over 25 years ago (GHD 1977).

Recommendations included: -

- A national program of research, demonstration and education
- An integrated approach to water supply, sewerage and solid waste disposal as an integral part of one planning process
- Smaller, simpler sewer networks based on regional plants located near opportunities for reuse,
- A major thrust towards irrigation, both landscape and agricultural, with agricultural use reoriented to agricultural gain rather than disposal,
- Use for conserving water resources in rivers and streams and recharging aquifers providing nutrients were controlled
- Current world potable water standards be extended, related to Australian conditions and applied to existing situations of inadvertent use
- Melbourne being seen as offering scope for a variety of reclaimed water uses
- Assessing the substitution of recycled water for freshwater in Adelaide and inadvertent groundwater recharge in Perth
- Assessing the elasticity of demand for various uses of water and the real cost of providing for variations in demand
- Representative studies of the economics of reclaimed water projects where reclaimed water might be economic, encompassing issues of the definition of the reclaimed water ‘system’, to take into account savings in conventional water supply and waste disposal systems, use of marginal costs rather than average or historical costs and definitions of methods of financing reclaimed water schemes where comparisons over the total ‘system’ including social costs, show this to be economically preferable
- Development of conceptual models, pilot applications and some full scale projects, particularly for the ‘interception’ method (presumably ‘sewer-mining’) and the ‘dual pipe’ supply concept.

The report highlighted that the overall social concern must be the certain safety of the public, with relevant information widely circulated and subject to informed debate.

A member of the 1977 study team observed, coming to Australia 25 years later, that the effort put into the report seems to have had virtually no policy impact (Shuval, 2003).

4.1.2 More Recent Developments

However, since the 1980s, issues of environmental health, sustainability, water availability and water quality for consumptive uses have emerged as significant political issues (Taylor and Dalton 2003).

A Productivity Commission inquiry into water resources and waste disposal began in 1991 and highlighted the need for wide ranging reform of the water industry to improve its efficiency (Productivity Commission 1992). This led to policy drivers being developed, spearheaded by the Commonwealth through the Council of Australian Governments (CoAG), coming together from 1994 as the *National Water Reform Framework.*

This policy framework, which is still being implemented, encompasses urban and rural water and wastewater industries and includes economic, environmental and social objectives. The reform program is aimed at improving the efficiency and effectiveness of the provision of water services and instituting water management planning to take into account the effects of all water use by agriculture, industry, households and the environment.

The water reform framework explicitly links economic and environmental issues within a coherent and integrated package of reform measures. These measures include:

- pricing water for cost recovery and removing cross subsidies;
- comprehensive systems of water allocations and entitlements, separated from land, and backed by secure access rights to water;
- providing for trading in water entitlements;
- specific provision of water for ecosystems;
- water service providers to operate on a commercial basis;
- improved institutional arrangements, including separation of service provision from
- regulation and devolution of responsibility to the lowest possible level; and
- public consultation and education.

However, until 2003, the National Water Reform Framework had excluded recycled water from its considerations (Campbell 2003).

As a consequence of the establishment of the National Water Reform Framework and the need to address issues arising from it related to wastewater management, the Commonwealth has contributed financially to a number of recycling projects from programs including: -

- *Natural Heritage Trust - Coasts and Clean Seas* program,
- *Landcare* programs,
- *Better Cities* program, and
- *The Urban Stormwater Initiative.*

The *National Action Plan for Salinity and Water Quality* may also contribute.

A Senate inquiry into Australia's management of urban water recommended the establishment of a National Water Policy including State and local targets with timeframes for effluent reuse, stormwater retention and pollution removal, decentralised, small scale sewage treatment and reduced effluent to ocean outfalls (Allison *et al.* 2002).

Following the August 2003 CoAG meeting, an additional policy driver, the *National Water Initiative* was announced. One of the four components of this initiative included the encouragement 'of water conservation in our cities, including better use of stormwater and recycled water' (PM&C 2003).

An Intergovernmental Agreement (IGA) on the *National Water Initiative*, is to be developed for COAG. The Senior Officials Group on Water (SOGW) has established Task Teams including one on water conservation in our cities, entitled the Urban Water Reform Task Team, to assist with providing the analysis and detail necessary to specify the commitments under the IGA. This Task Team is addressing improvements in urban water use efficiency through measures including water pricing, catchment planning, demand management, and the increased re-use and recycling of wastewater and more efficient management of stormwater and is charged 'with specifying any regulatory measures that might be adopted by jurisdictions to further reduce water consumption following a review of work aimed at encouraging the more efficient use of water currently being undertaken under the auspices of relevant Ministerial Councils, including water re-use and recycling guidelines and water sensitive urban design guidelines for urban renewal and green field development'.

This work 'will take account of a report by the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) on urban water reuse and recycling'.

A Working Group presented a report *Recycling Water for our Cities* to PMSEIC on 28 November 2003 (Rathjen *et al.* 2003). Its recommendations are set out in Box 1

In November 2003, the Hon Warren Truss, Minister for Agriculture, Fisheries and Forestry, announced the Australian Government Water Savings Ideas Project. The project invited public submissions in an effort to find new and innovative ideas on ways to improve water efficiency in rural and regional Australia. The project received over 550 submissions containing ideas to improve water infrastructure, technology, management and institutions, including many on recycling of water. The assessment phase of the project has been finalised and further discussions with State and Territory Governments will capture the best ideas for possible feasibility studies, including some projects involving reuse. A new project has been initiated to undertake further work on technologies, social attitudes, regulatory models, economic incentives and benefits and systems approaches relating to reuse and recycling.

Box 1 Conclusions and recommendations from the PMSEIC Working Group on Water Recycling (Rathjen *et al.* 2003).

CONCLUSIONS AND RECOMMENATIONS OF THE PMSEIC WORKING GROUP ON RECYCLING WATER FOR OUR CITIES

1. The urban theme of the CoAG *National Water Initiative* should include:

   - Water awareness and education programs to build broad based community support for water conservation and recycling water in households
   - Environmental sustainability and cost effectiveness scorecards for evaluating water supply options, for appliances, new houses and buildings, new suburbs and city-wide, and use of this for accreditation, planning approval, new home grants, and access to related federal resources.
   - Pricing policies for drinking and recycled water that ensure efficient use of these valuable resources. Environmental externalities, the cost of disposal of stormwater and treated effluents and research funding requirements should be factored into the price of drinking water.
   - Encouragement of better integrated water planning and management in urban areas through institutional reform involving local government, catchment boards, water utilities, and state government agencies with relevant responsibilities.
   - The NWI could encourage the development of a range of decision-making tools for urban water management, as well as a scorecard tool.

2. Fast track current proposals for reform of the Health and Environmental Guidelines for the production and use of recycled water.

3. In order to get the most cost effective outcomes any targets for water use should be set on total water use rather than on components such as the volume or percentage of water recycled.

4. Continuing research into treatment processes and sensor development will lead to progressive improvement in costs and efficiency of advanced wastewater treatment and should be supported. Substantial opportunities exist in encouraging research into innovative approaches to whole urban water systems that explore ways of putting the various technologies together into water systems that meet the needs of urban communities.

5. Investment in water recycling projects should be stimulated. A grants scheme should be developed to stimulate 'icon developments' incorporating innovative urban water systems and ensuring rigorous evaluation to improve subsequent innovations. Federal funding should be conditional on an integrated approach to the whole urban water lifecycle, implementation of rigorous evaluation of the performance of the development, and transfer of the knowledge gained to all stakeholders through publication and workshops.

4.2 The States

4.2.1 New South Wales

The **NSW Water Conservation Strategy** (DLWC 2000) included a whole-of-government policy on effluent management and reuse. Within NSW, water policy is coordinated through a **Water CEOs unit** encompassing **Agriculture, Cabinet Office, Energy Utilities and Sustainability, Environmenet and Conservation [**includes previous **Environment Protection Authority** (EPA NSW), and **National Parks and Wildlife**]**, Fisheries, Infrastructure Planning and Natural Resources, Sydney Catchment Authority, Sydney Water**, and **Treasury**, with **Health** having observer status. There is a **CEOs' Task Force for Demand Management and Integrated Water Management**. The NSW Health Department has Memoranda of Understanding with major water utilities regarding health standards, and the EPA NSW licenses wastewater systems.

On 18 December 2003, the Premier of NSW, the Hon. Bob Carr, and the Minister for the Environment, the Hon. Bob Debus, announced the creation of a new government department, the **Department of Environment and Conservation**, to bring together the **Environment Protection Authority,** the **National Parks and Wildlife Service**, **Resource NSW**, the **Royal Botanic Gardens and Domain Trust** with links to the **Sydney Catchment Authority**.

The pricing of water and sewage charges is subject to regulation by the **Independent Pricing and Regulatory Tribunal** (IPART). Although the Ministry of Energy, Utilities and Sustainability provides a general advisory role to the Minister on metropolitan water issues, the Tribunal has the function of setting prices for 'regulated' monopoly services and publishes current maximum water price determinations. It also ensures regulated entities are meeting their licence requirements for quality of product, environmental impact and consumer protection, and has the role of Licence Regulator, responsible for monitoring compliance with licenses and the operational audits of Sydney Water, Hunter Water and the Sydney Catchment Authority (IPART 2003).

4.2.1.1 Sydney Water Corporation

Water and sewerage services in the Sydney Region are provided by the **Sydney Water Corporation** (Sydney Water). It is a State Owned Corporation, fully owned by the people of NSW. It is the largest water services provider in Australia and a major contributor to the NSW economy. Sydney Water is responsible for meeting the water and wastewater needs of more than four million customers. It has 3,500 staff, assets worth $14 billion and an annual capital works program of $500 million.

As a monopoly service provider, its activities are therefore governed by an Operating Licence, which is issued under the *Sydney Water Act 1994* and regulated by IPART. It is also bound by the *State Owned Corporations Act 1989*.

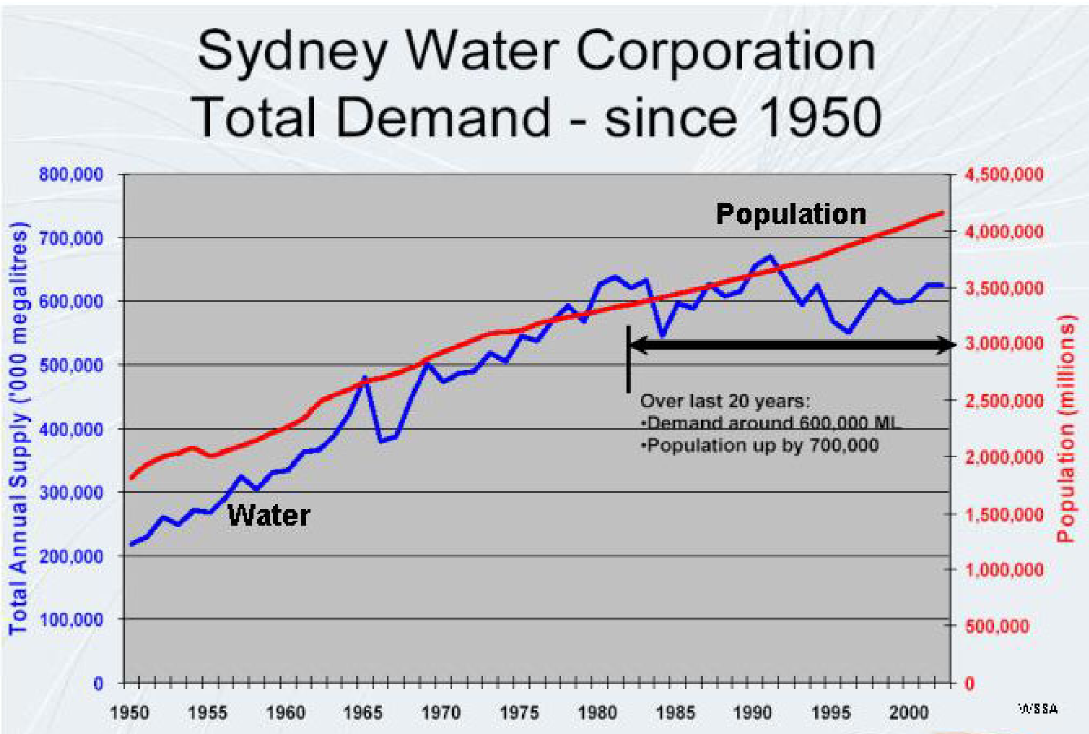
Sydney's bulk drinking water supply is largely drawn from four main river system catchments that occupy more than 1.6 million hectares (16,000 square kilometres) in eastern New South Wales. The catchment stretches from the Coxs River near Lithgow in the Blue Mountains, to Goulburn and the Mulwaree and down to the headwaters of the Shoalhaven River near Cooma. The main reservoir supplying about 80 per cent of Sydney's water is the Warragamba Dam, which has a catchment area 9,050 km². Eleven water treatment plants and 20,000 kilometres of pipes are required to deliver drinking water to Sydney consumers (Sydney Water 2003a).

From 1999, the NSW Government announced interim environmental objectives for 31 catchments, with the **Healthy Rivers Commission** recommending longer-term environmental objectives. These included for the Hawkesbury-Nepean and Shoalhaven Rivers. It has been suggested that water supply demands are now at 106% of safe dam use. The site of Sydney's next potential water storage has been declared a nature reserve, confirming that the **Welcome Reef Dam** on the Shoalhaven River will not be constructed in the foreseeable future (Carr 2002). The calculated sustainable yield of the **Warragamba Dam** (600 GL/year) may be reduced through the need to provide environmental flows for the Hawkesbury-Nepean River system.

Despite the progress already made, Sydney Water must reduce *per capita* consumption by 35% by 2010/11 as a condition of its operating licence or face buying additional water on the market (Corbyn 2003). These developments are leading to reuse schemes being reappraised. To encourage water use efficiency, the NSW EPA is considering developing a system of tradeable certificates for refits that result in water savings (Smith, Simon 2003).

Sydney Water has successfully applied demand management policies through differential pricing. Figure 20 shows the growth of Sydney's population and water consumption. In the last 20 years Sydney has absorbed an additional 700,000 people with no growth in water consumption.

Figure 22 Water consumption and population, Sydney, 1950-2002 (Rathjen *et al.* 2003).



Gregory (2000) observed that least cost planning analyses of recycling options for Sydney demonstrated that, in general, it would be more effective and environmentally sound for the community to reduce demand for water in preference to recycling water. A large number of schemes had been reviewed in the past, but few were viable or implemented.

Sydney Water operates 27 sewage treatment systems collecting approximately 1300ML/day, with 29.9ML/day being processed for reuse (Sydney Water 2002)

Sydney Water is developing an Integrated Effluent Management Strategy with an independent Chairperson (Richardson 2003). The EPA NSW has already developed as-yet unpublished guidelines for the use of effluent by irrigation (Corbyn 2003). It already has 13 reuse schemes, five being regulatory-driven and eight customer-driven (Gregory 2003).

Seven of the reuse schemes are in developed urban areas and urban irrigation of parks and golf courses.

A very successful example of the uptake of reuse water is that of the **Dunheved Golf Club**. This privately owned golf club is located in St Mary's, approximately 50 kilometres west of Sydney and is supplied by Sydney Water with up to 1ML per day of tertiary treated, disinfected effluent from the **St Mary's STP**. The club agreed to repay the capital cost of the distribution system as a monthly fee over 20 years. Since commissioning of the scheme in June 2000, the club has enjoyed unrestricted access to irrigation water and has consumed an average of 310 kilolitres per day.

Access to a drought proof supply during the severe drought of 2002-03 has proved of great value to the club. Dunheved Golf Club have recognised the benefits from the recycled water product to the extent that they have offered to repay the entire capital cost of the scheme in full rather than spread the cost over several years (Lloyd 2003)

Three reuse schemes, located at **Picton, Gerringong-Gerroa** and **Richmond** involve using the effluent for agricultural production.

The **Picton STP**, costing $13m, is an automated plant operated by Sydney Water Corporation, is designed for a flow of 2.4ML/day and is required to use 100% of dry weather flows. The treated water is stored in two dams. One is for irrigation, and the other is for discharge to creek or discharge to the irrigation dam if capacity. All of the wastewater undergoes screening and passes through intermittently decanted extended aeration lagoons (IDAL). Any water that is discharged to the creek is also filtered and undergoes UV disinfection (Figure 21).

A company in which Sydney Water is a shareholder, owns a farm with 135 Ha of recycled water irrigation. An agricultural consultancy firm manages the operation of the farm. The water is used for growing lucerne and ryegrass/clover pastures and a woodlot, with centre-pivot and fixed irrigation systems. The irrigation area is 134 hectares and has a demand of 0.8 to 4 ML/d. Overall, 97% of the nitrogen and phosphorus is recycled.

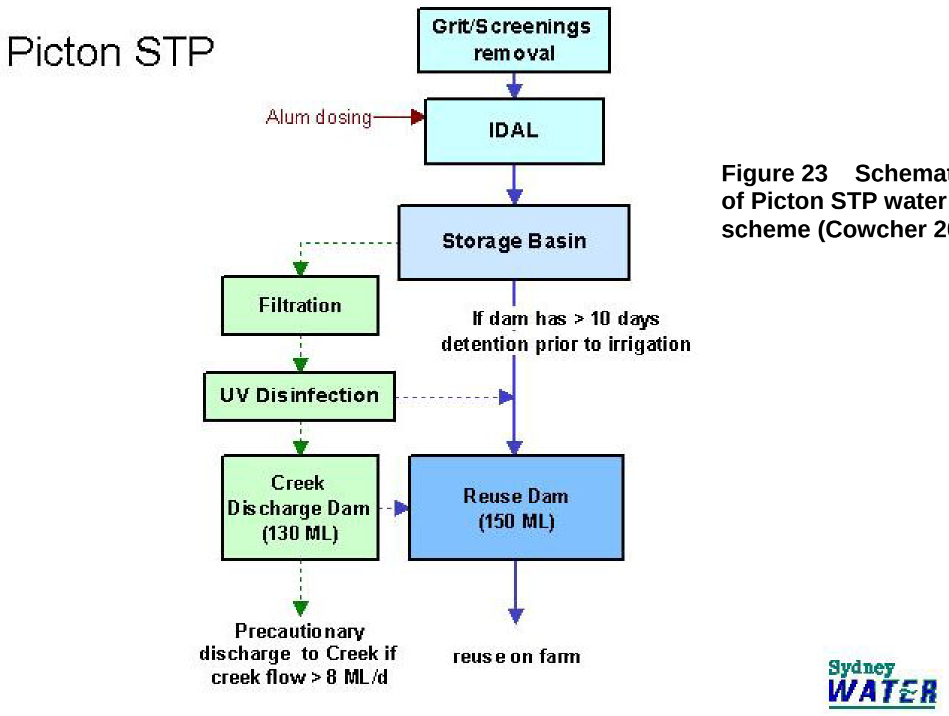


Figure 23 Schematic diagram of Picton STP water recycling scheme (Cowcher 2003).

The **Gerringong-Gerroa** sewerage scheme is a BOOT scheme developed for a previously unsewered area around Kiama. The STP, located adjacent to the Crooked River, is managed contractually for Sydney Water. The plant has secondary and tertiary treatment using a biological reactor, clarification and sand filtration, followed by advanced tertiary treatment involving ozonation, biologically activated carbon, microfiltration and UV disinfection. An obligatory minimum of 80% of effluent is used for pasture production on an adjacent dairy farm that currently irrigates 70 Ha, but has a capacity to irrigate 120 Ha. A 50 ML holding dam is used to manage the flow, and surplus flows are discharged to an on-site dunal system (Boake and Ovens 2003; Kidd 2003).

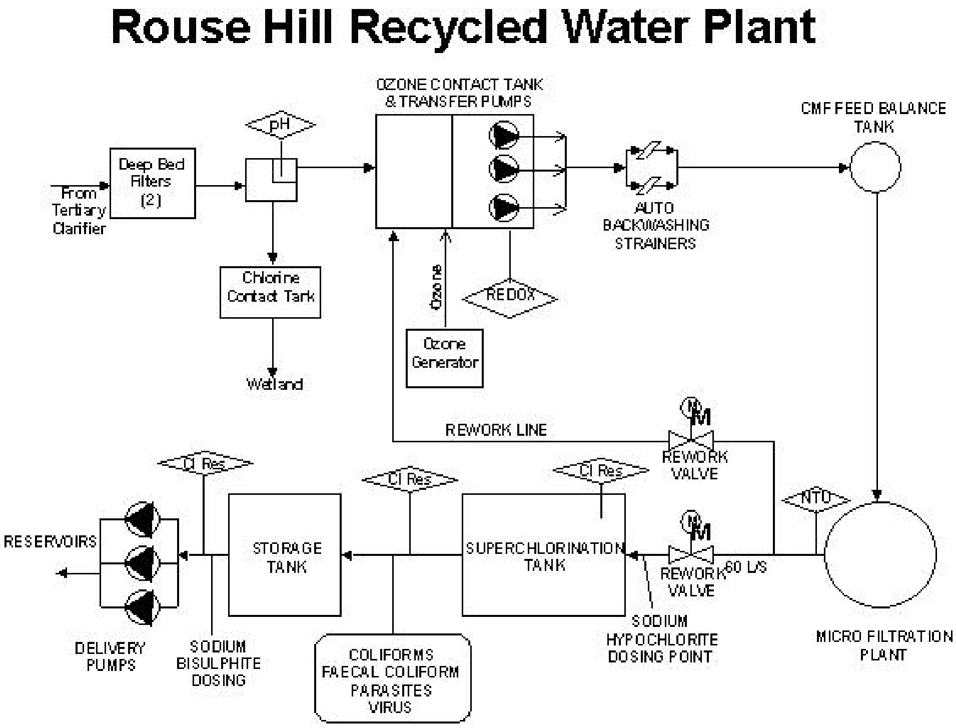
Effluent from the **Richmond STP** for irrigation is supplied to the Richmond Golf Club (a user since 1963) and **University of Western Sydney** (UWS). Sydney Water is investing $11.4 million to upgrade the **Richmond STP** from trickling filter to Intermittently Decanted Extended Aeration Lagoons (IDAL) technology. Treated effluent to the University’s Hawkesbury Campus is initially held in a 93 ML Turkey Nest Dam. An adjacent effluent wetland has been designed to provide capacity for capturing a maximum of 24 ML of wet weather flows from the STP for up to five days. The recycled water is used for pasture production for the UWS dairy, horse unit and grazing unit, for a range of horticultural crops and orchards and for watering UWS playing fields. A complementary set of applied research and demonstration facilities is being developed in association with this upgrade (Booth *et al.* 2003).

Based on the NSW Recycled Water Coordination Committee’s guidelines (1993), a residential “third pipe” scheme has been installed from the **Rouse Hill STP**, which can treat 4.4 ML/day for reuse with ozonation, microfiltration and superchlorination, and is now servicing 12 000 homes using purple pipes and fittings (Figure 22).

Figure 24 Potable water tap (left) and recycled water tap with lilac fittings (right), Rouse Hill (De Rooy and Engelbrecht 2003 ppt).

The first deliveries of “reuse” water were made into the system on 31 July 2001. The treatment scheme for the Rouse Hill STP is shown in Figure 23.

Figure 25 Diagrammatic representation of the recycled water treatment stream, Rouse Hill Sewage Treatment Plant (A. Gregory, Sydney Water, pers.comm.)



The water quality monitoring for Rouse Hill has met the guideline values for all microbiological parameters in Table 9 below.

Table 9 Water quality monitoring parameters, Rouse Hill recycled water (Gregory 2003)

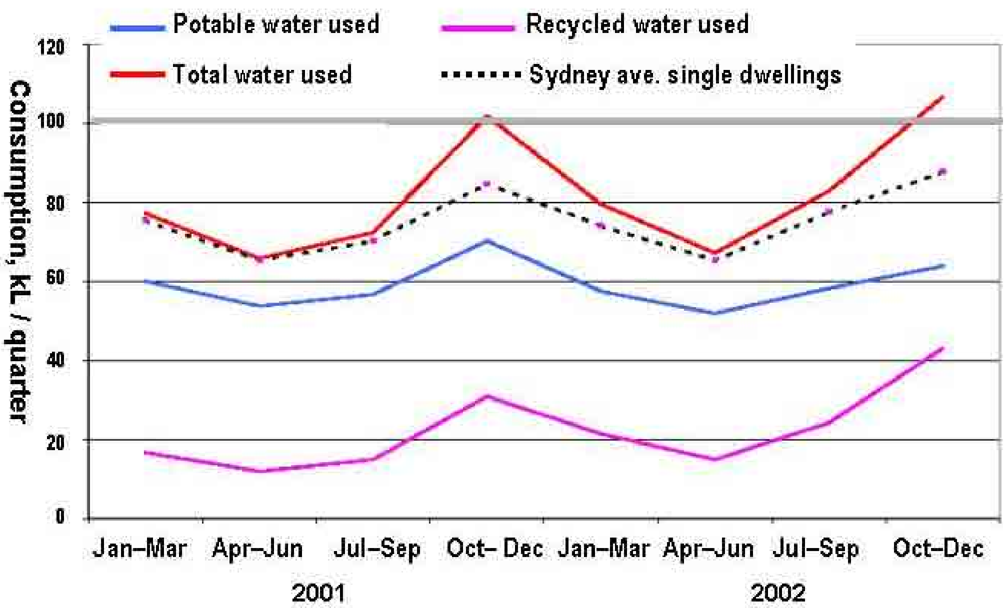
Parameter	Recycled water guideline	Monitoring frequency
Faecal Coliforms	< 1/100mL	5 days/week
Total Coliforms	< 25/100mL	5 days/week
Viruses	< 2/50L	Weekly
Parasites	< 1/50L	Weekly

Ozonation was selected as a process in the final treatment train because of its greater potential than chlorine to target removal of protozoan parasites. The ozonation process, installed as trial equipment in the transfer pumping station wet well, has been subject to a range of technical problems leading to an inherent unreliability. As a consequence microfiltration is a required process step for parasites and super-chlorination is used to back up the ozonation disinfection process for viruses.

The major risk/issue associated with the introduction of the recycling scheme is the quality of plumbing work done between the Sydney Water main and the final house fittings. An inspection verified main to meter, meter to house and internal house plumbing for every property prior to commissioning, with many errors detected. These issues are further discussed in Chapter 5.

Charges from July 1 2003 at Rouse Hill are 28c/kL for reuse water vs. 98c/kL for potable water, a considerable saving when recycled water can be used. Research indicates that the residents have a pride in the scheme and feel that they are at the cutting edge of how future communities will live. Recycled water was seen to be economical, especially for uses that require much water such as establishing gardens and lawns. However, a consequence was that in the summers between January 2001 and December 2002, Rouse Hill total consumption was about 20% above the Sydney average.

Figure 26 Monthly Rouse Hill single dwelling water use compared with Sydney single dwellings, (de Rooy and Engelbrecht 2003)

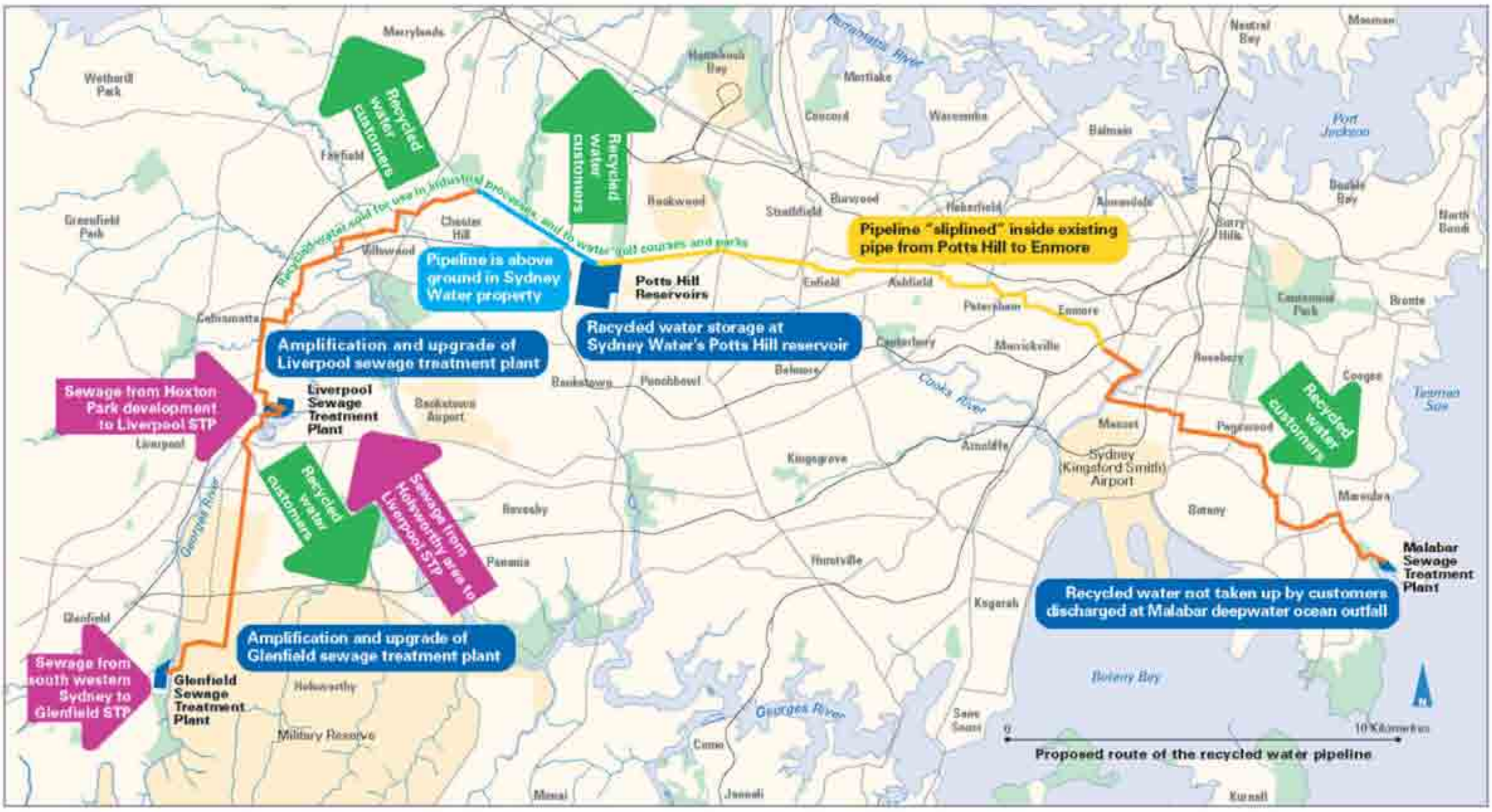


During this period, the recycled water (all uses) accounted for approximately 35% of total water consumed at Rouse Hill (de Rooy and Engelbrecht 2003). Figure 24 shows that water consumption at Rouse Hill is higher than the Sydney average.
The production cost for recycled water has been estimated at \$3-4/kL when the Rouse Hill scheme is fully operational.

An initiative which has been explored is the **Georges River** project involving over 50 km of pipelines linking the **Glenfield** and **Liverpool STPs** to the **Malabar outfall**. Up to 100 ML/day of recycled water could be produced. While this would continue an existing disposal to an ocean outfall, but with the occasional over-capacity wet weather flow going to estuarine disposal, it has been hoped to sell much of the recycled water to current potable water consumers adjacent to the pipelines.

A potential market from 76 customers for 51 ML/day has been identified. Any remaining water will be discharged at Malabar. The scheme, illustrated in Figure 25, is to be fully commissioned by 2008 (Lloyd 2003; Schuil 2004, Sydney Water 2003).

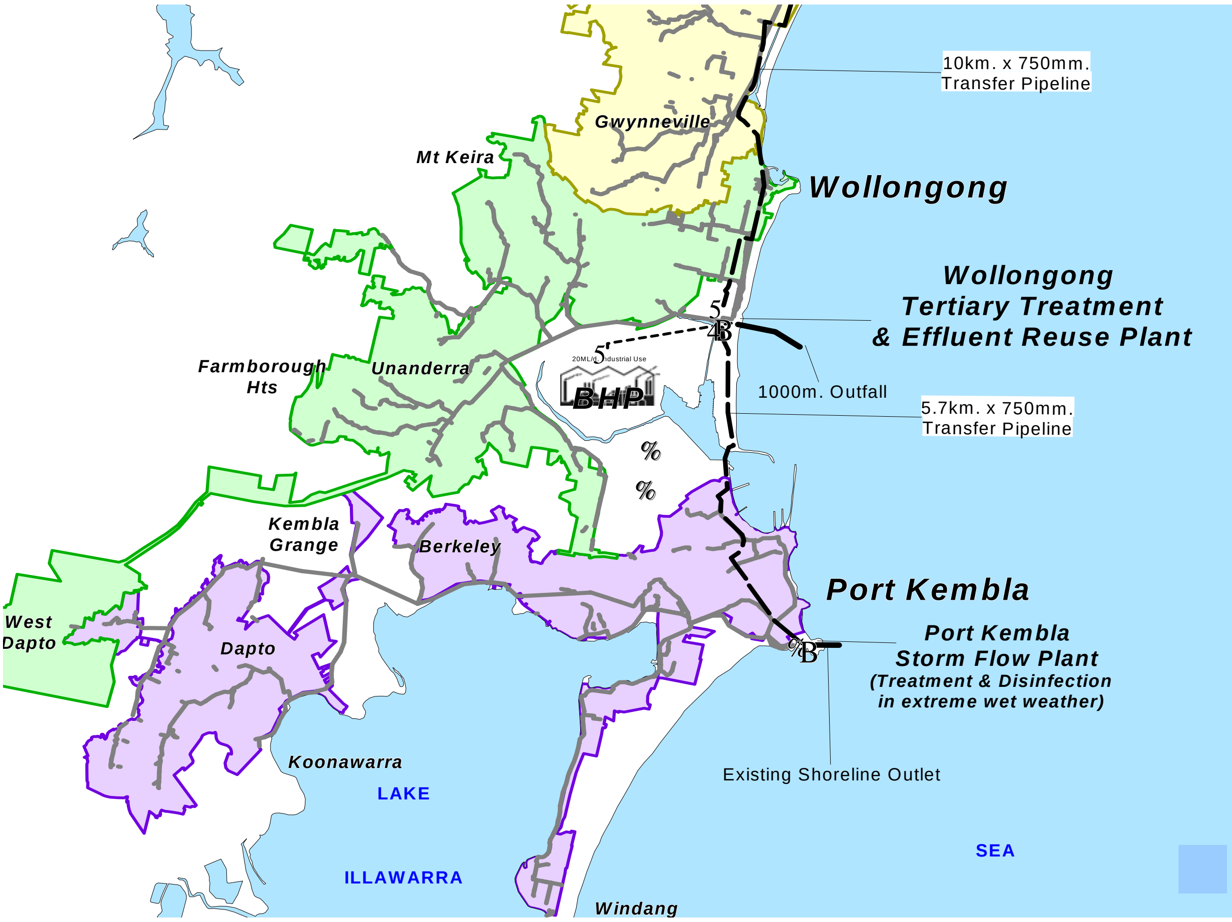
Figure 27 Representation of the Georges River pipelines recycled water scheme (Sydney Water).



There is industrial recycled water use at Australian Steel Mills, Port Kembla.

The **Illawarra Wastewater Strategy** involves upgrading the **Wollongong STP** to provide tertiary treatment using a two stage membrane process (microfiltration and reverse osmosis) to produce 20 ML/day of recycled water that will contain less than 15 mg/L chloride and 50 mg/L TDS for supply to BlueScope Steel, (formerly BHP Steel) in place of the potable water currently used. The supply of recycled water is a commercially viable proposition, which will help achieve demand management requirements of Sydney Water (Brown and Ramachandran 2001).

Table 28 Location of Wollongong STP in relation to BlueScope Steel (formerly BHP Steel) (Sydney Water)



Sydney Water has investigated the viability of recycled water schemes in different guises over some years. Until recently, the most concerted effort to build a recycled water market was the formation of a dedicated business development team in 1996 known as 'Aqua Reuse'. This business unit was charged with recovering all costs from the intended recycled water customer as well as achieving a return on investment at rates agreed with the NSW Treasury (around 9% at the time).

'Aqua Reuse' investigated many schemes but wound down in 1999 as Sydney Water's mandate for commercial ventures was diminished through legislative changes. Some of the schemes investigated by Aqua Reuse have subsequently been progressed to implementation. At least 30 schemes involving more than 100 customers were assessed for their public health and environmental feasibility and financial viability. Full recovery of scheme costs through revenue from the recycled water customers was the defined benchmark of viability.

Recognition of other returns from recycled water schemes has recently been accepted as a principle for funding recycled water infrastructure. On this basis, some of the previously investigated schemes may now be viable.

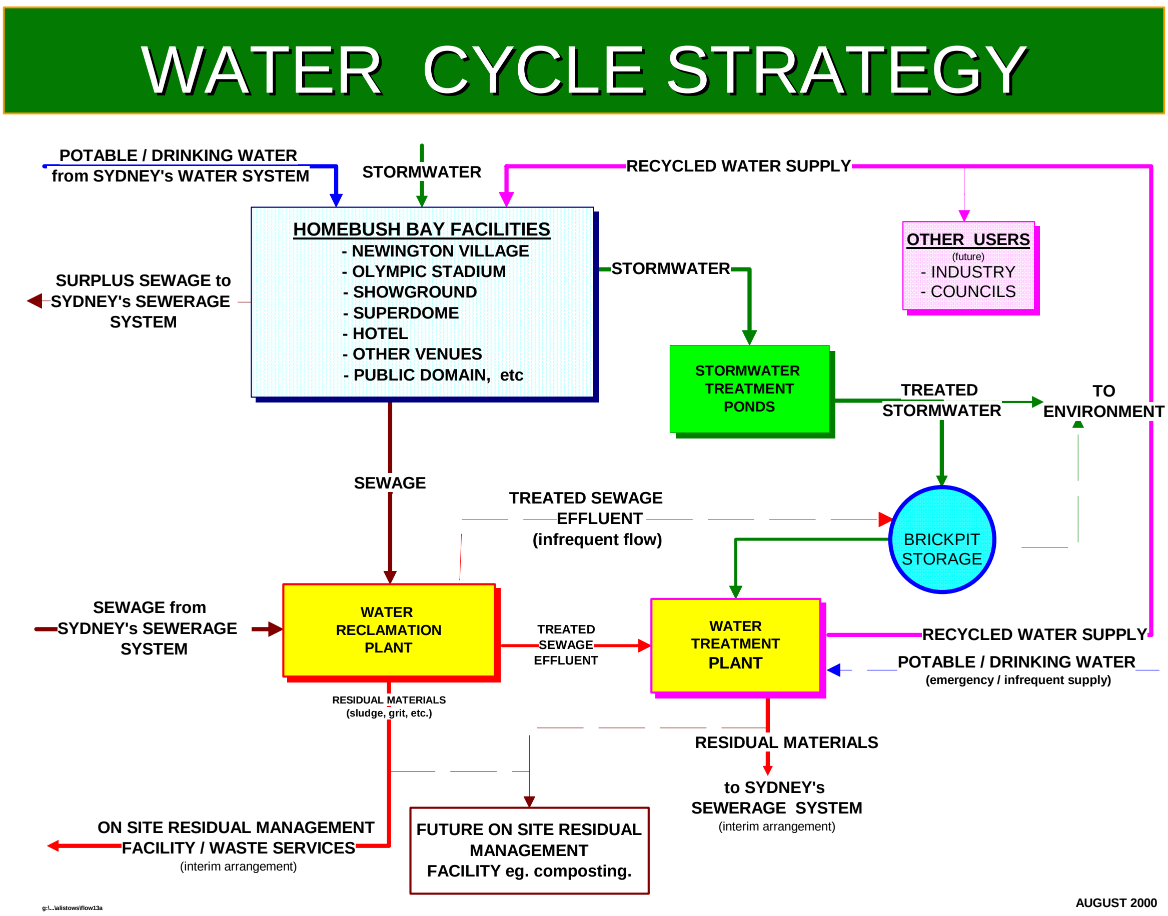
Sydney Water is now developing a Recycled Water Program to identify the range of recycled water products for specific markets and the schedule for delivering to those markets. The program will be an integrated marketing and construction program for the next 10 years. Once the scale of the viable recycled water market is known, a community education program will be delivered to support the introduction of recycled water. The Recycled Water Program will be fully developed within the 2003/04 financial year.

4.2.1.2 Sydney Olympic Park Authority

In preparation for the 2002 Olympic Games, the **Sydney Olympic Park Authority** (SOPA) designed a showcase water recycling facility that integrates sewage treatment and stormwater collection, and after advanced tertiary treatment, uses the water for all non-drinking purposes to residents, commercial premises, sporting venues and irrigation of parklands and playing fields (Figure 26).

The **Olympic Park STP** (capacity 2.2 ML/day) has advanced biological treatment using two sets of sequencing batch reactors, one set of which can be disconnected at times of low flow. There is no stormwater leakage into the sewage system. After removal of the pollutants and nutrients, the high quality effluent is disinfected with UV.

Figure 29 Schematic diagram of water, sewage and stormwater drainage at Olympic Park (SOPA)



All stormwater, which passes through remediating wetlands, is collected in a secured 300 ML capacity ex-brickpit, which can also hold surplus treated sewage effluent.

Water from both the STP and the brickpit is given advanced treatment with microfiltration to remove particles up to 0.2µ (including all parasites, viruses and bacteria) and then reverse osmosis to remove salts. The resulting product is then chlorinated before being supplied to customers at 83c/kL. The plant can treat 7ML per day. Monitoring is on-line for various parameters including conductivity and pH. The direct operating cost is $1.60/kL. A major post-treatment storage is located under the plant.

As well as Olympic Park, the recycling facilities also serve the adjacent suburb of Newington through a “dual reticulation” system. All buildings have two metered connections, one for drinking water and one for recycled water. The water is supplied to all new developments and is suitable for toilet flushing, washing clothes, cars, pets, buildings and brickwork, filling ornamental water features, fire fighting and watering gardens (including vegetables), lawns, parks and playing fields.

The net benefits are

- the saving of about 850ML of drinking water per year,
- there is no sewage effluent discharge to waterways or the sea, and
- the system effectively controls surface water from storm events and maximises its beneficial use. (Listowski 2003; Rathjen *et al.* 2003).

4.2.1.3 Newcastle

Hunter Water Corporation (HWC) is a statutory State Owned Corporation established under the NSW *State Owned Corporations Act 1989*. It provides water and wastewater services to almost half-a-million people from five local government areas – Newcastle, Lake Macquarie, Maitland, Cessnock and Port Stephens. The Corporation’s shareholders are the Treasurer and one other Minister of the Crown (on behalf of the State).

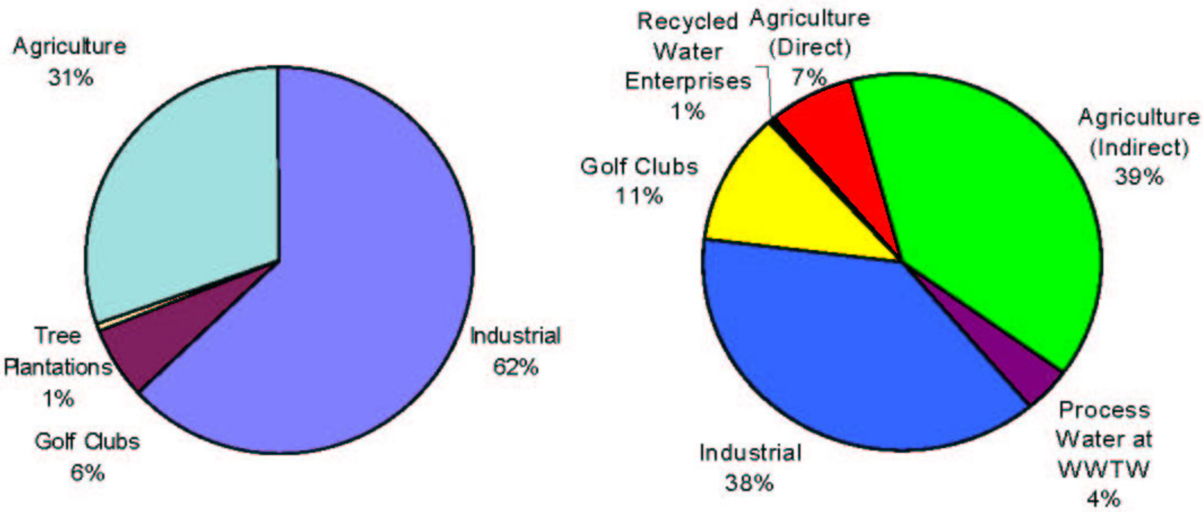
Hunter Water was already recycling 10% of its dry weather STP flow in 1996 from its 22 STPs for coal washing, power generation, road works, golf courses, farm irrigation and a woodlot at Branxton. The then new **Dora Creek STP**, which was constructed in 1994 to serve 16 000 people, had originally been planned to discharge effluent under Lake Macquarie to an extended ocean outfall at Belmont, but subsequently Pacific Power’s Eraring Power Station, which provided 25% of the power requirements of New South Wales negotiated a 15 year contract for access to 5 ML of recycled water per day. The Power Station installed a further on-site microfiltration / reverse osmosis water treatment plant using recycled water from Dora Creek. The power plant uses this water for all functions except drinking and showering, and saved money over the annual operating costs of its previous demineralised water plant ($100 000) and purchase of potable water ($1 m). This example illustrates the economic benefits that may accrue to an industry from its own further treatment of recycled water delivered on site.

In 1998, Hunter Water signed an agreement with BHP for 3ML/day of advanced secondary-treated effluent from the then new **Shortland STP** to be used at the Newcastle steelworks. Unfortunately, economic conditions in the world steel market forced the closure of this old steel mill in 2001, obligating Hunter Water to look for new consumers for its recycled water.

By 2000, Hunter Water was directly recycling about 7% of its effluent, and a further 3% was being used indirectly for agriculture immediately downstream of STP discharge points. The outcome was the use of 62% of its recycled water in industry, a 25% increase over the previous year. This rise was largely due to increased demands from the Rhondda Colliery for fire suppression. However, the long-standing fire was increasingly controlled and a new technique of using fly-ash slurry for fire suppression means there is increased human exposure while cleaning the equipment. The treated effluent from **Edgeworth STP** was no longer of adequate standard for this purpose.

In 2001-2 Hunter Water was recycled about 5.3GL of its dry weather effluent flows. But by 2002-3, the proportion used by industry had fallen to 38%, with annual recycled water use falling by 0.8 GL/year. A comparison of where the water was used in 2000 and 2002-3 is given in Figure 27.

Figure 30 Proportionate use of recycled water, Hunter Water, Newcastle, NSW, 2000 (left) and 2002-3 (right) (Yeomans 2003).



Hunter Water has been holding discussions over a number of years with a major potential industrial consumer on Kooragang Island, Newcastle's principal industrial area, with a view to contracting a significant supply of recycled water. If this is successful, it will justify the capital cost of installing a recycled water pipeline for the supply, and will open up markets *en route* to small users which of themselves would not justify the capital investment (Yeomans 2004).

The experiences of Hunter Water highlight the importance of securing markets for recycled water, and the difficulties faced by a water agency in doing so on a secure, long term basis in a mature industrial and processing environment undergoing structural adjustment.

4.2.2 Rural and Regional New South Wales

In country towns of New South Wales, prime responsibility for provision of water supply and sewage treatment services rests with general purpose Local Government Councils and County Councils. In 1999, their senior staff established the NSW Local Government Water Industry Directorate to fill the void left by the withdrawal of State Government services and technical support and to provide:-

- an independent source of advice to councils on water and sewerage operations
- a more efficient operation of Local Government water and sewer infrastructure
- support and technical direction to water authorities
- a vehicle for networking and knowledge exchange within the NSW water industry (McGregor 2003a)

In the main, the Councils provide services using their own-developed water supply systems and other infrastructure. Some however, purchase bulk water supplies from the irrigation water supply instrumentalities for example, where the townships are linked to irrigation schemes, or from the County Councils that operate and manage regional water supply schemes.

Schemes owned and operated by corporatised Shire Council water entities provide reticulated water to more than 1.5 million people in 375 towns and reticulated wastewater to 1.3 million people in 264 towns.

Any effluent treatment scheme must be approved by NSW Health, including those of Sydney Water and Hunter Water, which are both covered by Memoranda of Agreement. While the use of the effluent is at the discretion of the scheme operator, discharge conditions are subject to licensing by the NSW Environment Protection Authority (now within the Department of Environment and Conservation).

Financial and technical assistance is provided to Councils under the Country Towns Water and Sewerage Program administered by the Ministry of Energy, Utilities and Sustainability. The program provides up to 50 per cent of the capital cost of approved new works, after deducting developer contributions. Financial assistance is subject to a means test as due to diseconomies of small scale, subsidies are required to serve small communities to ensure that reasonable levels of service can be provided at an affordable cost. They may also be warranted to protect the environment and public health, and to assist Councils forced into water treatment by declining water quality or forced into higher quality sewerage treatment due to increased standards for effluent quality. Consequently, some larger regional cities do not qualify for assistance.

The adoption of Integrated Water Cycle Management is being encouraged by the Ministry of Energy, Utilities and Sustainability, to which country town water treatment and recycling responsibility was recently transferred following the replacement of the Department of Land and Water Conservation by the Department of Infrastructure, Planning and Natural Resources.

In 2001-2, effluent recycling schemes from 109 NSW Local Government STPs reused 26% of a total wastewater flow of 171 GL/year from NSW country towns, and 56 of these country STPs recycled more than half of their total effluent flow. Details are summarised in Appendix 1 (Water Directorate 2000).

There was 2.5% reuse from Coastal STPs, 20% reuse from inland plants east of the Great Dividing Range, and 50% reuse from plants west of the Great Dividing Range (Langdon 2003).

4.2.2.1 Barwon Region

Examples of schemes that are or have been assisted by the Country Towns Water and Sewerage Program include the following taken from the NSW Barwon Region, where many of the medium to large towns are now either recycling treated effluent for irrigation or are undertaking detailed investigations into reuse (Burton 2003).

- **Effluent Reuse at Mungindi: –**At Mungindi, located on the Barwon River, the Moree Plains Shire Council recently entered into an agreement with a private landholder to use treated effluent from the Mungindi Sewage Treatment Plant for irrigation of crops on land adjoining the plant.
- **Effluent Reuse at Moree: -** Currently around 20% of wastewater is reused for irrigation of the golf course, cemetery and playing fields. The Council resolved some time ago to pursue maximum effluent reuse through irrigation, rather than discharge to the river system. **A**n Environmental Impact Statement (EIS) for the reuse of Moree’s treated effluent on cotton land near the treatment works has been approved. Design of a pump station and rising main to convey the treated effluent to the farm is under way.
- **Tamworth:** - An Environmental Impact Statement (EIS) for 100% effluent reuse has been completed and approved by the Department of Environment and Conservation (formerly the Environment Protection Authority). The Tamworth City Council has purchased 1500Ha of land west of the city, with 800 Ha to be irrigated. Large-scale irrigation of fodder crops is proposed using 16 centre pivot irrigators. Development Approval has been given by Parry Shire Council for that part of the scheme located within the Shire.
- **Gunnedah:** There is 100% reuse for irrigation of cotton on private land. The scheme has been in operation for several years.
- **Manilla:** An existing reuse scheme has been enlarged following extension of the town’s sewerage scheme to include North Manilla, with 100% reuse for pasture and fodder irrigation.
- **Narrabri:** The Council has developed an irrigation farm with financial assistance from the State Government. Winter and summer crops are irrigated using treated effluent from the town’s STP. The farm uses all effluent produced by the town of Narrabri. A board of local business people and school representatives administers the farm. The farm returned a profit in the last financial year, with proceeds going to local schools.
- **Guyra** Council has entered into an agreement with a local flower producer to take a significant quantity of the treated effluent from Guyra for irrigation of bulbs and cut flowers.
- **Armidale:** Extensive reuse of treated effluent and biosolids is undertaken on land around the STP,

- **Tenterfield:** Currently, the majority of treated effluent is used for irrigation of the golf course and the farm next to the treatment works.

Significant other country reuse schemes included water for *Pinus radiata*, *Eucalyptus camaldulensis,* lucerne and natural wetlands from **Waterview STP**, Albury; hay, silage and woodlots at Armidale; and class A recycled water to 85 domestic properties after microfiltration at **Kooringal STP**, Wagga Wagga.

Hastings Council at Port Macquarie, NSW is spending $2m on a reclamation plant that will deliver 2 ML/d for reuse. The plant will employ microfiltration, reverse osmosis and UV, with hypochlorite to ensure residual disinfection. The project design and implementation are by Hunter Water Australia and the NSW Department of Commerce.

The uses made of effluent from the New South Wales country STPs are given in Table 10, with golf courses and pasture production being the most significant uses. Some of these uses include complementary enterprises developed by the sewage treatment operators themselves. Additional enterprises have come on stream since that time. An increase of 4.6% reuse of wastewater flows was expected to be achieved between 2000 and 2005 (Water Directorate 2000).

Table 10: Uses recorded of effluent from New South Wales country STPs, 2000 (Radcliffe, 2004, derived from Water Directorate 2000).

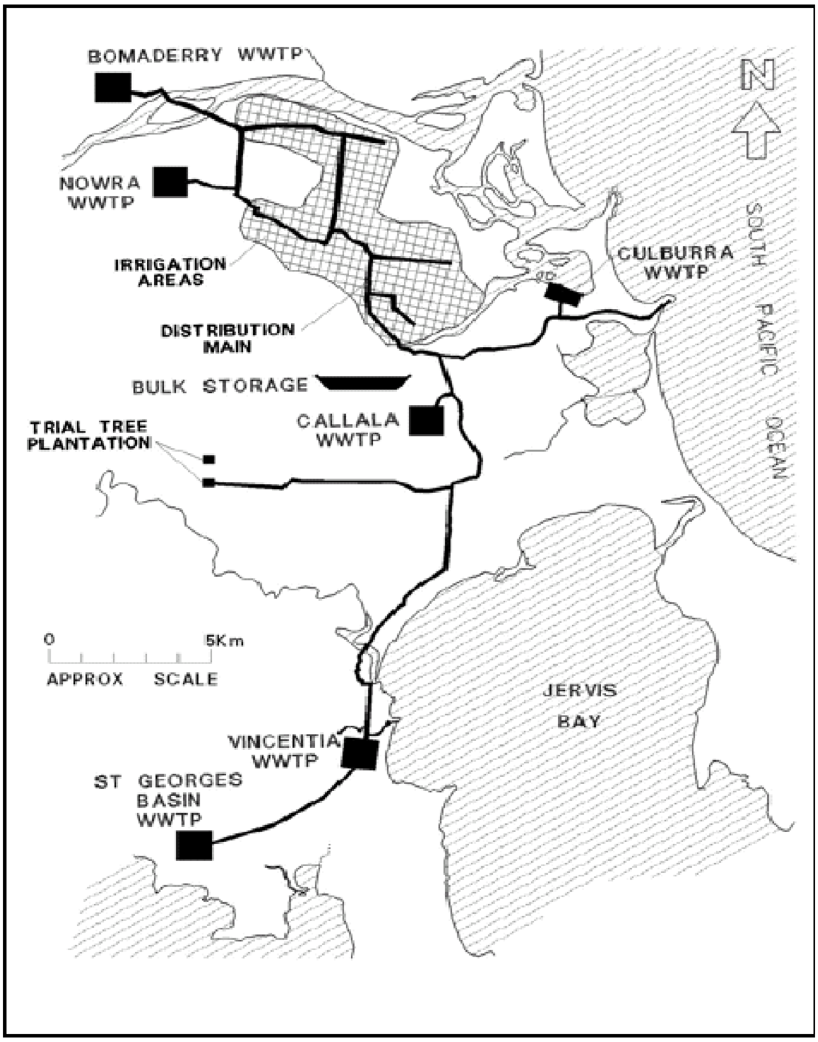
4.2.2.1.1 Uses of Effluent	No. of country Council STPs recycling (Includes multiple uses)
Golf Courses	46
Pastures (Dairy, beef, Sheep)	32
Sports fields and Ovals	19
Woodlots, Trees, Forestry	14
Racecourse	10
Landscaping, parks, amenities	9
Schools	4
Lucerne irrigation	4
Fodder and Hay	4
Cotton irrigation	3
Cemetery	3
Horticulture	2
Mining processes	2
Showgrounds	2
Dust suppression	2
Nursery	2
Timber Mill	1
Bowling Club	1
Hydroponics	1
Wetlands	1
Dune stabilisation	1
Truck Wash	1
Power Station	1

4.2.2.2 Shoalhaven REMS Scheme

Noteworthy among of recent new schemes is the already well-established **Shoalhaven Water's Reclaimed Water Management Scheme** (REMS). In 2003, this was handling 2 GL effluent/year from four interconnected STPs, and when completed, will recycle 4 GL/year.

A public consultation process supported a proposal that additional rates be charged to the community to support the scheme so that discharges to Jervis Bay became generally unnecessary. The recycled water is provided through purple pipes, without charge to local dairy farmers. They have converted from dryland to irrigated dairying, leading to a major boost in production and efficiency. This has allowed the farmers to adjust to the dairy industry deregulation reforms and ensured retention of the town's dairy factory (Moore 2003). The layout of the scheme is shown in Figure 28.

Figure 31. Configuration of Shoalhaven Water STPs, allowing effluent to be brought together at the Coonemia storage for recycling, minimising the need to use the ocean outfall (Gould *et al.* 2002).



4.2.3 Local Government and Development Planning

Increasingly, Water Sensitive Urban Design is being taken into account as local government and developers move towards adopting integrated water cycle planning and management. Water sensitive urban design in new subdivisions is being encouraged with new guidelines for the Sydney Region, building on earlier Hunter Region guidelines (WSUD 2003).

A recent example is the *Water Conservation Strategy* of **Albury Water** (McGregor 2003b), which has embraced this philosophy, particularly for new subdivisions. It suggests that

- rainwater tanks for garden watering be encouraged by becoming exempt from requiring a development permit unless the water is to also to be used for toilet flushing and provided with "top-up" connections from the City's potable supply, with possible subsidy of backflow devices being considered.
- Albury Council should encourage the re-use of domestic water (greywater) subject to appropriate statutory requirements,
- the notion of harvesting and reusing stormwater be adopted in principle with opportunities assessed for all new developments.
- beneficial recycling options for water from local sewage treatment facilities should be pursued, with options for urban reuse reconsidered and fully costed,
- future budgets should provide for constructing infrastructure capable of returning reclaimed water to the City for re-use in residential garden watering, parks and recreation watering and industrial use.
- the possibility of sale of reclaimed water to downstream irrigators via discharge to the River Murray be explored.

The Strategy was the subject of a Community Forum and was then placed on public exhibition for 6 weeks in April 2003. The only comments received were generally supportive and, as a result, Council formally adopted the Strategy on 25 August 2003. Council's support for the initiatives within the strategy is extremely strong and the Strategy will be incorporated in the City's 2004/05 Management Plan. (McGregor, D. (2004).

4.2.4 On-site recycling projects

4.2.4.1 Michael Mobbs' House

Michael Mobbs and Heather Armstrong have developed a pioneering example of on-site recycling on their small house block of 35m long by 5m wide located in the densely populated inner-west Sydney suburb of Chippendale. By developing a carefully protected roof catchment, they collect all rainfall following an initial diversion to a tank below the house-deck. All sewage from the house is collected in an underground concrete tank containing three filter beds, undergoing biological amelioration. The 100 kL/year of effluent outflow, after UV disinfection, is used for toilet flushing, clothes washing and garden watering, with any excess going to a dry reedbed. Initially, there were occasional shortages of rainwater, and the sewage management scheme took about one year to function acceptably (Mobbs 1998).

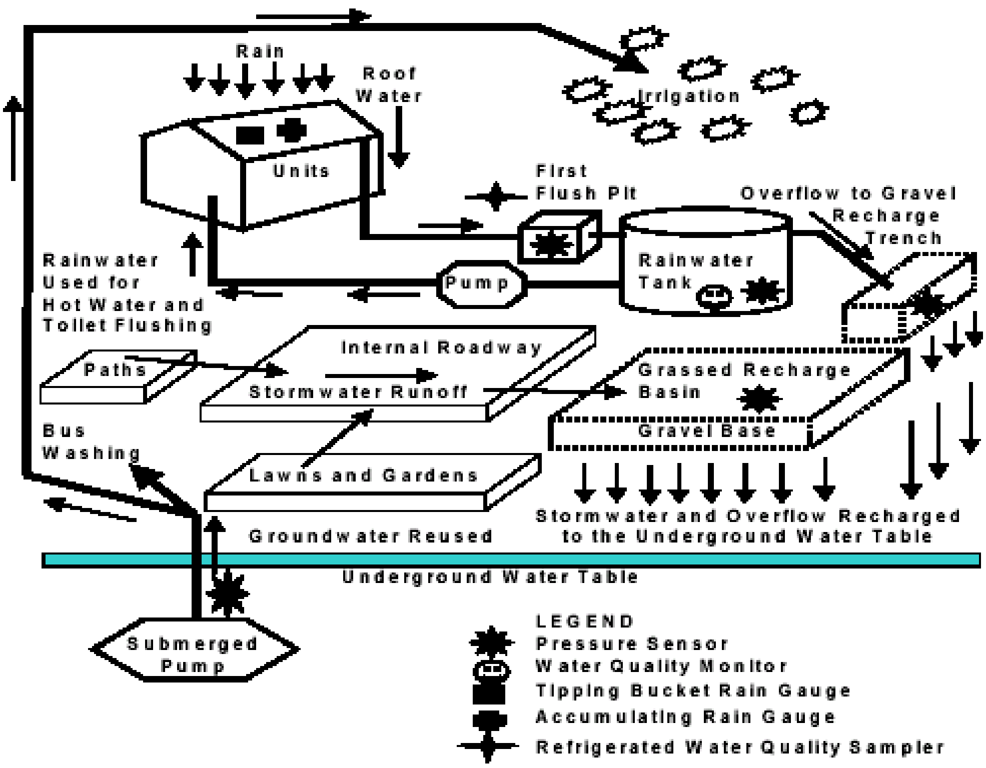
4.2.4.2 Fig Tree Place Development

Newcastle is the site of an innovative water sensitive urban development in which rainwater tanks and cleansed stormwater have been incorporated into an integrated water-management system for an urban redevelopment project. The project, located on the site of a former tram depot in **Figtree Place**, Hamilton, is comprised of 27 residential units with an effective housing density of 45 units per Ha. The planning provided for the scheme to supply 50% of the in-house needs for hot water and toilet flushing, all of the domestic irrigation needs of the site, and surplus water to supply all the bus-washing needs of the adjacent Hamilton bus depot.

The components of the scheme include:

- underground rainwater tanks fitted with "first flush" diversion devices; between four and eight houses per rainwater tank;
- gravel-filled trenches at front or rear of 19 home sites: trenches receive rainwater tank overflow and provide recharge to groundwater;
- all runoff from paved area (including carriageway and driveways) in front of 19 homes gathered and diverted to central Detention Basin Recharge Area; recharge of cleansed stormwater to groundwater;
- design flood capacity (before overflow to Denison Street, north boundary): "once in 50 years";
- paved area surface runoff from seven units in northeast corner uses conventional street drainage system; roof runoff from these units collected in a rainwater tank.
- ground water from a bore located in the recharge area provides water for irrigation and bus washing at the adjacent Bus Depot.

Figure 32. Schematic diagram of the Figtree Place integrated water management development (Coombes, Argue and Kuczera 2000)



Some difficulties were experienced in achieving the design parameters of the project, though these were ultimately overcome (Coombes, Argue and Kuczera 2000). Rainwater collection on the site has reduced mains water consumption on the site by 54%, while stormwater run-off from the site has been eliminated.

4.2.4.3 Household Rainwater Tank Subsidies

To encourage the collection and incorporation of rainwater on-site into household water management systems, the New South Wales government introduced a subsidy scheme to encourage their purchase and installation. The scheme provides the following subsidies:

- 2000-3,999 litres: $150
- 4000-6,999 litres: $400
- 7000+ litres: $500
- PLUS $150 if a toilet and/or washing machine is connected to the rainwater tank (Sydney Water 2003c).

Take-up of the subsidy scheme was relatively limited following its introduction but the scheme has been extended to 30 June 2005.

4.2.4.4 New Technologies

A useful tool for encouraging greater efficiency in the use of natural resources at a subdivision and household scale has recently been developed. This is a planning program to evaluate the efficiency of current and proposed designs for, among other components, water management. New water and energy use targets have been established for all new homes built in NSW. The *BASIX - Building Sustainability Index* has been developed to facilitate compliance with these targets. From July 2004, the *BASIX* assessment will become a mandatory part of the development approval process for new housing in NSW. *BASIX* is a web-based application that can be used to assess the potential performance of residential developments against a range of sustainability indices including water use efficiency, and provides for the inclusion of stormwater as well as rainwater harvesting (Planning NSW 2003).

The **Cooperative Research Centre for Waste Management and Pollution Control** (CRCWMPC) has recently developed a small-scale compact automated Multiple Water Reuse unit suitable for use on-site, based on microfiltration and reverse osmosis without any biological treatment. The technology has been marketed through the Centre's commercialisation company, Water Technologies of Australia Pty Ltd, which has licensed its use in Australia and New Zealand to Zeolite Australia Ltd. The technology may have potential for use in high-rise buildings (CRCWMPC 2002, Garman and Borton 2003).

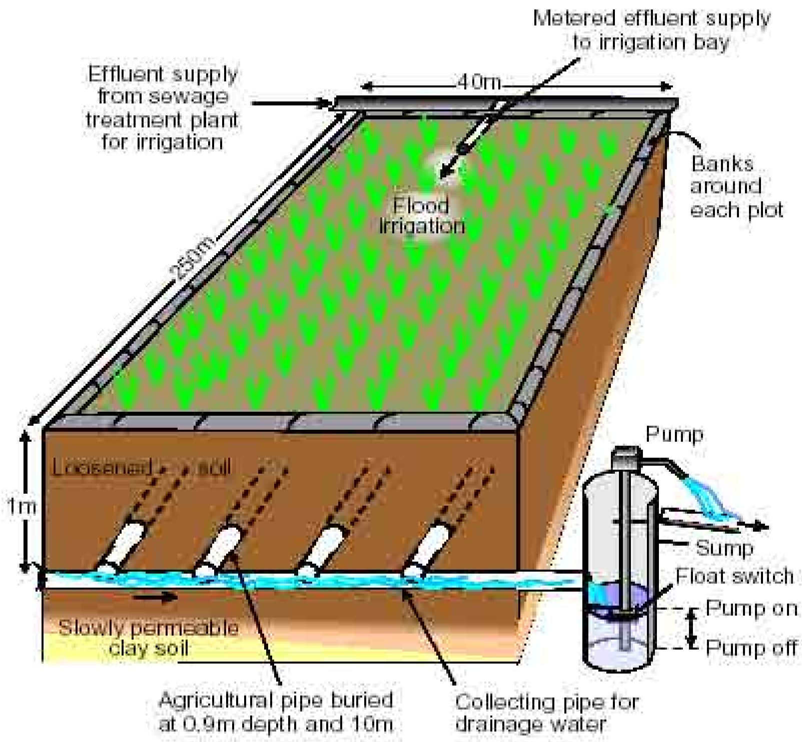
Seventy per cent of new residential starts in Sydney have recently been high-rise. However, it may be noted that there appears to be a deficiency in the NSW regulatory system in that although local government can regulate water recycling in single dwellings with less than 10 people, and there are regulations for developments of more than 2000 people, there is an unregulated gap in between, into which high-rise apartment buildings with in-house wastewater treatment and recycling plants might fall (Power 2003; Gregory 2003).

The use from 1991 of secondary-treated effluent at three application rates, compared with a low nitrogen/low phosphorus bore water as an irrigated control, in the establishment and growth of *Pinus radiata* and *Eucalyptus grandis* forest plantations at Wagga Wagga, NSW has formed the basis of the publication *Sustainable Effluent-Irrigated Plantations - An Australian Guideline* (Myers *et al.* 1999).

Use of applications of saline sewage effluent by the FILTER ('Filtration and Irrigated cropping for Land Treatment and Effluent Release') over four cropping seasons at Griffith, NSW, on land areas ripped and fitted with subsurface drainage systems at a depth of 1.5m (Figure 31), reversed the accumulation of salinity and sodicity and showed that high volumes of wastewater could be handled at periods of low cropping activity and/or periods of high rainfall (Jayawardane *et al.* 2001).

A companion trial for a year at Gatton, Queensland, using a hydraulic loading about two and one half times that of irrigation demand showed that irrigation with secondary effluent led to tertiary quality effluent in nutrient terms being generated from the subsurface drainage system. However, deep percolation losses below the drainage lines accounted for some of the high infiltration rates achieved (Gardner *et al.* 2001). The layout of the application area showing the deep drainage is illustrated in figure 30.

Figure 33. Layout of flood irrigated effluent disposal site, Wagga Wagga, NSW (Blackwell *et al*. 2000)



4.3 Australian Capital Territory

The Australian Capital Territory achieved self-governing status in 1989, and at self-government, all utility services including electricity, water and sewerage were brought together under the one government-owned organisation known as the ACT Electricity and Water Authority (ACTEW). This arrangement lasted until 1995 when the organisation was corporatised (ACTEW Corporation Ltd).

In July 2003, the ACT Government released *Water ACT – a draft Policy for Sustainable Water Resource Management* (Environment ACT, 2003a). This provides for a 12% reduction in per capita potable water use by 2013 and 25% by 2023, to increase the recycling of effluent from 5% to 20% of current inward flow, reduce stormwater run-off and develop strategies to encourage the retrofitting of existing commercial space and landscapes for more efficient water utilisation.

4.3.1 Canberra

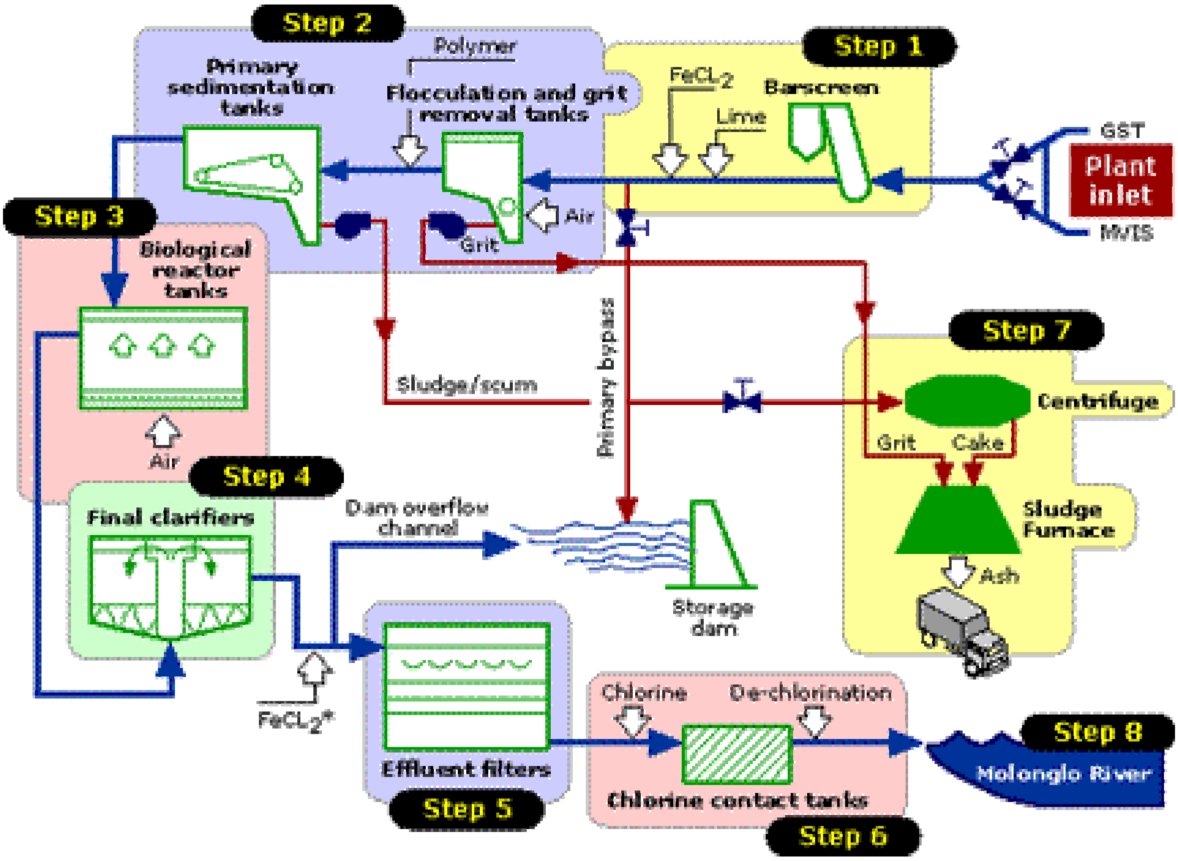
Water supply and sewage services for Canberra, which has a population of 320,000, are managed by ActewAGL, a joint venture established in October 2000 between ACTEW Corporation Ltd and Australian Gas Light Company (AGL), one of the largest private sector energy companies in the nation. The water and sewerage business is run under contractual arrangements in two phases. Phase 1 is a transitional period of up to four years in an Alliance Agreement to establish true costs and risks associated with the business, with most risks in this time borne by ACTEW. In Phase 2, a utility management agreement (UMA) will be implemented for a longer period with appropriate risks either shared with or fully taken by ActewAGL. (Perkins *et al.* 2003).

The ACT's jurisdictional regulator, the Independent Competition and Regulatory Commission (ICRC) determines the price paid by consumers for water and wastewater services.

Water reclaimed by secondary treatment at the Fyshwick STP has been used for over ten years on the playing fields at the Duntroon Military College as part of the North Canberra Effluent Reuse Scheme (NCERS). The Fyshwick Sewerage Treatment Plant is being upgraded at an estimated cost $3.4m and the plant is scheduled to be operational by February 2004. Leading edge membrane (microfiltration) technology is being installed at the plant to provide exceptionally high quality reclaimed water. The plant will provide 20 L/sec of treated effluent and will have the ability to upgrade to 40 L/sec. The plant will supply irrigation water for 40 Ha of public parks and sporting fields in O'Connor, Ainslie, Braddon, Reid, Campbell and Australian National University as well as 20 Ha at the Australian Defence Force Academy. Capacity can be expanded to 40 L/sec, potentially providing water for all of inner North and South Canberra (ActewAGL 2003a, Baria 2003).

The Lower Molonglo Water Quality Control Centre (LMWQCC) is the main wastewater treatment facility for Canberra and is the largest inland treatment centre in Australia, treating 90ML of effluent daily. The treatment train is shown in figure 31.

Figure 34. Lower Molonglo Water Quality Control Centre treatment train (ActewAGL 2003a)



Tertiary treatment at the LMWQCC provides water for a local golf course, vineyards and treatment processes with the remaining water discharged to the Molonglo River and thence to the Murrumbidgee River to enter Burrinjuck Dam. The high quality treated effluent that is discharged from LMWQCC into the Murrumbidgee is available for reuse by downstream users many times over and can be recognised as an effective form of reuse.

4.3.2 Experimental installations

ACTEW has experimented with several innovative reclamation schemes. A sewer-mining (‘watermining®’) unit has been operated since 1995 at 3-6 L/sec in Southwell Park, with screening, lime settling, microfiltration and chlorination, the output being used on local playing fields (ActewAGL 2003b). Derived from this experience, ActewAGL (2003c) has developed and has been seeking markets for “CRANOS®” a newly developed compact wastewater treatment technology, designed to treat municipal and industrial wastewater containing biodegradable organic pollution. The CRANOS® facility uses about 5% of the space of conventional open tank sewage plants and there is scope for relocation. A 'fluidised bed' process is used to treat wastewater in closed pressure vessels, and a dissolved air flotation tank with no moving parts removes solids after the biological treatment. The plant operates unmanned under computer control. Its enclosed design aims to contain all odours.

When fully developed, CRANOS® can be sized for 1,500 to 30,000 people, and is modular allowing for the addition of extra modules as loads increase.

ACTEW, the then ACT water resource manager, undertook trial installation of domestic-sized wastewater treatment plants in each of six houses in urban Canberra, commencing in 1994-5. The wastewater is either treated aerobically to a high standard and transferred to a holding tank on each block, or is managed with an intermittent activated sludge process, in which an air stream used to keep organic material in suspension is periodically turned off, the suspended material allowed to settle and the clear effluent decanted from just below the surface. The treated and disinfected effluents from the two systems are pumped for use within their property boundaries for toilet flushing and irrigation. A UV disinfection system was included at one site. The chemical and biological testing cost $50,000 per year, and the monitoring $25,000 per year. The hydraulic loading of 100 sq metres/person from three adult users per household generated an irrigation loading of about 600 mm/year. (It has been estimated that the average supplementary irrigation demand in the Canberra environment is 643 mm/year.) Householders were encouraged to replace grass areas with deep-rooted trees, use low flush toilets, low flow shower roses, short showers to minimise water use in winter, and to use detergents sparingly to minimise salt loading in summer. The trial established from the user perspective that the approach was successful. The local standard that the effluent turbidity be less than 2 NTU could not be met, but in practice would not have been required in the water, which was fit for the purpose it was being used. The total annual operating cost of $5,000 to continue the trial over the 6 houses has been considered acceptable. However a health requirement that samples be collected and analysed fortnightly to meet biological monitoring standards at a cost of $5000 per year for each dwelling is not acceptable at an individual household level (Bencke 2001).

ACTEW is continuing to undertake research into water reuse to provide the best possible advice to government

4.3.3 Planning

In November 2003, the ACT Government provided information on and explanation of strategies for implementation of a plan for the future of the ACT's water. A further expansion of the North Canberra Effluent Reuse Scheme and to Belconnen, and Gungahlin systems is suggested. Additional sewer mining facilities could be built at other major playing fields similar to that at Southwell Park. Such installations would service about 1.6 ha, at an anticipated unit capital cost of $1.8m. Other more expensive developments to South Canberra and Tuggeranong would be further into the distance. In putting forward these suggestions, it has been noted that any form of further reuse would require extensive consultation with the Canberra communities – it is known that some schemes have not come to realisation due to public rejection (Environment ACT 2003b).

Consideration has also been given to using Class A recycled effluent at Parliament House Canberra for landscape watering and toilet flushing (Andrew 2003).

4.4 Victoria

Of the water extracted from rivers in Victoria, the Melbourne area uses 8%, irrigation uses 77% and the remainder is used in regional cities and town. In Melbourne, 60% is used in residences, 28% commerce and industry, 8% is lost by leakage and 4% goes to miscellaneous non-revenue uses. Demand in Melbourne was increasing at 3% per year until the drought of 1982, but following an education programme, is currently increasing at 1% a year. With no reduction in demand, severe restrictions would be required by 2012-2015 (Millis 2002).

Victoria commissioned a report *Planning for the use of Reclaimed Water in Victoria* in 1978 (GHD 1978). The report noted

- …marine disposal was to regarded as a last resort rather than a favoured one… the decision whether to consider a substance a 'waste' rather than a 'natural resource' is based on economic rather than scientific principles,
- …the approach to sewage treatment in Australia has perpetuated the patterns established by tradition and experience… 'resource consciousness'....is a relatively recent concept,
- …increasing water deficits are expected in Victoria by the year 2000
- …increasing re-cycling of water in industries and in homes, garden watering restrictions, use of sewage effluent and higher costs for water supplied are all possible developments in this state,
- Australia should keep abreast of overseas developments in potable reuse…considered unlikely that such reuse will arise for some lengthy period,
- Flushing of toilets represents 30% of domestic usage.
- Home garden watering is generally wasteful of good quality (potable) water
- There are few cases where effluent cannot be used for landscape irrigation,
- Food production appeared less of a future problem than energy production
- There appear to be advantages in use of sewage effluent to grow cellulose material such as water hyacinth or bullrushes which could be used in a large regional anaerobic digestion scheme
- There is an area of perhaps 1,000 km² of land to the immediate northwest and west of Melbourne, and it would seem that appraisal of disposal/reuse there of Werribee's treated effluent could be well worthwhile
- It is appropriate to question whether the trend towards the very large treatment plant is the most suitable…or whether a number of smaller and simpler networks with multiple plant systems is better
- Land use planning can facilitate the use of sewage, *i.e.* location of suitable industries adjacent to treatment plants (and *vice versa*)
- A suburban neighbourhood of 5,000-8,000 persons could be served by a viable local treatment and reuse system
- A notional analysis of a corridor extension of an existing city indicates that a district plant of, say, 30,000 persons could economically act as a resource factory – in the case of Melbourne, extension of both the South Eastern Purification Plant and the outfall could be postponed
- A beneficial use for part of this wastewater would be to augment the flow in the Yarra…it was not one of the considerations when the SEPP was located and designed, but Carrum is a great distance from the present point of discharge of the effluent, Bass Strait.

- Victorian prices for agricultural irrigation water are subsidised to such an extent little is to be gained from reclaimed water use.

The opportunities for recycling were seen as use on landscape and recreational areas, both in Metropolitan Melbourne and in other towns, especially Mildura, Bendigo, Horsham, Kerang, Wangaratta, Morwell, Echuca, Geelong, Sale and Moe-Yallourn. The use of reclaimed water for groundwater recharge or deep percolation, and surface water streamflow augmentation was noted. Municipal uses recognised included for fire fighting, street flushing, sewer flushing, landscape irrigation and lakes, recognising that eutrophication due to phosphorus and nitrogen has so far ruled the latter out in Australia. Domestic uses by means of a ‘two-pipe’ system, and cooling water use in industry and for boiler feed and process water were also suggested.

The statutory policy State Environment Protection Policy (Waters of Victoria) followed, and listed water recycling as the preferred approach for managing treated sewage in 1988. This resulted in an increase in water recycling through the 1990s. Twenty-five years after the 1978 report, Victoria has begun to develop more of an awareness of the 1978 report’s predictions and suggestions. The importance of water resource management and the potential role of water recycling to contribute to environment remediation, and improvement by minimising treated wastewater effluent discharges; to contribute to economic development and to contribute to the security of water supplies is now being seriously considered. A paper, *Securing our Water Future – Green Paper for Discussion* (DSE 2003) was released in August 2003. Noting that 273 Victorian towns were then on water restrictions, and that while Melbourne had reduced its annual *per capita* water consumption from 349 kL in the early 1980s to 210 kL in 2001, the paper suggests that a further 15% reduction in its drinking water use should be sought by 2010, with 20% of Melbourne’s wastewater being recycled by that date. Proposals include: -

- Greater use of rainwater tanks, particularly in new homes – all new homes to have either a rainwater tank or a solar hot water system from 1 July 2005,
- work on a regulatory framework for greywater, which if managed properly, can be used in toilets,
- management of stormwater as a water resource rather than a drainage problem, with potential uses which include substitution for potable water by large scale irrigators, such as golf courses, racecourses, sportsgrounds, public open space and suburban agriculture, and for “third pipe” domestic applications,
- using recycled water for domestic non-personal uses such as toilet flushing and garden watering including its possible compulsory use in new developments, and for watering park and recreational areas and some industrial uses,
- developing targeted opportunities for sewer mining for adjacent markets

It is not proposed that recycled water be placed in the potable supply system, but that technical developments and implementation elsewhere be monitored. A new dam for Melbourne is considered not sustainable.

The Victorian Government had previously had developed a number of water recycling scoping reports (GHD 2002a, b), an issues and options report for water recycling (SKM 2002) and released its *Water Recycling Action Plan* in October 2002

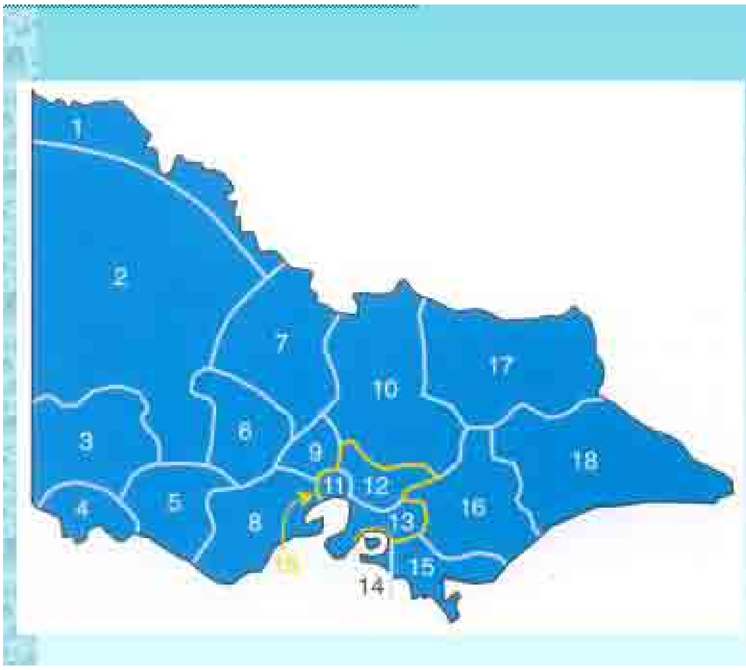
(DNRE 2002). A number of opportunities for recycled water use in the greater Melbourne area have been identified (Bluml *et al.* 2002). It has been estimated that if 50% recycling were achieved by 2020, it would allow replacement of 35% of the potable water currently used, providing the opportunity for deferment of additional infrastructure for up to 50 years (McDonald 2002).

Victoria's *Guidelines for the Use of Reclaimed Water* were also updated and reissued in 2003 (EPA Victoria 2003).

The **Economic Services Commission** was established as the economic regulator of the whole water industry from 1 January 2004, while the **EPA Victoria** has responsibility for setting environmental standards, and regulates environmental performance, particularly of wastewater treatment plants. There have been recent studies of the impact of the major Melbourne effluent outfalls into Port Philip Bay (Harris *et al*. 1996) and at Boags Rocks (Newell *et al*. 1999).

Victoria has 19 water authorities whose boundaries are shown in Figure 32. Between them, they operate 174 STPs, involving 15 coastal discharges. However, most STPs are small plants discharging inland, involve high levels of reuse (half being at 100%), but represent a small volume in total (Reid 2003). The extent of recycling in those Victorian STPs using effluent re-use is given in Appendix 1. Less than 40GL of treated wastewater is reused in Victoria. Only 6 GL/year is reused in Melbourne, being 2% of the current 295 GL/year of effluent produced.

Figure 35. Water Authorities in Victoria
(Byrnes 2003, from Victorian Water Industry Association Inc.).



Map Ref Number	Business Name
1	Lower Murray Water
2	Grampians Water
3	Glenelg Water
4	Portland Coast Water
5	South West Water
6	Central Highlands Water
7	Coliban Water
8	Barwon Water
9	Western Water
10	Goulburn Valley Water
11	City West Water
12	Yarra Valley Water
13	South East Water
14	Westernport Water
15	South Gippsland Water
16	Gippsland Water
17	North East Water
18	East Gippsland Water
19	Melbourne Water

4.4.1 Melbourne

Melbourne's water is distributed by a water wholesaler, **Melbourne Water Corporation**, to three water retailers, **City West Water**, **South East Water** and **Yarra Valley Water**.

Unlike Sydney with its numerous STPs, Melbourne is primarily dependent on two major Melbourne Water Corporation STPs, the **Western STP** at Werribee and the **Eastern STP** at Carrum. Currently, Melbourne Water supplies small quantities of recycled water from its Eastern STP to primary producers, open spaces and golf courses. During the 2002-3 drought, Melbourne Water invited applications for recycled water available by tanker for non-potable uses complying with EPA guidelines (Melbourne Water 2003).

The Melbourne retail water companies treat about 25GL effluent/year. Yarra Valley Water, the largest of these, has nine small plants, all of which produce effluent to Victorian EPA Class B. The **Craigieburn STP** supplies around 10% of its effluent to the Craigieburn Sporting Club, and small proportions go from the **Brushy Creek STP** to two golf courses. The remaining STPs use less than 1%, internally for operating the plants, but Yarra Valley Water has been developing an Irrigation Strategy to establish the potential for establishing a recycled water scheme to the Yarra Valley horticulture Industry. However, high rainfall does limit the market demand. Other opportunities are also being explored. Three of the plants are to be closed, but one discharges into the Merri Creek that is the habitat of the Southern Bell Frog, which is listed as threatened. The proposal to cease discharging from the STP has been deemed a ‘controlled action’ by the Federal Department of Environment and Heritage under the *Environment Protection and Biodiversity Conservation Act* and YVW has been obliged to continue the current discharge from the STP pending resolution as to whether it must maintain a minimum environmental flow if the STP is closed.

South East Water supplies agricultural areas from its **Pakenham STP**.

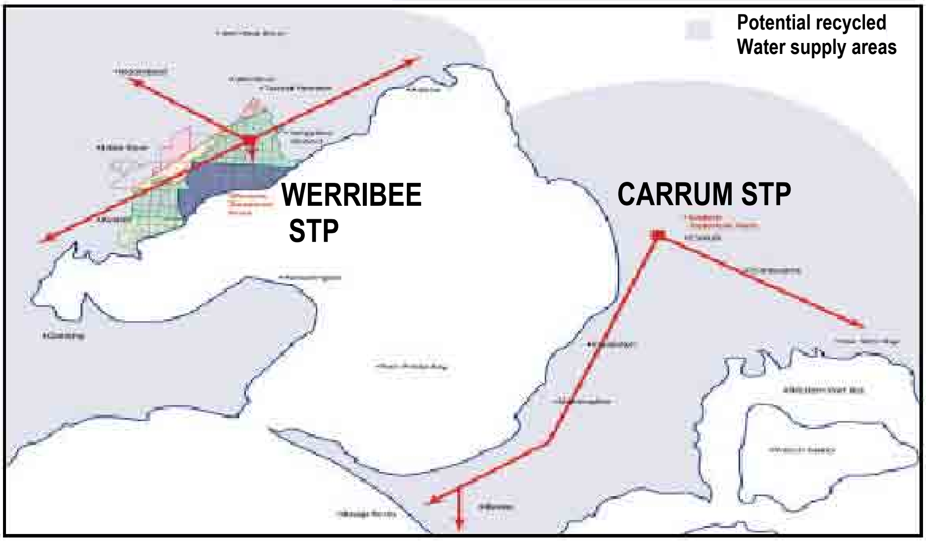
With Victorian Government support, City West Water, South East Water, Yarra Valley Water and Melbourne Water have established the *Smart Water Fund* to encourage the development of water saving projects, including water recycling.

KBR (2003) has undertaken a detailed study of a proposal to establish the beneficial reuse of 35 GL of recycled water per year from the Western STP, Werribee, for new intensive horticultural and agribusinesses using a 38km pipeline to the Balliang district, replacing its current broad acre dryland agriculture. Since salinity and/or sodicity of the recycled water are likely to be key determinants of the feasible uses of the water, a salt return pipeline has been proposed for the same trench as the supply line. There is also scope to encourage intensive horticultural producers currently using water from the Werribee River and the adjacent groundwater basin to move to the new area, freeing up that water for potable use, recognising that servicing the adjacent urban growth area is currently among the most expensive in Melbourne due to its distance from the principal reservoirs in the east. Increases in land values would be a significant component of the economic evaluation of the proposal. A demonstration project at Werribee involving access to 400ha for agricultural enterprises is under consideration. Up to 5.5 GL of recycled water will be available for Werribee growers from the 2004-5 summer, with subsidised potable water from the Thompson dam in the interim. A further initiative is the supply of recycled water to the Werribee tourist precinct. Up to 15 GL/year is being considered for intensive agriculture and rural living in the Little River area. There is future scope for the installation of domestic ‘third pipe’ recycled water reticulation with concomitant potable water savings in Manor Lake, Wyndham North and Werribee over the next twenty years with a projected recycled water demand of 5 GL/year. Industries in the Altona-Laverton area also present potential recycled water market opportunities (GHD 2002b). Production cost has been estimated at $2.68/kL, significantly above the current cost of potable water to consumers (GHD 2002a). There is potential in the longer term for some wastewater flows to the Eastern STP to be diverted to the Western STP, prospectively raising recycled water capacity to 95 GL/year.

The Eastern STP currently produces class C effluent but is to be upgraded to tertiary treatment with an added polishing plant by 2005 (Wright 2003), and by early 2004, 43 farmers at 54 sites in the Cranbourne and Five Ways area had signed up for the $20 million scheme (Thwaites, 2004). However, efforts by the Federal Government to support this upgrade earlier failed due to local authorities being unwilling to undertake increased treatment without some up-front agreement with potential customers (Nott 2003). The major water recycling opportunity being developed is the Eastern Irrigation Scheme. The initial stage of this project will supply recycled water to the Sandhurst Club development for irrigating golf courses and eventually for a “third pipe” residential system. Future stages of this project may involve extension of the pipeline to the east to service agricultural customers through the Cranbourne – Koo Wee Rup corridor, where there are established horticultural enterprises (Ireland 2003). There are also potential industrial markets in the Dandenong and Campbellfield/Somerton areas. Recycled water production costs from the Eastern plant could be over $3.00/kL (GHD 2002a).

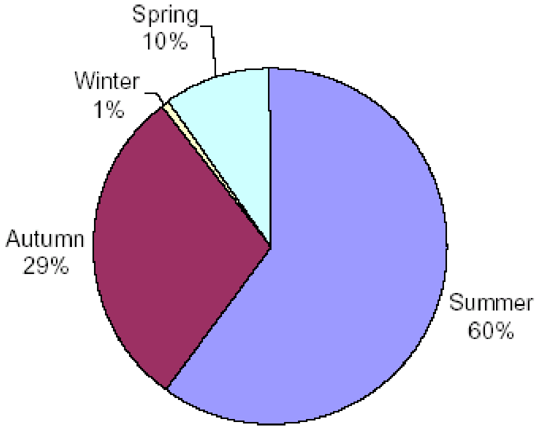
The location of Melbourne’s two main STPs and associated recycling projects are shown in Figure 33.

Figure 36. Location of Melbourne’s two main STPs showing directions of potential recycling mains for reuse schemes (adapted from Mallia 2003).



Victoria as yet does not have any “third pipe” housing developments, but the **Urban and Regional Land Corporation** (2002) is incorporating this technology, along with its continuing use of water sensitive urban design, into the new Aurora development at Epping North, 25 km north of the Melbourne CBD. Aurora will contain 9000 residential dwellings and incorporate its own STP. Recycled water will be available for public and private landscape irrigation, car washing and toilet flushing. Rainwater will be used for all hot water outlets in houses (subject to centralised management and proof of concept with UV disinfection), and lower potable water demand figures are being adopted, based on low water consumption appliances and effective reduction in flow through the use of restrictors at outlets. A particular challenge is provision of facilities that will be required for storing reclaimed water in winter when demand (Figure 34) is low (McLean 2003).

Figure 37. Modelled seasonal recycled water demand, Aurora, Victoria (McLean 2003)

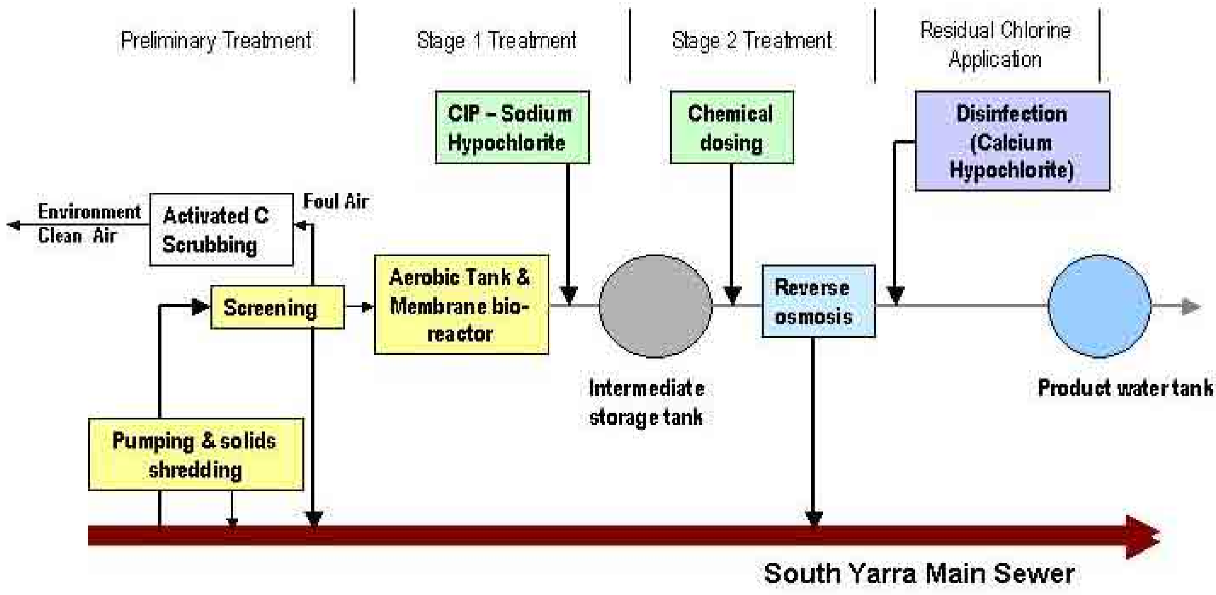


4.4.1.1 On-site recycling – Melbourne

There have been other recent water recycling developments in Melbourne. A portable sewer mining plant established initially in the Domain Gardens, later at Albert Park Lake, and now transferred to Werribee, showed that membrane technologies (ultrafiltration and reverse osmosis) could produce a Class A reclaimed water from Melbourne's sewers. The unit, mounted in a 12m shipping container (Figure 35), had no significant environmental impacts, and was suitable for taking advantage of on-site water reclamation opportunities to irrigate Melbourne's parklands (Mallia 2003) or top-up Albert Park Lake. Its product stream is shown in Figure 36.

Figure 38 – Portable STP in 12 metre shipping container used for sewer mining trial, Melbourne Domain Gardens (Mallia 2003).

Figure 39: Process Flow Sheet, Portable Sewer Mining facility (after Mallia 2003)



A further sewer-mining project at Flemington Racecourse, facilitated through Victoria's *Smart Water Fund*, will demonstrate 100 kL/day Multiple Water Reuse Technology developed by the CRC for Waste Management and Pollution Control, and licensed to Zeolite Australia Ltd.

The refurbished building at 60 Leicester Street, Carlton, occupied by the Australian Conservation Foundation, incorporates waterless urinals and an in-house biological STP, with water from it being used to flush toilets and irrigate the internal and rooftop gardens. The design brief included collected rainwater to replace 100% of normal mains water unless health considerations dictated otherwise, 100% on-site treatment of 'grey water' and 'black water', and to establish a new benchmark for low water consumption in a commercial building (Krockenberger 2003).

On the site of the former St Kilda Municipal Depot at Inkerman Street, St Kilda, a site subject to 70% flooding, a 236 unit housing complex has been developed. Assistance was provided from the Urban and Regional Land Corporation (Mitrevski 2003). The Commonwealth's Urban Stormwater Initiative supported an enhanced greywater recycling system with a grant of $267,214. The complex incorporates recycling of domestic greywater (bathroom basins, baths and showers), from about half the units in four buildings using an activated-sludge (aeration) tank, with secondary filtration in a 400 square metre native wetland and sand filtration on the site. There is recycling of the combined grey/stormwater for sub-surface garden irrigation and toilet flushing across the entire development (Melbourne Water 2002b).

There are proposals to develop residential allotments at Sanctuary Lakes with recycled water from City West's Altona STP (Wright 2003).

Oaklands Park, developed independently of metropolitan sewerage services, is a low-density village of 80 allotments with a minimum size of 0.4 Ha, set in approximately 121 Ha. of open space, which includes Deep Creek frontage. Individual wastewater systems produce treated water suitable for use in gardens (Foster 2000).

Such has been the extent of Melbourne's water shortages in the past two years that the Victorian government has introduced a subsidy of $20 on $100 worth of water saving equipment. Buyers of a 600 litre rainwater tank can get a rebate of $150. Installing a greywater recycling system, which previously attracted $150, from January 1 2004 is now eligible for a $500 grant where the installation has cost over $1500

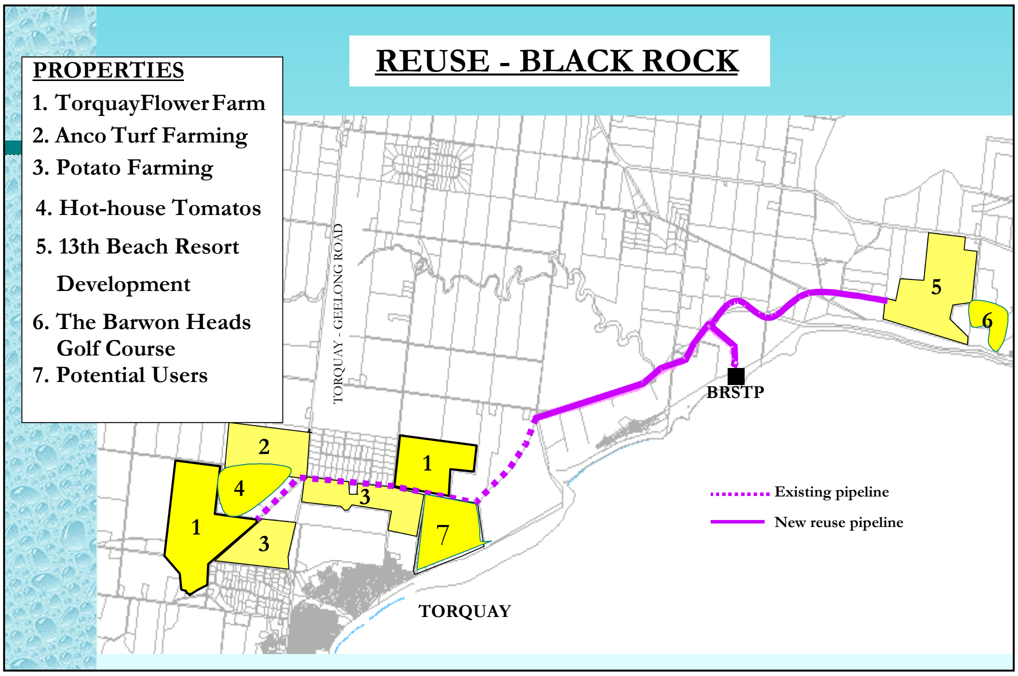
4.4.2 Rural and Regional Victoria

Water reuse, already in percentage terms, much higher than Melbourne, continues to expand in Victorian rural areas.

Barwon Water, which serves the Greater Geelong area, has a Water Resources Development Plan which notes that the local community had strong support for rainwater tanks. Barwon Water does not support their use for drinking water in built-up areas due to potential contaminants, though it accepts their rainwater for gardens and internal use in toilets, bathrooms and laundries. Recycling greywater is also seen as a highly efficient and long-term water re-use method for gardens and toilet flushing subject to appropriate installation. Stormwater reuse has potential in new large-scale developments where suitable storages can be planned, and a pilot demonstration re-use scheme is being considered for Indented Head on the Bellarine Peninsula.

Local community feedback has demonstrated significant support for recycled water. A Recycled Water Action Plan is being prepared by Barwon Water, which has nine STPs. The company supplies Victorian Class C effluent for the irrigation of golf courses, grape vines, flowers, potatoes, tomatoes and turf production from its Black Rock STP (Figure 40). Reverse osmosis of part of the stream from this plant is being considered for lowering the salinity of effluent being used for flower growing, turf and potato production (Barwon Water 2003a).

Figure 40 Current and potential recycled water users from Barwon Water's Black Rock STP (Barwon Water 2003b)



Barwon Water is completing a study looking at the potential for sewer mining and reuse to take loads off the extremities of its system, including at Lara, Leopold/Clifton Springs (part of Bellarine Peninsula) and Pt Lonsdale/Ocean Grove, the latter involving potential golf course use.

Western Water has implemented its $2.9 million Sunbury-Melton pipeline, to which the Victorian Government contributed $350,000, to supply class B recycled water to agricultural producers. To facilitate grower understanding of the potential for use of recycled water and develop a market for it, Western Water organised tours of recycling schemes already operating in South Australia (Western Water 2002).

Grampians Water now has 31 third party recycled water customers ranging from agricultural, horticultural and recreational/municipal uses, the first starting over 30 years ago. It provides over 600 ML of recycled water annually from its Ararat STP, from where a 16 km pipeline leads to a 224 ML storage at Hyde Park Winery at Great Western. Other wineries served are Dalkins West Gate Vineyard, Southcorp Wines, Garden Gully Winery and Toomey's Phoenix Vineyard. A golf course, racecourse, cemetery and a school oval are also served. This project attracted $350,000 of Commonwealth Landcare funding. Grampians Water is in the process of finalising a Reclaimed Water strategy, which has involved a wide variety of stakeholders, including Grampians Water staff and customers, rural water suppliers, regulatory agencies, Catchment Management Authorities and local government. An Issues Paper provided the opportunity to make stakeholders aware of the wider issues beyond their own particular agendas. A second stage has been to develop the planning tool. This is based on a number of stages. These involve: -

1) Developing a Commitment or Policy Statement
2) Integrated water resource planning so that reclaimed water is considered in the water resources, environmental, economic, and development strategies that might influence a particular town/region.
3) Identification of options. (This involves an assessment of 12 technical principles to sieve out unfeasible options, with consultation of relevant parties.)
4) Evaluation of options, involving a similar TBL assessment tothat developed in the Victorian Department of Sustainability and Environment (DSE) guidelines for planning and reporting recycled water programs. The Department's project and that of Grampians Water were developed in parallel at the same time.
5) Implementation of preferred option.
6) Monitoring and review (Coutts 2004).

Goulburn Valley Water recently upgraded its **Tatura STP** including provision for effluent reuse. An adjoining farm area of 126 Ha was purchased and developed for irrigation with reclaimed water from the plant. In addition, offsite supply under third party re-use agreements was developed with four neighbouring irrigation farmers. Pipelines to supply reclaimed water to their properties were constructed. The supply of reclaimed water to a number of users minimises the risk to the Authority of any default by one user, and allows long-term environmentally sustainable reuse. These works ensure that discharges to the local drainage network will no longer be required

(Wall *et al.* 2001). Third party agreements have recently been established for new farming enterprises, new woodlots and an agreement reached for reuse water for the Yea Golf club. To maximize the use of reclaimed water, winter storage lagoons have been constructed at its STPs and the land available for irrigation increased. These improvements have resulted in full reuse of reclaimed water at most facilities.

Coliban Water has let a 25 year contract to Earth Tech to design, build, finance, own and operate a water reclamation plant on the site of the present lagoon-style treatment plant at Echuca, and subsequently construct a 30 km pipeline from Rochester to transport wastewater to the new plant. When completed, the treated effluent will be used for irrigation on farmlands between the two towns, much of it by centre pivots for pasture (Wright 2003).

The extent of reuse by the other Victorian water authorities is included in the Victorian table, Appendix 1.

4.5 Queensland

Queensland processes nearly 340,000 ML of treated sewage effluent each year in over 240 sewage treatment plants, with the vast majority discharged into rivers and estuaries. Of the 27,400 ML/yr used for urban purposes, the vast majority is used for golf course irrigation (Gardner 2002).

4.5.1 The State Water Recycling Strategy

The Queensland government has established the *Queensland Water Recycling Strategy* (Wells 2001) with implementation by the **Queensland Environmental Protection Agency** (QEPA), to enable Queensland to use recycled water more effectively and efficiently, to accommodate increases by 40% in population over the next 21 years and to support economic growth while helping to protect the environment and safeguarding public health. The Strategy defines water recycling as the sustainable and beneficial use of appropriately treated wastewater, urban stormwater and rainwater in ways that safeguard public health and environmental values, and that the quality of the water must be matched to its purpose.

Opportunities and challenges for use include recycling from:

- Municipal effluent
- Industrial effluent
- Agricultural effluent
- Greywater in sewered and unsewered areas
- Urban stormwater
- Rainwater.

Current legislation does not allow the use of treated or untreated greywater in sewered areas, though amendments to allow regulated trials are proposed. On-site use of treated or untreated blackwater is not allowed in sewered areas, and the government does not intend to change this position, an approach that effectively rules out modular sewage treatment units for high rise buildings. However, the use of rainwater tanks for both potable and non-potable purposes is permitted.

Businesses that are defined in the Strategy as being potentially able to use recycled water include:

- Commercial car washes
- Paper mills
- Mines
- Petroleum refineries
- Power stations
- Manufacturers of concrete, bricks, textiles, metals and paints
- Road construction companies,
- Tanners and hide curers
- Tourist resorts and
- Distilleries and wineries

The Queensland Government does not support the use of treated effluent for direct potable purposes and does not intent to change that position.

Queensland is still revising its water reuse guidelines. Queensland's needs for environmental flows are still being determined. Government support for water infrastructure is based on an integrated approach to water management, in which water recycling is one element of an overall water management process.

Water and wastewater services are provided in Queensland by local government instrumentalities. Provision is available on merit for the Queensland government to provide up to 50 percent of the cost of up-grading STPs.

4.5.2 Greater Brisbane / Gold Coast

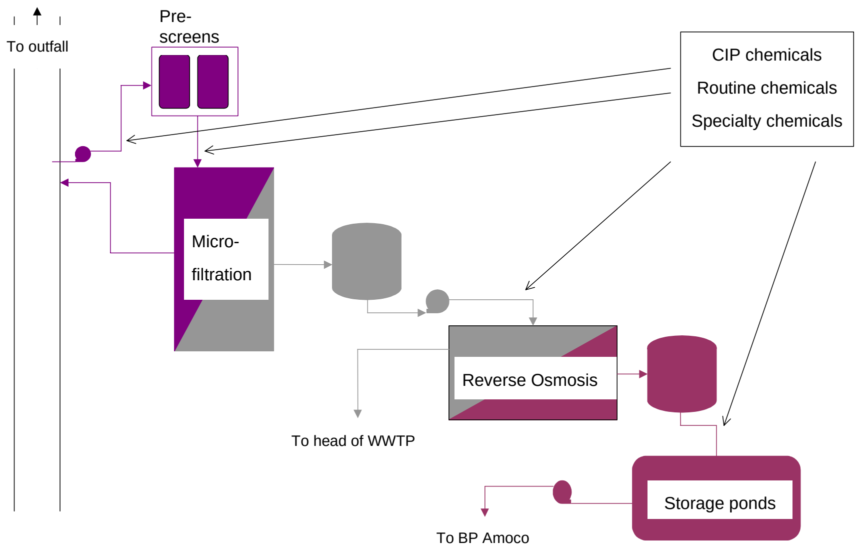
4.5.2.1 Water and Wastewater Services

Brisbane Water, which is a corporatised arm of the Brisbane City Council, provides both water and wastewater services. It is one of nine Councils that are "shareholders" in the **South-East Queensland Water Authority**, the bulk water authority that manages the Wivenhoe Dam as its primary asset.

Brisbane Water has ten STPs, from which it discharges 285 ML daily into the environment. About 8 ML are used on golf courses. (Woolley 2003)

A further 10 ML is recycled from the advanced water reclamation plant added to its activated sludge STP at **Luggage Point**, located near the mouth of the Brisbane River. A commercial contract with BP Amoco requires Brisbane Water to provide between 10.6 and 14 ML/day continuously for 20 years. The recycled water, which is produced from ten percent of the Luggage Point plant output through an advanced microfiltration and reverse osmosis process, is used at the refinery as boiler feedwater. Its conductivity is to be between 60 and 120 µS/cm, pH 6.5 – 7.2, Turbidity <0.1 NTU and free chlorine 0.3 – 0.5 mg/l (Hopkins and Barr 2002). The product train is shown in simple terms in Figure 41. The recycling component of the plant cost around $20 million. It received $400 000 support from the Commonwealth's Natural Heritage Trust (NHT) Coasts and Clean Seas program, and about $1½ million from the Queensland government.

Figure 41 Product train for the advanced tertiary treatment of treated effluent at the Brisbane water Luggage Point STP (Hopkins and Barr, 2002).



The Brisbane City Council's policy is to recycle as much as possible, driven from a commercial perspective. The Luggage Point installation was an attractive option for supplying the adjacent refinery when compared with the cost of the alternative of bringing in a large new main for the carriage of potable water, apart from also representing a significant saving in potable water (Woolley 2003).

4.5.2.2 Demonstration Water Recycling Projects

Two demonstration water-recycling projects have been established in Brisbane.

At **Springfield**, a 2,850 ha residential development located between Brisbane and Ipswich, with a projected 18,000 home sites and a final population of 60,000, is served by the **Ipswich Water's Carole Park STP** with a treatment capacity of about 1.2GL/yr. The recycling component of the project is a joint venture between the Queensland EPA, Ipswich City Council and Delfin Lend Lease with $625,000 from the NHT Coasts and Clean Sea program being the major contribution. The components of the $1.5M scheme involve a 500 kL/day tertiary disinfection plant achieving California Title 22 standard effluent - i.e. 5 log reduction in viruses, 2 NTU and <2 coliforms/100 ml (DHS 2001) from a secondary treated effluent from Ipswich Water's Carol Park sewage treatment plant. The other water quality targets include TN ≤ 5mg /L, TP ≤ 4mg/L; SAR ≤ 7; EC ≤1.3 dS/m. Secondary treated effluent is being pumped 6 km through an existing pipeline into a 3 ML water reservoir where extended chlorine contact (CT ≥ 450 mg.min/L) takes place after suspended sediment is largely removed in a clarification – dual media filtration system at the base of the tower (Gardner 2002). The recycled water is being supplied for the irrigation of public open spaces including road verges and median strips on the Springfield Parkway, and to Bob Gibbs Park. It is also used on an oval, grassed areas and gardens at Woodfield College. The recycled water pipes are coloured purple, tap handles on the recycled water outlets can be removed so children cannot access the water, irrigation occurs only between 10pm and 3am, and children eat their lunch away from the irrigated areas. Provision has also been made for recycled water to be used in up to 20 houses after passing through a further 4.5 kL/day microfiltration process, followed by UV disinfection and chlorination

Thirteen have already been retrofitted with a 'third pipe' system to provide water for toilet flushing and two external taps at an average cost of $2000. Reuse water is charged at half the potable water rate which is $1.28/kL for volumes above 150 kL/quarter. Reuse water has also been reticulated to an industrial park development, but as yet has not been accessed. A consultant has estimated the 'whole of life' cost of the recycled water at $1.45/kL (Queensland EPA 2002; Hall 2003).

A small scale **Advanced Water Recycling Demonstration Plant** with nine modules encompassing commercially available lime clarification, dissolved air filtration, dual media filtration, ozonation, Biologically Activated Carbon (BAC) filtration, microfiltration, reverse osmosis and UV and chlorine disinfection was constructed by Aquatech Maxcon Pty Ltd at a cost of over $1 million. The Pine Rivers Shire Council hosted the plant at the South Pine Sports Complex, Brendale, from mid 2000 to 2002, using treated effluent from the adjacent Brendale STP to test various component trains (Queensland EPA 2003). The plant is being relocated to the Gold Coast.

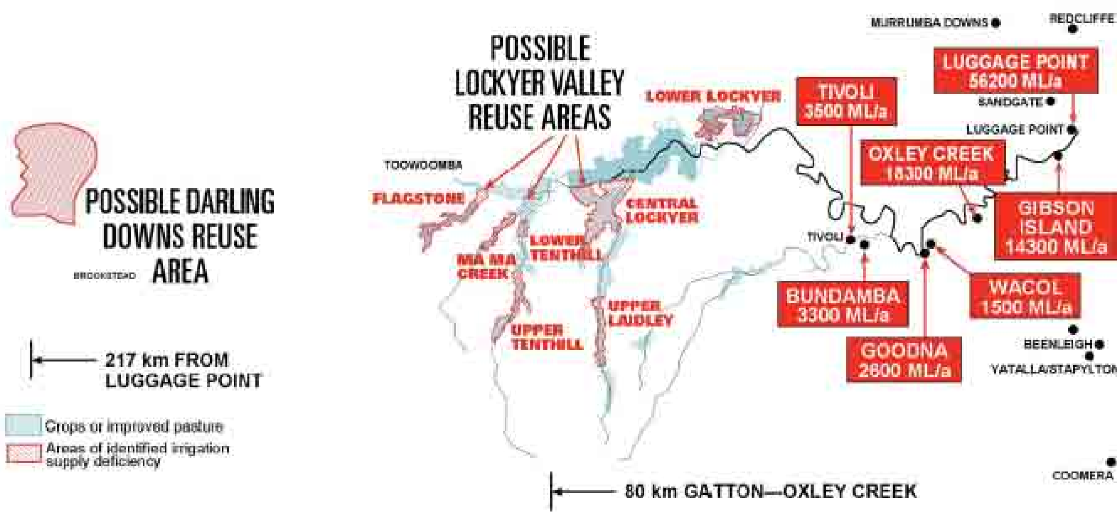
4.5.2.3 Planning, Heathwood/Brazil

Mitchell *et al*. (2003) have examined options in a greenfields study for a possible development at Heathwood/Brazil, using rainwater, stormwater and reuse water for non-potable purposes rather than potable water. Reductions of 77% in the import of potable mains water, 25% in the export of sewage and 27% in the export of stormwater would be achieved from residential properties by designing an integrated urban water management system that installed all of these components when developing the greenfields site. Capital costs of headworks and infrastructure for this option which includes a third pipe system, for residential use were 22% higher per ha and 21% higher per hectare for industrial sites. Operating costs were a further 10% higher for the residential area and 15% higher for the industrial area. However, a preliminary analysis of externalities due to water supply and wastewater supply zone cost savings indicate they are of sufficient in size to more than counteract the additional direct infrastructure costs. After a fuller assessment of externalities, it was anticipated that this scenario would be likely to be a more sustainable development than the base case of providing a conventional water supply, wastewater and stormwater infrastructure.

4.5.2.4 South East Queensland Water (Lockyer Valley-Darling Downs) Project

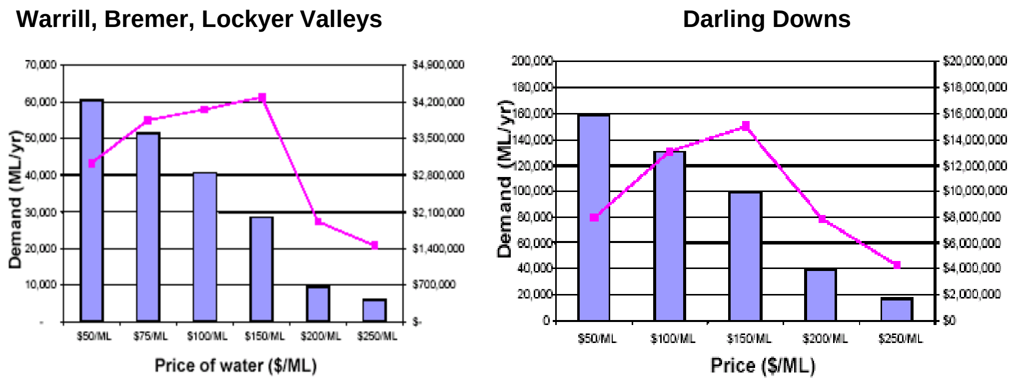
The Lockyer Valley, east of Brisbane, is a major irrigated horticulture production area, but the groundwater resources upon which it depends have been diminishing. In 1996, a local grower group, 'NuWater', conceived the idea of treating wastewater from **Brisbane**, **Ipswich** and **Logan** to an advanced tertiary standard and piping it to the Lockyer Valley and up the 460 m escarpment to the Darling Downs in their 'Vision 2000', thereby addressing two significant water-related issues for the region, the environmental impact of effluent discharge to the Brisbane River and Moreton Bay, and current water shortages for agricultural irrigation in the Lockyer Valley and eastern Darling Downs. The project would deliver a high standard recycled water to irrigators in the Warrill, Bremer, Lockyer Valleys and the Darling Downs. The general layout of the proposal is shown in Figure 42.

Figure 42 Potential layout of Lockyer Valley – Darling Downs recycled water infrastructure scheme (T. Gardner, pers, comm., adapted from Kinhill)



A market assessment of growers identified a potential demand for recycled water of the order of 127,000 ML per year at a cost of 15 c/kL, as shown in Figure 43.

Figure 43 Demands for water in the Warrill, Bremer and Lockyer Valleys and Darling Downs at a range of supply prices (Hamlyn-Harris 2003)



The volume of water available in 2005 from the Ipswich, Brisbane and Logan STPs is currently 112,700 ML per year, increasing to 155,300 ML per year in 2025. The **Queensland Department of State Development** (QDSD) commissioned a consultancy to scope and cost the required infrastructure to source and treat wastewater from existing STPs in Brisbane, Logan, Ipswich and the northern Gold Coast areas. Consideration was also given to supply from possible future plants. In all cases, it was assumed the wastewater was provided without charge. It was shown that the project was technically feasible, with a capital cost ranging up to $600m and operating costs of approximately $30m per year (Brown and Root 2001). Further studies were suggested. In the end result, it was determined that a full scheme supplying all potential users would cost around $790m to construct and $20.5 m per year to operate, i.e. a total cost of around $894 per ML, or an O&M cost of $167 per ML of water delivered. The capital costs are dominated by the cost of pipelines (60-70% of the total), while operating costs are dominated by pumping energy costs (50% of the total). A scheme supplying the Darling Downs would require over 300 km of trunk pipeline and pumping stations with a total of 39 MW of installed capacity, including a 15 MW pumping station at the Toowoomba Range. Providing a smaller supply to the Lockyer Valley only would reduce the cost to around $124 m , equivalent to $920 per ML or $144 per ML O&M only.

The problem for the SEQ Recycled Water Project is that, while there is proven demand and the scheme is technically feasible, the amount that farmers have indicated they are prepared to pay for the water is barely enough to cover operating costs, and therefore, substantial external funding would be required for the scheme to proceed. (Hamlyn-Harris 2003). The scheme has been declared unviable by the Queensland Government, potentially involving subsidies of between $1 million and $2 million per farm (Barton 2003).

4.5.2.5 The Pimpama-Coomera *Waterfuture* Project

Gold Coast Water, a commercialised business unit of Gold Coast City Council, is completing the Pimpama Coomera *Waterfuture* project which is investigating the more sustainable provision of urban water services. The project area is located south of Brisbane in an area whose population is growing fast with an additional 150,000 residential population anticipated over the next 50 years. The current housing stock of 2500 in the area has been predicted to rise to 26,756 in 2021.The region is water resource constrained and treated water release sites are adjacent to environmentally sensitive areas.

A Northern Wastewater Effluent Reuse Advisory Committee established in November 1997 recommended after community consultation that two advanced tertiary water treatment plants should be developed in the Northern Wastewater Study area between the Logan and Coomera Rivers, with cane land irrigation, wetlands regeneration, open space irrigation and cooling water for the Rocky Point Cogeneration Power Plant cited as the principal uses of its recycled water (Lawrence *et al.* 1998)

With this work already available, the Gold Coast City Council embarked on a new integrated urban water management planning approach, initiating its *Waterfuture Project* (Gold Coast Water 2003a).

The project aimed to ensure the more sustainable urban use of the region's water resources and achieve the following outcomes:

- the City water supply being in balance to ensure the water supply capacity meets demand,
- improved health of Gold Coast waterway systems,
- reduced greenhouse gas emissions (recognising that sewage pumping and wastewater treatment are very energy intensive),
- minimise impact of urban water infrastructure on ecosystems,
- minimise the impact of treatment by-products,
- ensure availability of fit-for-purpose water quality,
- improve service reliability to customers,
- improve satisfaction of customers' expectations
- reduce whole-of-life economic costs.

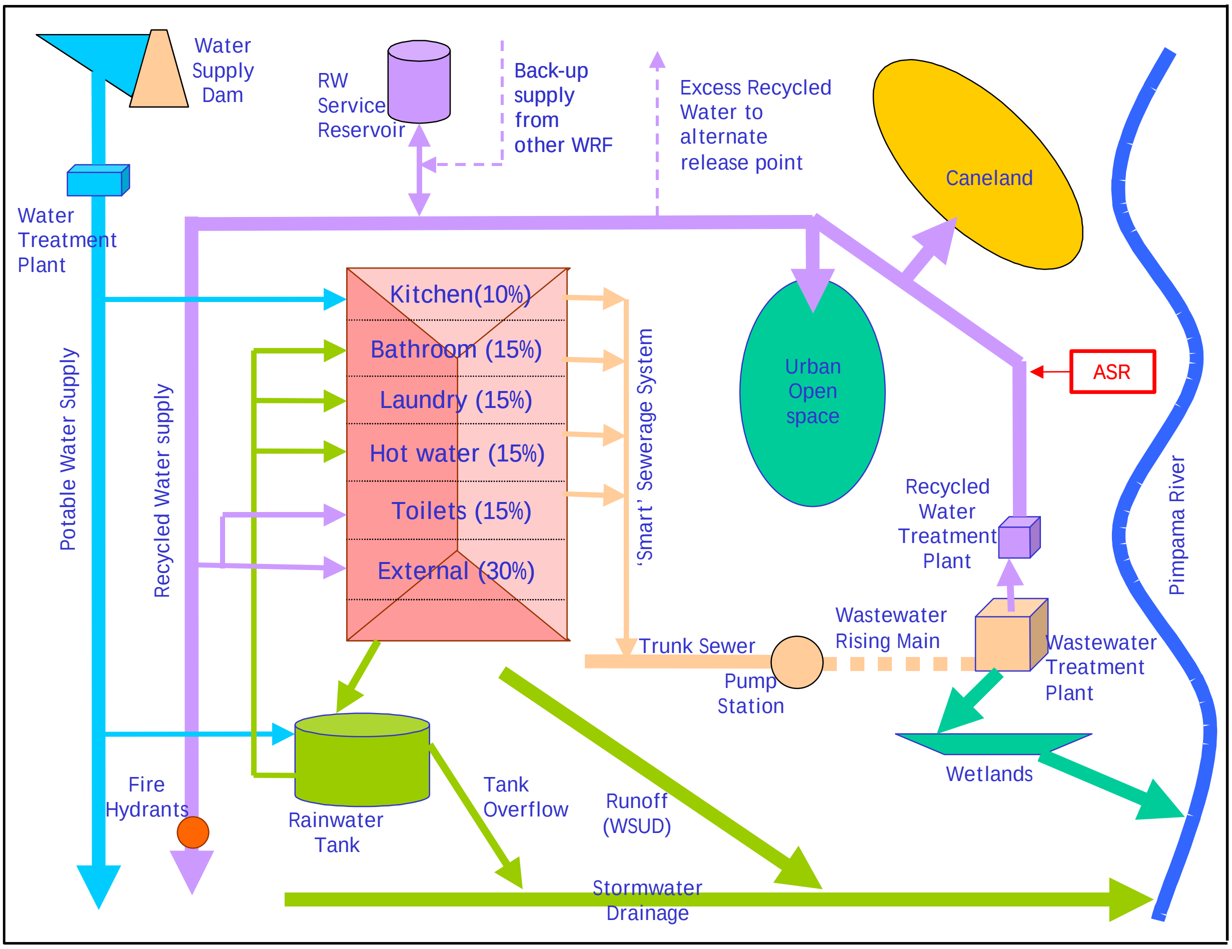
After a series of workshops between Gold Coast Water and government stakeholders in 2002, an Advisory Committee was established, involving a broad range of stakeholders, including community members, to develop the Master Plan from its earliest stage. Targets were set in comparison to a business-as-usual model, including:

- replacing 25% of drinking water with other sources for non-drinking uses;
- setting a maximum of 40 kg Nitrogen release per day from the regional wastewater treatment plant,
- releasing less than 12.5 ML treated water per day, with 5% less stormwater flow, and a 15% reduction in peak instantaneous water demand rates,
- 30% reduction in potable water system retention,
- 25% reduction in unaccounted for water (losses),
- 20% net reduction in greenhouse gas emissions,
- defer or eliminate the need for new surface water storages,
- improved consumer acceptance response to the service provided and improved local amenity.
- Improvements in the work environment and
- No increase in the whole-of-life cost to the community for all services.

Ten options were initially developed. Later these were reduced to five, but two more devised by the Advisory Committee were added. A shortlist of five was selected from this group for final appraisal, with various water, stormwater and recycled water options with a range of environmental outcomes, potential issues and risks. An example of one of the options is shown in Figure 44.

Community consultations took place in late 2003, with a finalised Master Plan submitted to the Gold Coast City Council in early 2004.

Figure 44 Gold Coast Water Futures Option B (formerly 3) – Dual reticulation for gardens and toilets, rainwater tank water used for bathroom, laundry and hot water, aquifer storage and recovery of treated water from the treatment plant and "smart sewers" that measure and record water use at specific periods (Gold Coast Water 2003b).



4.5.3 Rural and Regional Queensland

4.5.3.1 Coastal Development Projects

A variety of projects are being examined through the **Urban Development Institute of Australia**, ranging from use of rainwater tanks to substantial effluent reuse. Some seek to be totally self contained such as the 32-unit **Agnes Water** housing development near Bundaberg, with water needs being met without connection to a community water or sewerage scheme, using on-site wastewater treatment, recycled for toilet flushing, gardens and possibly clothes washing.

Some projects are driven by the opportunity to develop coastal and beachfront properties, but are constrained by regional water supplies and discharge standards. Some communities appear to have set development limits on their future growth, with water being a constraining factor. This has obliged any nearby developments to be self-contained, in terms of water supply, stormwater management and wastewater disposal (Nott 2003). An example is **Noosa Shire** has imposed a population cap based on its water supply limits that will be reached within the next 5 years. This is causing conflict between existing and potential water users.

Other regional schemes include that of **Wide Bay Water** at Hervey Bay, a high population growth area with effluent previously being discharged into the sea adjacent to a tourist area, a fisheries reserve and a whale habitat. Two wastewater irrigation schemes are now in place, being used on 400 Ha sugar cane, 60 Ha of native pastures, 60 Ha of native woodland, a turf farm, golf course, sports field and the airport, currently achieving 75% reuse, but aiming for 100% by 2007 (Lever 2003). The recycled water is prepared by active sludge secondary treatment, is chlorinated and held in a lagoon for 30 days. Initially, it was used experimentally on a cane farm with traditionally low production, but which after the use of recycled water, became the highest producing property in the district. This change generating a considerable interest in and demand for recycled water by other growers. To provide for fluctuations in demand, Wide Bay Water has an effluent storage capacity of 1,600 ML for an average sewage volume of 2,900 ML per annum.

Wide Bay Water has also instituted an innovative stormwater reuse program by harvesting stormwater from flood retardation basins at night and channelling the water through its sewers when there is very little sewage flow, for treatment at STPs. This project, the initial stages of which attracted a 50% Queensland government matching grant and $805,000 from the NHT Coasts and Clean Seas program, has a number of advantages, including:

- exploits existing sewer infrastructure
- optimises existing effluent reuse infrastructure
- involves innovative hydraulic modelling,
- decreases farm water demand from other sources,
- reduces urban nuisance floods,
- increases water for agricultural irrigation and thereby farm profitability,
- minimises odour production and corrosion within the sewerage network and prolongs infrastructure life (Heron and Lever 2001).

Toowoomba, one of the largest cities in the Murray Darling Basin with a population of around 100,000 people, is served by the **Wetalla STP**. Design flows from Wetalla are 9,500 ML/yr in 2000 increasing to 11,000 ML/yr in 2010. Toowoomba is providing 1GL/year effluent from its Wetalla treatment plant through an 80 km pipe to the Millmerran powerhouse for cooling, and has developing a new 16 ML/day plant to produce further recycled water. Uses could include coal washing, horticulture, agriculture and at an industrial distribution centre (Clark 2003).

However, survey results indicated that farmers did not want to pay more than about $25-50/ML for piped effluent. There was no interest expressed in purchasing water at more than $100/ML (10 c/kL). At present, farmers on Gowrie and Oakey Creeks irrigate with effluent from the creek essentially at no direct cost apart from nominal licence fees The proposed pipeline would deny them access to this ‘free’ creek water and provide an alternative piped supply for which they must pay. So why would they want the piped water? However, competition may develop for the water from other non-agriculture consumers, and EPA concerns about effluent discharge to the creek, could see them lose access to the water altogether (Hamlyn-Harris 2003). Growers have yet to appreciate that a piped supply is inherently of greater value to the irrigator because it provides improved supply reliability and therefore improved certainty in the production cycle.

Gladstone, which has an abnormally high industrial base, recycles all of its wastewater, as secondary effluent, to industry. This was the outcome of the **Gladstone Water Board** having to impose water restrictions during the drought of 2001-2. Industry uses about 80% of Gladstone’s water supply. (For most urban water supply agencies, 80% goes to domestic users.) Initially, industries were obliged to accept a 25% water restriction, with the prospect that this would have to be increased to 50%, which would have a serious impact on the town’s economy. Many industries were able to accommodate the 25% reduction by redesigning their trade flows, and these savings are being retained. Gladstone’s treated wastewater is only Class B but is suitable for some industrial uses where large volumes of relatively low quality are required. The NRG Power Station uses 0.5 ML/day for ash conditioning and 1.5 ML/day for dust suppression The remainder of the effluent goes to Queensland Alumina which has signed up to take up to 100% of the Class B effluent for 20 years, with a right of renewal for a further 10 years (Doak 2003).

Industrial and amenity use options are being considered in **Rockhampton**, **Townsville** (commercial, residential and industrial), **Mackay** (agricultural and industrial), **Dalby** (industrial) and **Stanthorpe** (agricultural).

The **Queensland Department of Natural Resources and Mines** recently asked for an extract of a rolled-up figure for recycling by Councils in Central Queensland (Gladstone to Sarina and west to Emerald). Allowing for the increased uptake in Gladstone (100%), the level of water recycling in that region has reached an encouraging 45.5% (Davis 2003).

4.5.3.2 MEDLI

To facilitate the development of appropriately sized infrastructure for recycled water use for irrigation, a computer-based model, **MEDLI** (‘**M**odel for **E**ffluent **D**isposal by **L**and **I**rrigation’), has been developed between the Cooperative Research Centre for Waste Management and Pollution Control, the Queensland Department of Primary Industries and the Queensland Department of Natural Resources and Mines. The program brings together options for pond size and irrigation area optimisation, taking into account enterprise and climate inputs, waste estimation, pre-treatment, pond water chemistry and water balance, irrigation and shandying, soil water and soil nutrient movement and plant growth to predict likely output, with area/volume optimisation based on costing.

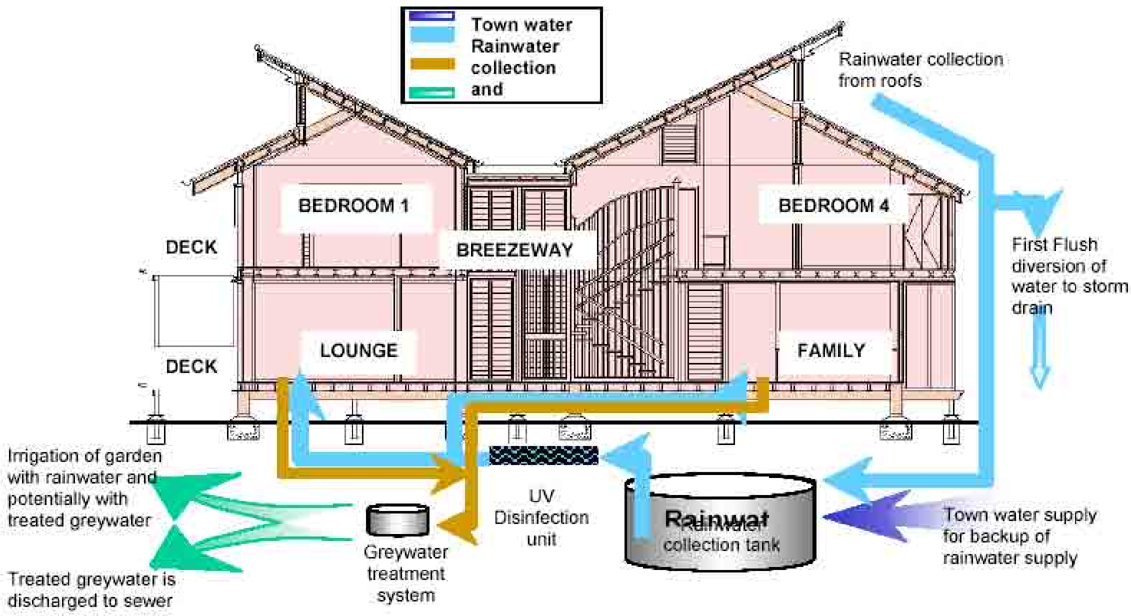
4.5.3.3 The Healthy Home®

The Healthy Home®, built on a beachside Gold Coast location, is a joint undertaking by the homeowners, architect Dr. Richard Hyde at the University of Queensland, and the Queensland Department of Natural Resources and Mines. The objective was to design and construct, with lightweight building materials, an energy-efficient and environmentally sensitive home which included a solar hot water system, rainwater for potable use, and a grey water treatment system for toilet flushing and garden irrigation (Gardner, Millar and Hyde 2003).

The home layout is shown schematically in Figure 45. An area of 120 m^2 of the 167 m^2 roof area supplies rainfall runoff to a 22 kL concrete cistern installed under the low set house. “First flush” devices located on each down pipe ensure that the first 1 mm of roof runoff goes to waste. The rainwater is reticulated through the house using a 0.7 kW pump after first passing through a 20 µ filter and 40 W UV disinfection system. The rainwater cistern is supplemented if necessary from the town water supply, after passing through a backflow prevention device. The greywater system is a recirculating sand filter contained within a partially buried 6 kL concrete tank. The tank compartments form a septic/surge tank, two pump wells and a 1.5 m^2 by 800 mm deep sand filter. The programmable flow controller doses the sand filter up to 96 times per day to maximise contact between the attached media growth and the percolating greywater. When the water level in the (second) pump well goes ‘high’, about 20% of the treated greywater is discharged to waste (or to another storage), to maintain hydraulic balance, with the remainder recycled through the system.

As indicated earlier, greywater reuse is prohibited in sewered areas of Queensland. Permission to install the greywater system was given by the Gold Coast City Council on the proviso that all greywater from the bathrooms and laundry was discharged to sewer. All other liquid waste from the house (toilets and kitchen) is discharged to sewer.

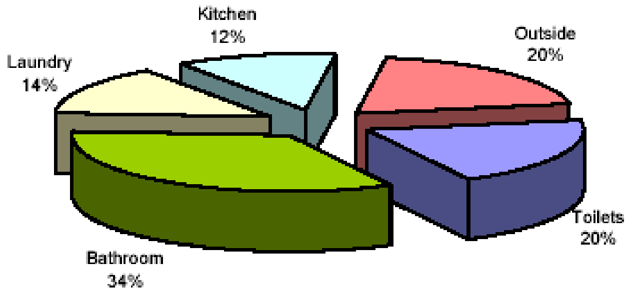
Figure 45 Rainwater and grey water systems in the Healthy Home® (Gardner, 2002).



The potable and greywater systems are intensively monitored. Despite the successful operation of first flush devices in the Healthy Home®, there were frequent intervals when faecal and total coliform levels in the rainwater tank exceeded the NHMRC (1996) drinking water standard of zero cfu/100 ml for both organisms, with peak values as high as 500 cfu/100 ml occurring after heavy rainfall events. Similar high concentrations of faecal coliforms have been reported by Coombes *et al.* (2000) for rainwater tanks in cluster housing at Newcastle. But in both cases, these levels are unlikely to be associated with human pathogenic organisms for which faecal coliform is an indicator (Cunliffe 1998). Nonetheless after a 40 W Trojan UV system was fitted to the rainwater tank at the Healthy Home® in August 2001, all subsequent fortnightly samplings returned zero values for faecal and total coliforms.

During the 24 months of water monitoring over 2000 and 2001, the Healthy Home® consumed 229 kL/year of water (627 L/day) compared with an average Gold Coast detached household consumption of 297 kL/year (averaged over 68,200 residences by Gold Coast Water) suggesting that the Healthy Home® residents (two adults and three children) are relatively frugal in their per capita water consumption. The use of water in the Healthy Home® is shown in Figure 46.

Figure 46 Percentage water use over two years in the Healthy Home® (Gardner 2002)



Both 2000 and 2001 were years of well below average rainfall of 1,460 mm/year on the Gold Coast with values of 1,030 mm and 1,180 mm, corresponding to the 15 percentile and 26 percentile rainfall years respectively. Consequently rainwater supplied only 36% of the total water consumption by the Healthy Home®. In an average rainfall year, this level of independence would be expected to be about 65%. Were toilet flushing water (91 kL) able to be sourced from treated greywater, with 50% of the balance of greywater (58 kL) used for garden irrigation, the home would have little need for access to mains water (Gardner 2002). Adoption of technology such as this could have a considerable impact on studies such as the Gold Coast *Water Futures* Master Plan.

4.5.4 Community Consultation

Many Water/Wastewater authorities have conducted significant consultation with their communities during the introduction of recycling proposals, the Gold Coast Pimpama-Coomera *Water Futures Project* being an exemplar.

Maryborough is diverting 73% of its effluent with the Maryborough Effluent Reuse Scheme, which was first mooted in the early 1990s. The scheme involves the irrigation of sugar cane crops with sewage treatment plant effluent from

Maryborough’s **Aubinville STP**. It is estimated that approximately 51,000 kg of nitrogen and 14,000 kg of phosphorus would no longer enter the Mary River system and would provide approximately 75% of the nitrogen and almost all the phosphorus nutrient requirements of the cane farms. Additionally, disposal of the sewage effluent by irrigation enables the Maryborough City Council to save costs on treatment plant upgrades. If the effluent reuse were not implemented, the Council would have to upgrade its Maryborough STP by incorporating Biological Nutrient Removal (BNR) to ensure the effluent is suitable for discharge to the Mary River. The annual costs to council for a BNR treatment plant upgrade would be approximately $995,000 per year compared with approximately $330,000 per year for the effluent re-use scheme.

To effectively implement the project and gain community input and acceptance, a community consultation program was undertaken. This consultation was in addition to the ongoing consultation/dialogue between organisations represented on a Steering Group. The community consultation phase of the project consisted of a five-step process, incorporating the following:

- Project inception
- Community information (announcement of scope)
- Feedback
- Community information (details), and
- Consultation report

As a result of the consultation, some modifications to the scheme were implemented. A proposed effluent balance storage tank was deleted from a site adjacent to the existing sewerage treatment plant (which is near residential areas) after objections from residents. This was interesting since it indicated that the residents possibly accepted the location of the existing STP but would not accept any expansions to it. With local groups involved actively in the formulation of the proposal, a considerable level of cooperation and goodwill was generated (Just 2001). Of the estimated $5.7m cost of the scheme, the Commonwealth’s NHT Coast and Clean Seas program provided $1.34m with the balance being contributed in equal parts by the Queensland government and the Maryborough City Council.

However, there have been several recycling projects in Queensland that have not proceeded as a result of community concerns.

Caboolture has established an advanced 10 ML/day reclamation plant. The first stage is biological denitrification using a Moving Bed Biofilm Reactor (MBBR) process. The reactor is operated in the anoxic mode and fed with a methanol substrate for the nitrogen reducing bacteria. The water is then dosed with ozone in the pre-ozonation reactor to oxidise organics, immobilise micro-organisms such as algae and to aid coagulation and flocculation. The water passes to flash mix coagulation and flocculation chambers where coagulation and phosphorus precipitation are achieved by alum or ferric sulphate dosing, and flocculation is facilitated by polyelectrolyte dosing. After coagulation and flocculation, the water is treated with combined dissolved air flotation and sand filtration in a single unit. The flotation process removes the bulk of the solids (including almost all algae), with the sand filter providing additional polishing. The water then flows to the two-stage primary ozone contact tank where controlled ozone residual is maintained for oxidation of organics (breaking them down into readily biodegradable components) and inactivation of pathogens. The water is then treated by the Biological Activated Carbon (BAC) Filters. The BAC filters harbour bacteria that absorb and metabolise readily biodegradable organics, which are produced in the preceding ozonation stage. The last process step is the final disinfection by ozone in a contact tank. The high quality treated water then passes to a storage from where water is drawn for re-use or discharge to the river. The scheme was developed to improve the quality of the Caboolture River and Moreton Bay and to provide Council with a valuable source of high-quality water for re-use. Initially the reclamation plant was used to improve river water quality by only discharging water of a very high quality. Based on comparison with currently proposed or operating re-use schemes overseas, the treated water from the plant would be ultimately suitable for potable type applications (Proctor, Ash and Lehmann 1999).

However, when it needed to upgrade its STP, Caboolture did not undertake any community education. It had been intended that after the Council and community were confident of the quality of the treated effluent being discharged from the STP to the river, the water would be mixed into the weir from where the town water supply is taken for treatment. The recycled water would augment both the water supply and protect the river and bay from pollution, and obviate the need for a discharge pipeline to the tidal zone of the river. There was a strong reaction against potable re-use by one Councillor and a small but vocal group of residents. A subsequent consultation and marketing exercise did not succeed in changing opinions, though it established that the number of people involved was indeed small. (Simpson 2002). The Council has made the decision to only use the treated water for non-potable re-use including for turf farming, industrial non-potable use, irrigation of public areas and ultimately "third pipe" domestic reticulation (Proctor, Ash and Lehmann 1999). The water was still being discharged to the river in 2002, the problem of future water shortages remains unaddressed and the Mayor was defeated at the following election (Simpson 2002).

The Caloundra/Maroochy Wastewater Management Strategy, a joint exercise between the Maroochy Shire and the Caloundra City Councils involved open community consultations with 60 focus groups concurrently with the engineers' investigations. The majority of people considered the option of potable reuse needed further investigation, with people in favour only if it could be clearly demonstrated to be safe. The Caloundra City Council decided, on the strength of the study, to discharge the high quality effluent from the new **Landsborough STP** (alternating bioreactor for N and P removal, post denitrification, clarification, tertiary sand filtration ozonation, BAC filtration, UV disinfection, sludge dewatering) to a dam that is used for recreation purposes. However, a local resident formed a group called CADS ('Citizens Against Drinking Sewage') and produced emotive publicity to prevent discharge to the dam. Council then had to construct a pipeline to another plant to dispose of high quality water from the expensive new plant through to their ocean outfall (Simpson 2002). The result is that part of the plant is now in 'mothballs', though it could be started in 5-10 years if needed (Palmer 2003).

4.6 South Australia

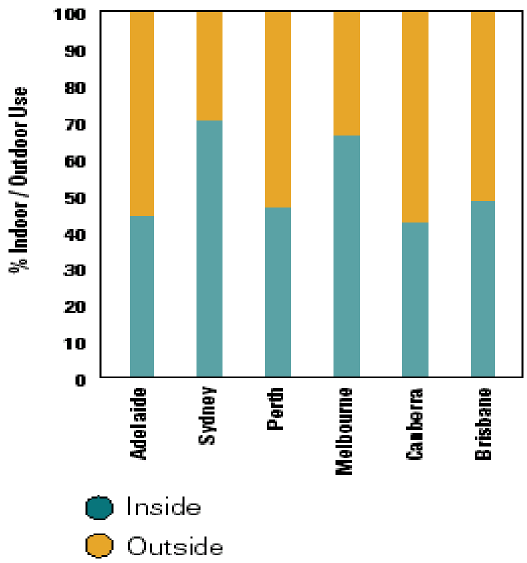
South Australia's water and sewage resources and services were traditionally supplied through the Engineering and Water Supply Department, but in the 1990s, the water resource management responsibilities were split from the service functions. Water resources come within the purview of the **Department of Water, Land and Biodiversity Conservation**, but statutory responsibility for most of the State's water resources is vested in **Catchment Water Management Boards** which subject to passage of forthcoming legislation, will be incorporated into Natural Resource Management Boards. The **SA Environment Protection Authority** oversees quality standards. The assets of the government are the responsibility of the **SA Water Corporation**, but much of the operation of these facilities has been contracted out. **United Water** is responsible under a 15 year contract from January 1 1996 for operating Adelaide's water and sewage services and for infrastructure maintenance.

The **SA Essential Services Commission**, South Australia's economic regulator, has no provision for water price regulation (Owens 2003).

The future management of the State's water resources is being managed within the framework of the South Australian *State Water Plan* (Brindal 2000). Based on a five year average, metropolitan Adelaide sources 61% of its water from the River Murray and 39% from the Mount Lofty Ranges. The estimated surface water use in the Mount Lofty Ranges Watershed exceeds sustainability limits by almost 200%. Approximately 33% of South Australians source their drinking water from their rainwater tanks (three times the national average), often quoting high dissatisfaction with the taste of mains water though it is quite potable, and 16% use bottled water (more than double the national average). One in ten South Australians claim they do not drink tap water at all due to the taste (SoE-SA 2003).

Adelaide residents use a high proportion of their reticulated potable water outside the home (Figure 47).

Figure 47 Proportion of water used indoors and outdoors in major Australian cities (SoE-SA 2003)



Over 1,000 GL of water is used annually for agriculture, mostly self-extracted from surface and groundwater resources. However, the use of reticulated mains water for agriculture has risen from 18.9 GL in 1997-8 to 23.3 GL in 2001-2, much of the increase being due to new viticultural plantings.

The *South Australian Reclaimed Water Guidelines* (DHS SA 1999) define standards for treated effluent. The *State Water Plan* recognises that recycled water is a resource that will become increasingly important in the development of the State's economy.

4.6.1 Adelaide's Water and Wastewater Services

In 2001-2, the four Adelaide metropolitan STPs (**Bolivar, Port Adelaide, Glenelg and Christies Beach**) treated 90 GL of wastewater, 85% being discharged to sea.

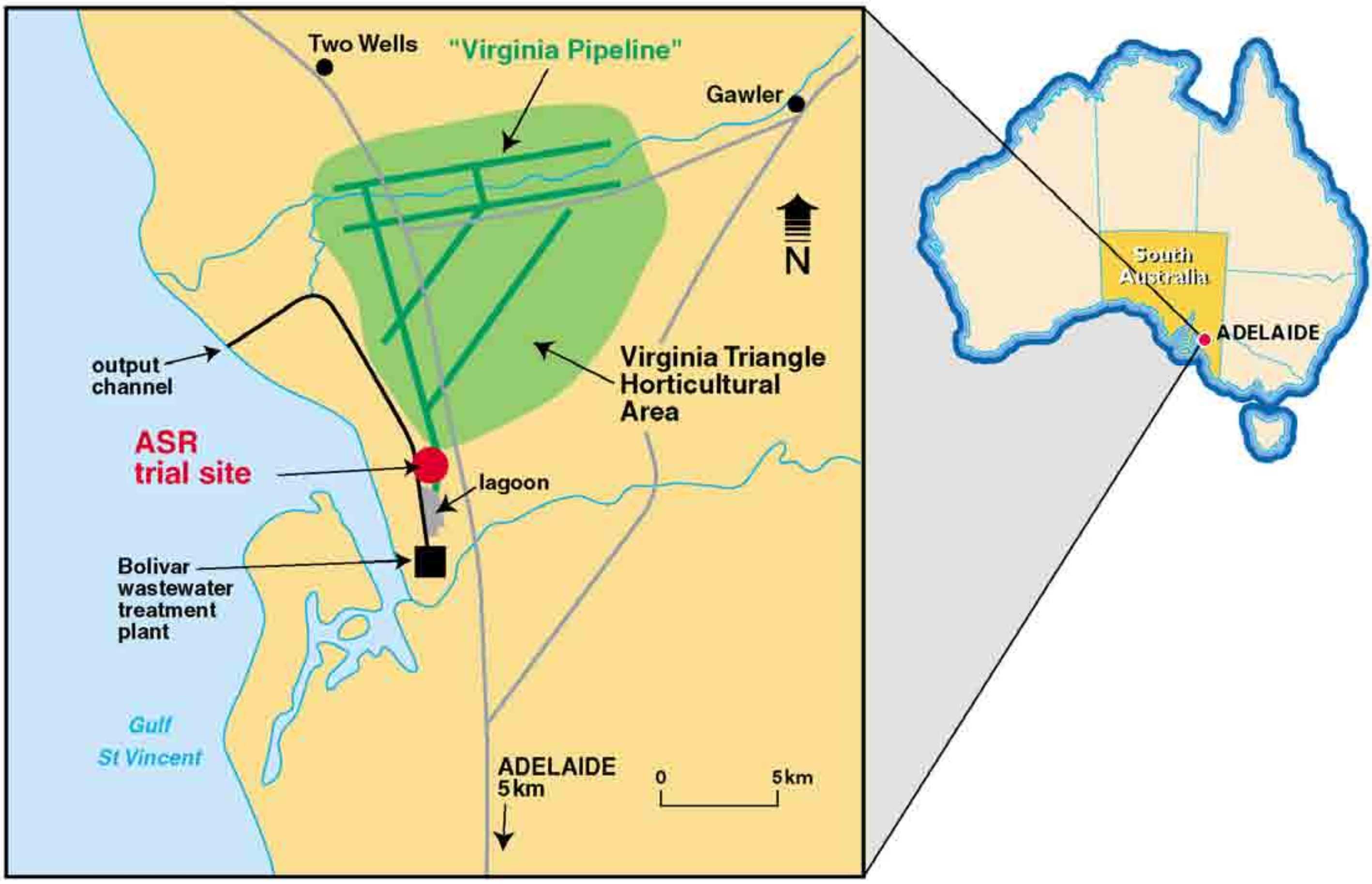
Studies into the use of treated effluent on a large scale were initiated in the late 1960s using effluent from the outfall channel of the Bolivar STP, Adelaide's principal STP, (Matheson 1972, Matheson and Lobban 1973, 1974). As a result, from about 1975, a small group of growers on the Northern Adelaide Plains began accessing secondary treated effluent from the outfall channel with their own infrastructure for horticultural production under Department of Human Services restrictions.

In the mid-1990s, when the South Australian Water Corporation was being established from the former Engineering and Water Supply Department, the then South Australian Environment Protection Agency was also being established. The Adelaide metropolitan STPs were required to develop Environmental Improvement Plans to upgrade the quality of the effluents they were discharging to ocean. There was concern that the marine ecosystem was being degraded by the 1,300 tonnes of nitrogen and 200 tonnes of phosphorus being discharged from Bolivar annually, leading to the destruction of 1,300 Ha of seagrass, loss of density in mangrove forests and the proliferation of large quantities of macroalgae. The initial response was to plan the building of a biological nutrient removal (BNR) treatment plant.

However, it was also recognised that Northern Adelaide Plains vegetable growers were withdrawing an average of 18 GL of groundwater from aquifers that could only sustainably support an annual abstraction of 6-10 GL. The cone of depression thus caused was resulting in salt water being drawn in from the adjacent gulf, leading to deteriorating irrigation water quality. It was realised that the Bolivar effluent could be used as a resource to support horticultural irrigation on the Northern Adelaide Plains. The Bolivar plant was converted from trickling filters with secondary sedimentation and lagoon sedimentation to activated sludge, and a Dissolved Air Floatation / Filtration (DAFF) plant was installed. The DAFF plant incorporated alum and polymer coagulation, flocculation, dissolved air floatation, granular multi-media filtration and chlorine disinfection. The stabilisation lagoons were retained for their natural biological and toxicological capacity, and as a buffer to minimise water quality deterioration from any abnormal industrial waste discharges. With a total volume of 4 GL, they also provide 2 GL of additional storage to enable more water to be committed for sale in the summer. The outcome is tertiary treated Class A recycled water which is equivalent to California Title 22 standard and is suitable for unrestricted horticultural use including spray irrigation of salad crops.

The contract to gain access to output from the DAFF plant was awarded to **Water Reticulation Services Virginia** (WRSV), a subsidiary of the Tyco Corporation and Earth Tech, who signed up clients for the water and built the water distribution system that delivers the metered recycled water to dams on individual growers' properties, from where they pump out the water through their own irrigation systems. The dams are required to hold three days' supply in case maintenance is required in the supply system. Though not greeted enthusiastically by growers, properties using recycled water are obliged to have signs on fencing reading 'Reclaimed water – do not drink'. The conceptual layout of the Virginia scheme is shown in figure 48. The cost of the $55m project, including the DAFF Plant and the reticulation system was shared between the Commonwealth Government, which contributed $10.8 million from the Building Better Cities funds, $574,000 from Landcare, $7 million from private investors, $7 million from the SA government, and the remainder from SA Water. Up to 24 GL/year of water is supplied without charge to WRSV, beyond which the matter would be for negotiation. Early grower contracts were for up to 21 GL in total, though this has been reduced to about 15 GL where growers have not used their allocation. The first growers signed at to take their contracted entitlement at a price of 5 c to 9 c/kL for their contracted water (irrespective of use), the actual price depending on season. More recent sales have been at slightly higher prices (Marks *et al.* 1998; Huijbregsen *et al*. 1999; Ringham 2003).

Figure 48 Conceptual layout of Virginia recycled irrigation scheme in relation to the Bolivar STP



Subsurface Aquifer Storage and Recovery (ASR) of reclaimed water is being trialled, using wells to inject water into aquifers in winter and to subsequently recover the stored water during the irrigation season (Dillon *et al*. 1999). The aims of the trial are to establish the issues confronting proponents when injecting a quantity of water that is less than potable, and would form the basis of designing a full-scale scheme capable of storing 10 GL/annum. Community acceptance in supporting such a scheme to store all the winter excess of reclaimed water from Bolivar is seen as an important pre-requisite to the success of such a project (Martin *et al*. 2002).

However, the introduction of the ready availability of recycled water has not been without impact. Rising water tables have been observed in the quaternary aquifers underlying the Northern Adelaide Plains serviced with the reclaimed Bolivar effluent (Zulfic 2002), and formed the basis of a recent workshop (Stevens *et al.* 2002). Nevertheless, the completion of the Virginia Scheme, seen at the time as the largest formal recycling scheme yet attempted, has generally been successful. The *State Water Plan* (Brindal 2000) notes an ultimate opportunity for 40 GL/year to be recycled to the Northern Adelaide Plains via the Virginia pipeline.

An innovative, entirely self-funded scheme has been developed to take Class B/C water that would otherwise be discharged to Gulf St Vincent to support a developing viticulture industry on former cereal-growing land in the Southern Vales region, south of Adelaide. The **Willunga Basin Water Company**, which was formed by a group of growers seeking additional water for their viticulture, negotiated access without charge for 10 years to chlorinated class B/C effluent from the activated-sludge **Christies Beach STP**. A 13 km piping and delivery system, including an intermediate dam at Noarlunga, was built without government assistance. An additional 75% of unused capacity beyond that needed by the founding consortium of growers, winemakers and landholders who formed the company, was included for on-selling for further development. Water is delivered directly to growers' irrigation systems through "purple pipes" pressurised to at least 300 Kpa. Of the 10,000 ML annual output from Christies Beach, the Company expected to have contracts for 4,000 ML by the end of 2003. New users are required to pay an up-front access fee of $6,000. Recycled water is delivered at 65% of the current SA Water mains supply price. Salinity varies, but at 750-900 mg/L, is less than that of the now fully-allocated groundwater resources of the Willunga Basin. Growers generally pass the water through spin filters or sand filters before use, and are required to use *Enviroscan* installations, mandated for vineyard water management by the Willunga Basin Water Company in terms of its Irrigation Management Plan established with the South Australian **Onkaparinga Catchment Water Management Board**. The curves from the readings, rather than the absolute values are of most value. Salinity was not perceived as a problem, though it has been noted that there is considerable importation of salt into the district through the pipeline system (Templeman 2003; Bekkers 2003; Smith, Stephen 2003).

A proposal was considered to develop a water recycling plant at the **Glenelg STP** with a view to laying a pipeline to the Adelaide Parklands. Local Governments were to be encouraged to purchase water from the line *en route*, but as the Adelaide City Council accesses mains water without charge as a result of a very long-standing agreement with the State government, the market demand to justify the scheme was not strong (Ledger 2003).

4.6.1.1 Domestic Systems

New Haven Village is a development of 65 medium density dwellings on 2 Ha at Le Fevre Peninsula, some 20 km northwest of central Adelaide, implemented under the direction of the **South Australian Housing Trust** with a number of public and private participants in 1995. It has been operating with innovative water and wastewater management including on-site treatment and re-use of household sewage (black and grey water) and a stormwater system which collects the first 50,000 litres of a given rain event, the remainder being diverted to a sports field acting as a retention basin. This means that virtually no wastewater leaves the site. Recycled water from the treatment plant is used for house gardens, toilet flushing and an adjacent oval with irrigation systems that are sub-surface although the recycled water meets the South Australian Health Commission's 'Class A' quality for unrestricted irrigation reuse. However, some difficulties have been experienced with the reclaimed water system not meeting health requirements (Thomas *et al.* 2000). In a recent survey of residents (Marks *et al.* 2002), although 95% of respondents initially said they have no concerns, all described problems relating to water quality at some point in the interview. Every respondent reported occasional problems experienced with toilet flushing involving odour, a murky colour, or sediment (or a combination of all of these). In all, 65% (13) described past, and now less frequent, disruptions to the service that become evident through odour or the water being cut off. Although sub-surface irrigation was originally stipulated, except for the system installed on the adjacent oval, public open spaces have always been irrigated with sprays and the original display homes featured above ground micro sprays as well as sub-surface drippers. Of the 20 respondents, 35% adapted their irrigation systems to suit their needs when problems were experienced with clogging of drippers and micro sprays.

Mawson Lakes has a dual supply system for use of recycled water. It is located 12 km north of the Adelaide central business district. In March 2003 there were 570 occupied dwellings with a population of approximately 1,500 residents. By 2010, the Mawson Lakes population will total 10,000 residents, 10,000 workers and 5,000 students. There is a mandate at Mawson Lakes for benchmarking innovations including water cycle management and an energy conservation system. Titles have an encumbrance requiring installation in the houses at the time of construction, of a dual water supply system with lilac pipes and taps for non-potable reclaimed water in addition to the normal potable mains. Installation of the dual water supply system must conform to the *South Australia Reclaimed Water Guidelines*. Recycled water will be sourced from storm water and wastewater generated at Mawson Lakes. Wastewater from the development goes to Bolivar (8 km away). Recycled water from the DAFF plant will then be transported back for reuse on the residential allotments and for irrigation of public open spaces. Storm water will be harvested locally and following primary screening, will be renovated through a series of engineered wetlands. The renovated storm water will be mixed with the recycled water prior to being distributed through the dual water supply system. Aquifer Storage and Recovery (ASR) will be used to balance supply and demand. The recycled water, at a price yet to be determined, will be used for toilet flushing, garden watering, and car washing. The Mawson Lakes Joint venture is currently reviewing options for storm water renovation in association with the local government body, the Corporation of the City of Salisbury. In 2003, mains water was being temporarily delivered through the recycled water taps. A telephone survey was conducted among 136 residents then living at Mawson Lakes in September 2002, enquiring about their attitudes to use of recycled water, as well as broader questions about why they had moved to Mawson Lakes and their attitudes to environment protection and other community issues. The primary reason for choosing Mawson Lakes was the location of wetlands and lakes as features of the development, with the dual water supply ranking 11th of 12 choice factors, suggesting it was a very low priority in the residents' decisions. There was general support for water recycling, but support decreased as the proposed use became increasingly personal. Acceptance was 99% for lawn irrigation, 49% for clothes washing and 0.7% for drinking. Support for recycling was greatest for those under 30 years of age, and least for those over 50 (McKay and Hurliman 2003).

4.6.1.2 Stormwater reuse

The Corporation of the City of Salisbury has been very innovative in stormwater management, having established 36 wetlands, and subsequently adopted Aquifer Storage and Recovery (ASR) for wetland-treated water, initially for its own parks and gardens. Recently, it has established a joint venture to store and treat stormwater on Parafield Airport to provide over 1 GL/year to G. H. Michell & Sons Australia Pty Ltd, Australia's largest wool processor. The scheme involves diversion of stormwater via a weir in the main Parafield stormwater drain to a 50 ML capacity 'in stream' capture basin. It is then pumped to a similar capacity holding basin, from where it gravitates to a two hectare reed bed. It flows continuously through the densely planted reed bed to biologically cleanse the water. Nutrient and pollutant loads will be reduced by up to 90 per cent. The residency period of the water in the treatment ponds prior to being directly pumped for use, or ultimately also for storage in the aquifer using ASR, is between seven and ten days, depending on inflow water quality (Hains 2003). The scheme is illustrated in Figure 49.

Figure 49 Development of Parafield Wetlands for production of recycled stormwater to GH Michell woolscouring factory (Hains 2003)

With advantage for the company's processing, this water is arriving at 200-250 ppm salinity, substantially lower than the potable water it replaced. There are also significant environmental and flood mitigation benefits through treating stormwater from the Parafield Airport catchment in terms of protecting Barker Inlet, an essential fish breeding ground and nursery for much of the State's fisheries. This inlet also supports an abundance of wildlife in its diverse range of habitats (Pitman 2003).

The project capital cost was $4.5 million, with initial funding support of $1.387 million through the Commonwealth's Environment Australia Urban Stormwater Initiative, $1million from GH Michell & Sons Australia, $140 000 from the Northern Adelaide Plains Barossa Catchment Water Management Board, an in-kind contribution of $40 000 from the then SA Department of Water Resources, with the balance being funded by the City of Salisbury.

A further Salisbury Council project involves wetlands on former Defence Science and Technology Organisation land at Edinburgh Park. With a design capacity of 1.3 GL/year, cleansed water from the wetlands is to be managed through ASR, and then sold to Holden Ltd for vehicle manufacturing operations and to other industrial users at Elizabeth. These projects have interesting legal ramifications (Hains 2003).

The **City of Playford** at Elizabeth is also developing a major stormwater project.

Investigations are now being undertaken into the extent that it may be possible to harvest stormwater in Adelaide, the scope for associated use of ASR, the flood frequency events that might be accommodated, the quality profile of the received water and the storage dwell times necessary before reuse by, say, industry. An intake of 20 GL/year is being examined (Freeman 2003).

Stormwater use has already captured the attention of local developers. Following the construction of the $5 million Stebonheath flow control wetland project by the then Munno Para Council with Better Cities Federal funding in 1993, the Hickinbotham Group investigated ASR and use of the reclaimed water for amenity plantings (Hickinbotham 1994). This resulted in recycling of stormwater by ASR being adopted at the new subdivision of Andrews Farm.

Recycled stormwater projects such as these, where recycled stormwater is substituted for previously used mains (drinking) water in industrial processes and amenity plantings, represents progress towards more effect total water cycle management. Such projects reduce the call on Adelaide's Mount Lofty Ranges catchments and its River Murray entitlement.

4.6.2 Rural and Regional South Australia

Unlike the eastern States, South Australia does not have any large cities in its rural areas beyond Adelaide (population 1 million), the biggest being Whyalla with around 30,000.

SA Water manages and operates 19 wastewater treatment plants in country areas, fourteen being based inland and five are coastal. In 2001-2, the country plants treated 10.3 GL of wastewater. Of this, 28.4% was discharged to inland waterways, 56.9% to the marine environment and 14.7% was recycled.

Almost all of the recycled water came from the inland plants, which reused 32% of their effluent. Reuse from the plants at Gumeracha, Mannum, Murray Bridge, which reused all their effluent in 2001-2, is described by Sickerdick and Desmier (2000). The output from a couple of Adelaide Hills STPs which discharge to creeks could be regarded as indirect potable supplies as reservoirs are fed from those creeks downstream (Cunliffe 2003).

There was no reuse by the five country plants discharging to the marine environment. (SoE SA 2003), though a small scheme is being developed at Port Lincoln. The location, though-put, treatment type, proportion being recycled, and the purposes for which is its used are given in the South Australian component of Appendix 1 for those South Australian STPs with SA Water sewerage schemes and which recycled some or all of their effluent.

A small sewer-mining project was installed at Flagstaff Hill, but the technology was unsuitable and the company behind it failed. (Ledger 2003). However, the Port Augusta City Council is establishing a sewer mining plant at its Central Oval to process raw sewage from an SA Water sewer main to Class B recycled water for irrigating surrounding parks and ovals with a concomitant saving in River Murray water taken from the Morgan-Whyalla pipeline. Effluent disposal to Spencer Gulf will be reduced by 25%. The plant cost is $900,000, of which the State government will pay one-third (Baluch, 2003). Options for further water recycling opportunities in the Upper Spencer Gulf cities have been reviewed by Connell Wagner (2002).

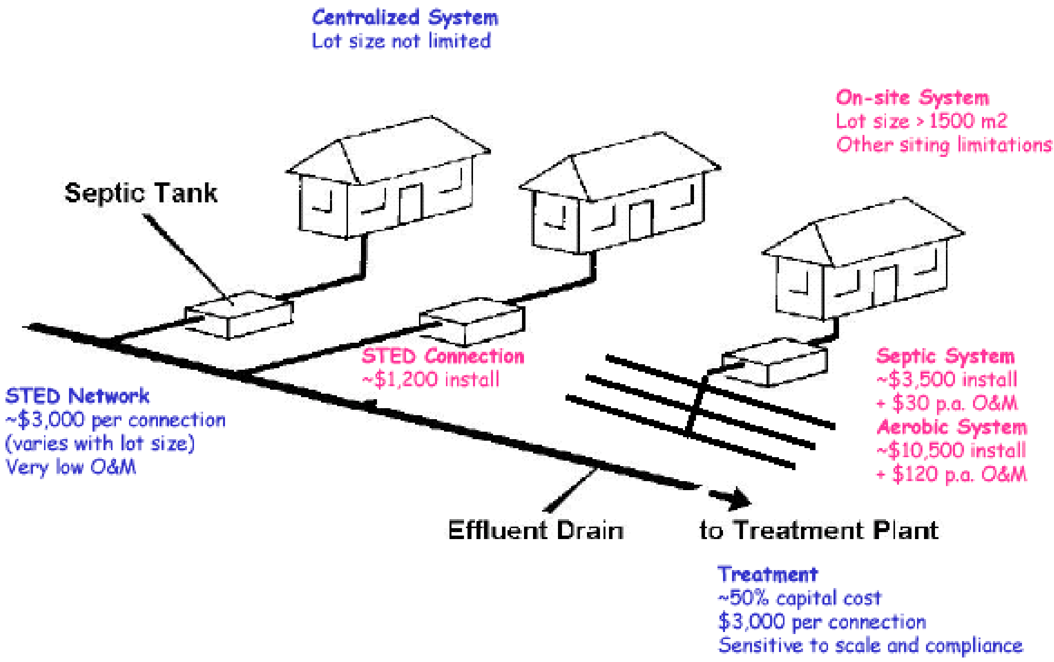
4.6.2.1 Septic Tank Effluent Disposal Schemes

Approximately 10% of all wastewater services in South Australia, being in those small country towns not serviced by the SA Water Corporation, have their wastewater treated and their health protected by use of Septic Tank Effluent Disposal Scheme (STEDS) installations

Each STEDS comprises a network of gravity drains connected to the outlets of individual septic tanks, instead of the septic tanks draining to soakage pits on the property. The drains convey all the effluent to a common treatment and disposal facility that is owned, operated and managed by local government. In most cases, simple oxidation lagoons provided secondary treatment.

More recently, reuse schemes have been developed, often in conjunction with small scale extended aeration plants. Compulsory desludging of the household septic tanks is usually required every four years (Palmer *et al.* 1999). Typical household installations, as compared with a stand-alone septic tank, are shown in figure 50.

Figure 50 On-site and communal waste control system features, giving comparative costs for a STEDS Connection for a new dwelling (left), connection of existing dwelling with septic tank (centre), and fitting a dwelling with a stand-alone on-site septic tank with soakage trenches (right) (Lightbody and Endley 2002).

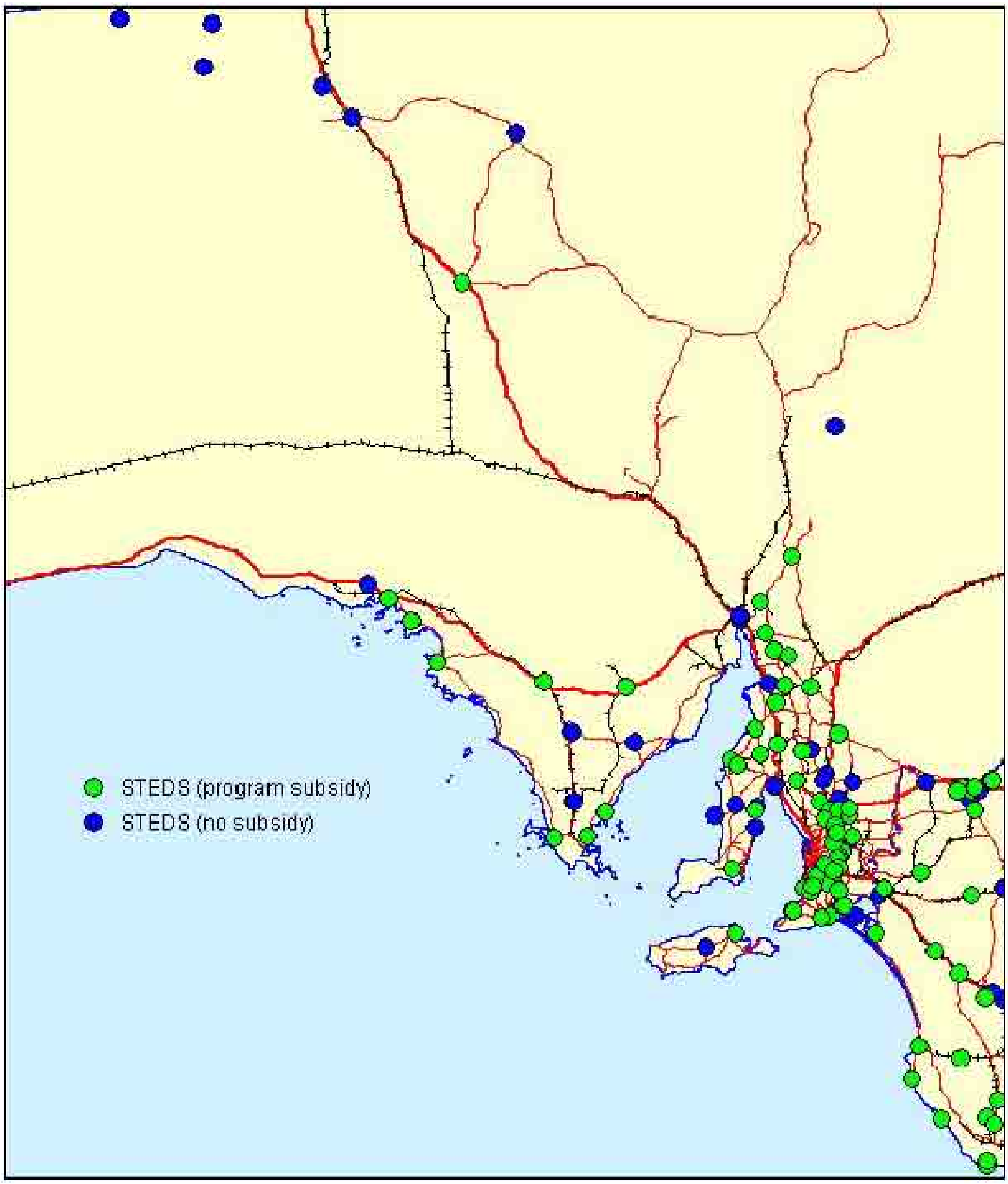


There are cost advantages associated with STEDS compared to conventional sewerage due to the provision and maintenance of the septic tank being the responsibility of the householder. From 1972 to 1995, the South Australian government managed the STEDS program, but since then, the South Australian Local Government Association has undertaken delivery of the program, with the government providing a subsidy to assist Councils with funding new STEDS. The investment in STEDS totals a replacement value of $326 million.

Each day, the STEDS treat over 18 ML of effluent, of which more than 50% is used in agriculture and the irrigation of sports fields, town commons and wood lots. Some towns (*e.g.* Maitland, Pinnaroo, Lameroo) use the STEDS effluent and stormwater conjunctively. However, in the more arid areas of the State, where some of the receiving lagoons are quite shallow and there is considerable evaporation, the salinity is typically being doubled during the oxidation process. Some towns have deepened the ponds or added mechanical aeration (*e.g.* Streaky Bay, Maitland) to speed up the treatment process as otherwise the increasing salinity makes the water less attractive for irrigation and plant growth. Typical salinities from country treatment plants include Whyalla STP 3,100 mg/L; Ardrossan STEDS 1,400 mg/L; Hawker STEDS 2,900 mg/L: Finger Point (Mount Gambier) STP 940 mg/L: and Streaky Bay STEDS 1,500 mg/L (van der Wel 2000).

Around 130,000 South Australians are served by STEDS (Figure 51), with a further 68,000 awaiting connection to similar services. STEDS serving populations of greater than 1,000 (100 in water protection areas) must be licensed under the *Environment Protection Act (1993).* Those below these figures are not required to be licensed, but must comply with the draft Environment Protection (Water Quality) Policy. It has been observed that compliance with licence conditions in some cases is considered to be ‘very poor’ (Lightbody and Endley 2002).

Figure 51 Location of Septic Tank Effluent Disposal Scheme installations in South Australia (Lightbody and Endley 2002).



Roxby Downs, a mining town of 3,800 people located in arid northern South Australia, presents an unique example of water cycle management incorporating ground water, desalination, stormwater and sewage effluent recycling. Its potable water supply is purchased from WMC Resources Ltd after the company has desalinated groundwater piped from the Great Artesian Basin 200 km away. Average annual water use is 164 kL per person. The township has a catchment of about 5 km^2, and the stormwater run-off, usually in summer, is collected in four catchment dams.

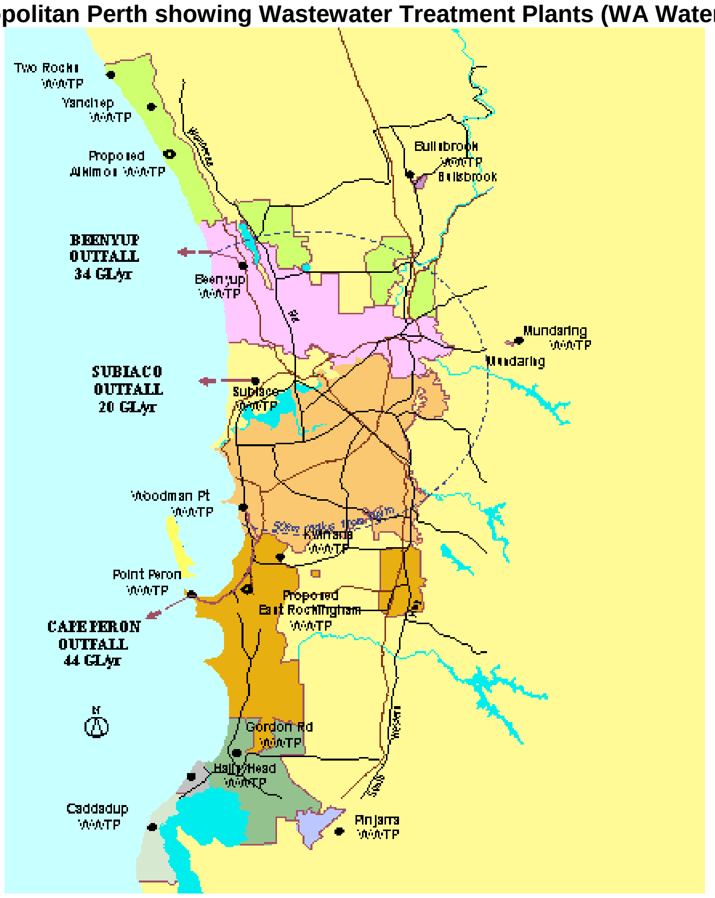
Annual catchment can vary from 15 to 75 ML/yr. This water is added to the holdings in the sewage treatment dams where it undergoes treatment through a facultative process over about a 42-day period to bring it to standards suitable for reuse. The sewage dams can hold a maximum 0f 110 ML, but require a minimum holding of 33 ML in the two primary and three secondary dams for effective passage of effluents through the system. The amount of water pumped to the sewer dams (effluent + stormwater) can vary from 150 ML to 400 ML/year. Management issues can arise when a large influx of stormwater enters the primary sewer dams from monsoonal summer storms, disrupting the normal facultative breakdown process. The high evaporation rate can lead to salt concentration in the treated effluent/stormwater, being particularly affected by salt-chlorinated private pools, of which there is a high number in the town. Chemicals from cleaning products in the effluent also present problems. Up to 150 ML can be lost by evaporation, which is 2.8 to 3.2 m annually. Water in the dams is pumped to maximise the depth where it is being held and minimise the surface area. Water is chlorinated before use on Golf Course and Town Oval, though restrictions can become necessary in late summer by March. The salt levels in the irrigation water and the soil profile are monitored and occasional heavy water applications are necessary to leach accumulated salts past the root zone. The stormwater/effluent recycling program saves the community $200,000 annually over the purchase of potable water if effluent were sent to an evaporation basin (Kroemer 2003).

4.7 Western Australia

Western Australian water resources are the responsibility of the **WA Waters and Rivers Commission.** In 2000, approximately 1,790 GL of water was used in Western Australia, all but about 100 GL being licensed. The unlicensed use was mostly from the 130,000 domestic bores used by 30% of Perth's population to access its unique form of sub-surface storage from natural percolation through the coastal sandplain. This unmetered domestic supply is used for irrigating home gardens, public spaces and for industrial use. While only 17% of the state's groundwater was being used in 2000, 39% of the resources of the Perth basin were already at or near the sustainability limit (Camkin 2002; McFarlane 2003).

The **Western Australian Water Corporation** generally provides water, wastewater and drainage services in WA, serving 700,000 residential customers and 50,000 business customers in 255 cities, towns and rural areas of WA, and manages 96 STPs. Water services are also provided independently of the WA Water Corporation by Bunbury Water, and Aqua-west (Busselton). Local Government operates facilities in about a dozen small wheat-belt towns. Perth has nine STPs, of which **Beenyup**, **Subiaco** and **Woodman Point** are the major facilities. Woodman Point has 4 km of ocean pipeline which discharges into the Sepia Depression. This STP was upgraded to secondary treatment only as recently as 2002 (Figure 52). Fifteen per cent of houses in the Perth metropolitan area, mainly built in the rapid expansion of the city in the late 1940s and 1950s, are not connected to the sewerage system. Their standards are overseen by the **WA Department of Health** (WA Water Corporation 2000).

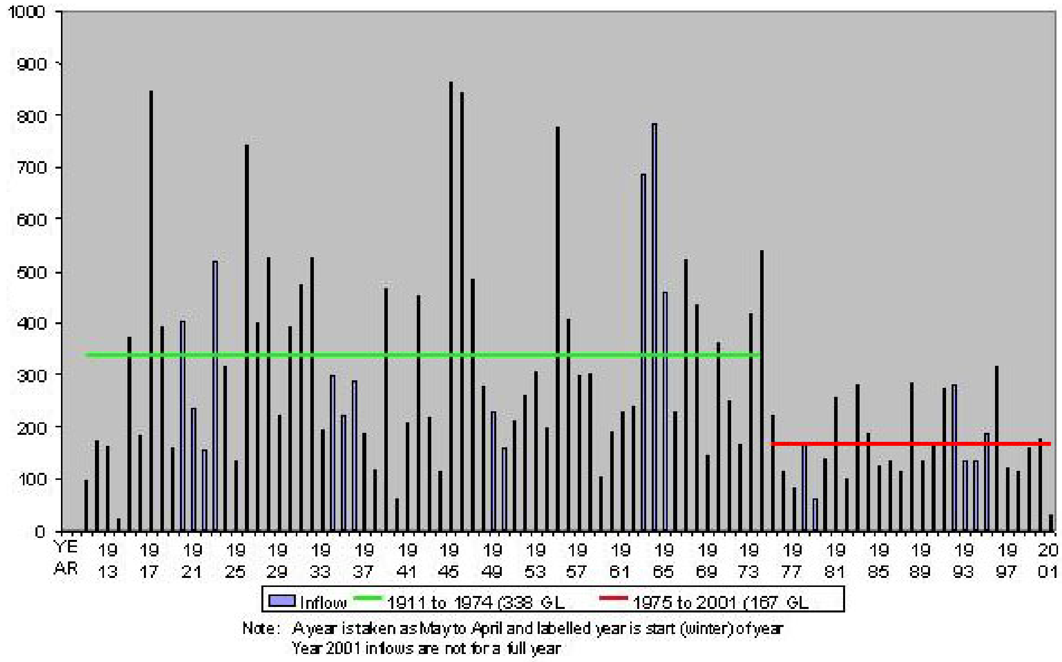
Figure 52 Metropolitan Perth showing Wastewater Treatment Plants (WA Water Corporation)



4.7.1 Metropolitan Perth

Perth's rainfall, and potential surface water catchment has undergone significant reduction since the 1970s. Average flow to dams 1911-1974 was 338 GL/year, and 1975-2001 was 167 GL/year (Figure 53).

Figure 53 Perth long term catchment trend, illustrating the lowered catchment average since the mid 1970s (WA Water Corporation).



Surface water deficits are being made up by additional demands on groundwater, but increased use of groundwater from existing aquifers could result in a draw down that could be detrimental to the environment (ATSE 2002). The winter of 2001 produced a surface water inflow of only 30GL. This raised awareness of the sustainability limits to Perth's current water resources, leading to a Reclaimed Water Forum at CSIRO in 2002, followed by a Symposium at Parliament House (Cox 2002).

Regulatory activities were also reviewed, highlighting that the arrangement for the Coordinator of Water Services to advise the Water Industry Minister on pricing has not worked as envisaged due to an inability to obtain the necessary financial details (Parry 2003). A new **Economic Regulation Authority** has since been formed.

Stormwater is managed within a framework set out in a stormwater manual (WRC 1998) currently being revised (WRC 2003). Water Sensitive Urban Design is espoused, with the management of stormwater being primarily oriented towards maximising infiltration, a process that is particularly appropriate on the Swan Coastal Plain. It may be noted that residents in Perth are prohibited from discharging stormwater off their properties. Effectively, stormwater reuse occurs via the Coastal Plain groundwater system (McFarlane 2003).

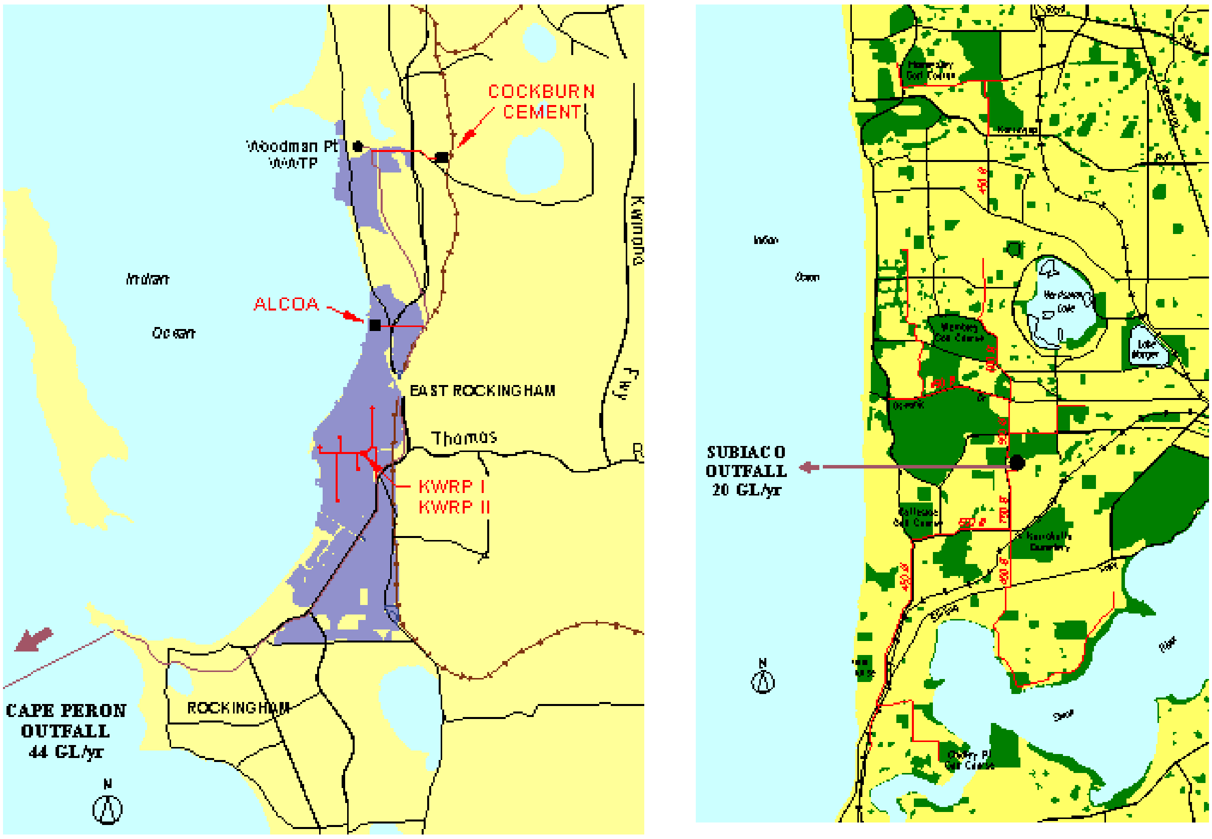
The *Western Australian State Water Strategy* (Gallop 2003) has since undertaken to achieve 20% reuse of treated wastewater by 2012, noting that water is a precious resource and should be priced accordingly.

The WA Water Corporation supplies 250 GL/year potable water in Perth, and receives 100 GL/year of sewage into its metropolitan STPs. Only 3.3% of Perth's wastewater is recycled, mostly within Perth STPs, but some indirectly is accessed via groundwater by Alcoa at Kwinana. With ready access to groundwater, there has been little incentive for much of Perth to consider using recycled water, particularly as the cost of supply for domestic groundwater has been estimated at 5 c/kL (Meakes 2002). Furthermore, were it to be readily available, careful management would be required to minimise risk of nutrient contamination of the groundwater (Gill 2002). The availability of groundwater also makes it unlikely a 'third pipe' recycled water system would be developed in Perth (Cox 2003).

Draft guidelines have been prepared for the reuse of greywater in Western Australia, and these also advise that care should be taken to avoid leaching into groundwater or surface water bodies (Dept. of Health WA, 2002)

Perth's first major water reuse scheme, the Kwinana Water Recycling Project (Figure 54), is due to be commissioned in 2004. It will produce 5 GL/year of water below 50 mg/L TDS by microfiltration and reverse osmosis at the Woodman Point STP for industrial use. The recycling plant cost is $16.5m and supporting infrastructure is a further $8.4m. Mining, power generation, chemical fertiliser and petroleum companies have already committed to use some of the output. Currently, the top 10 Kwinana industries use 7.3 GL mains drinking water/annum. In addition, Kwinana industries have entitlements to 23.5 GL of groundwater per year (Turner, Davies and Ryan 2003).

Figure 54 The location of the Kwinana Water Recycling Project (KWRP) [left] and Subiaco parks and playing fields (dark areas) [right] (WA Water Corporation).



New industries in the Kwinana Industrial Strip will be obliged to access the water for industrial use as they will be unable to access groundwater, and will be discouraged or even mandated from using potable supplies. They will be able to return any subsequent effluents reaching appropriate waste standards into the Cape Peron outfall.

The Subiaco STP discharges all of its 52 ML/day of secondary treated wastewater via a 1 km ocean outlet. The Western Australian Water Corporation therefore commissioned a feasibility study into irrigating areas close to Subiaco STP with wastewater treated at the plant (Figure 54). This established that there were numerous potential users of well-treated wastewater within a zone up to 15 km from the Subiaco plant. All currently used groundwater for irrigation and all would be interested in using reclaimed water for irrigation under the right conditions of price and quality. It was found that the charges to recover the full cost of the scheme may be too high for most users, but users whose groundwater supplies were deteriorating were seen as likely participants in any initial scheme. These users, plus the Subiaco STP, would be able to use about 4.5 ML/day of reclaimed water (Wajon *et al*. 1999). In consequence, a trial project is being commissioned at McGillivray Oval, Nedlands to demonstrate the effective use of reclaimed water for parks and sports grounds. There is now considered to be scope for up to 3.3 GL/year to be used in an area south from the Subiaco STP to Mosman Park and which, with ASR, could also serve to counteract saltwater intrusions into the groundwater, occurring as a result of draw-down of freshwater over some years. A further 4.4 GL could be available for users north to Hamersley.

Research is being undertaken by injecting potable water into the Jandakot mound. If successful, groundwater recharge with reclaimed water, tied into the establishment of a new STP including tertiary treatment, has potential for use into the Gnangara Mound. This resource provides a significant component of Perth's water supply. (Edmonds 2003).

To achieve the objective of 20% recycling by 2012, various proposals are being explored. These include

- industrial use at Kwinana - Stage 1 (5.5 GL/year), Alcoa (additional 1 GL/year), and Kwinana - Stage II (2.9 GL/year);
- golf course, playing fields and park use at Subiaco - Stage I (3.3 GL/year), Subiaco - Stage II (4.4 GL/year) and Lark Hill (1.8 GL/year);
- horticultural use at Gnangara (10 GL/year), Carabooda (8.8 GL/year, replacing a current groundwater allocation) and Guilderton (14.0 GL/year);
- possible indirect potable reuse by establishing ASR at the Gnangara Mound from the Beenyup STP following microfiltration and reverse osmosis (27 GL/year); and
- establishing a Western salt water barrier (16 GL/year).

Detailed studies with research and development, community consultation and implementation of pilot projects would be necessary prerequisites to the implementation of a strategy such as this. (Edmonds 2003).

In an experiment conducted for the City of Mandurah and the WA Water Corporation, Toze *et al.* (2002) have evaluated treated and infiltrated recycled water from the

Halls Head STP as an alternative source to groundwater for irrigation of parks, gardens and ovals in the Peel Harvey region. Over a 20-month period, 840 ML of treated wastewater was discharged into infiltration ponds. A total of 122 ML was recovered from the aquifer, 24% being used for irrigation. Eighty per cent of the recovered water was assessed to be infiltrated treated wastewater. *Escherichia coli* concentrations detected in the recovered water did not exceed 1 cell/100mL, and coliphage and human pathogenic enteroviruses were never detected, despite being found in the treated wastewater. Salinity was less than in the background groundwater. Nitrates were detected at 2.2 mg/L, but Total Organic Carbon and phosphorus concentrations were far below that of the treated wastewater. It was concluded that the indirect recycling of treated wastewater was suitable for irrigation and had negligible associated health or environmental risks.

4.7.2 Rural and Regional Western Australia

Western Australia had 67 reuse schemes in operation in 2002, with eight others not yet commissioned (Devine 2003). Apart from the minor recycling then occurring at Woodman Point, all were in rural locations, and most are quite small. Woodlots at Albany (Figure 55), Margaret River and Manjimup consume 3 GL/annum. However, although in Albany, the community was prepared to pay more for wastewater reuse rather than discharge through an ocean outfall and the trees are growing well, the model on which the facility was based over-estimated their ability to take up nitrogen, so there have been some ‘breakthroughs’ of nitrogen into the environment (Cox 2003). Overall, country areas achieve 41% reuse of wastewater (Edmonds 2003).

Figure 55 Albany woodlot (WA Water Corporation)

Proposals for new country plants also now take into account recycling as a critical disposal component. An example is a proposal to replace two STPs located north of Bunbury, the **Australind** and **Eaton STPs**, which dispose of their wastewater by use of infiltration lagoons, with a new 3.6 ML/day Intermittently Decanted Extended Aeration Lagoon (IDEL) plant at **Kemerton**, from where the recycled water would gravitate to a 17 ML holding pond, then being pumped in a 7.4 km pipeline to a 60 Ha planting of *Eucalyptus globulus*. Irrigation will occur in summer and winter, in the latter season, irrigation will exceed evapotranspiration, resulting in some nutrients being leached to the watertable. (EPA WA, 2001).

Details of STPs in WA that recycle some or all of their effluent are given in the Western Australian component of Appendix 1.

4.7.3 WA Community Attitudes

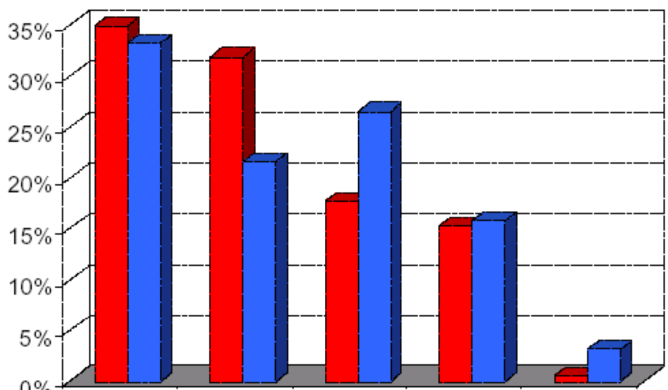
The Western Australian community, like most, has been shown to be sensitive to the source and management of its water resources.

Community preferences in 2002 for new water sources for Perth included using treated stormwater (95%), reusing grey water (85%,) water from the Kimberleys by pipeline (70%), new groundwater resources (65%), desalination of seawater (60%), storing treated wastewater (55%), and new dams in the South-West (45%) (Syme 2002). (The cost of water in Perth from the Kimberleys has since been estimated by Boland (2002) as $5.50/kL.)

Syme (2002) has identified four different types of consumers, which he has described as conservationists, lifestylers, utilitarians and the indifferent. However, attitudes have changed over the past twenty years. Those reusing water for outside use increased from 14.4% to 40.3% of a survey group, use of trickle systems has increased from 6.1% to 36.5%, planting of low water using plants has increased from 25.7% to 56.8%, while use of woodchips as mulch has risen from 15.7% to 82.5% (despite their implication as a house hazard as demonstrated in the Canberra bushfire).

Despite these attitudinal improvements to water use, total water use in single dwellings has increased since 1981/2 by 55%, most of it outside the home. A study of domestic water use in Perth (Loh *et al.* 2003) has shown that water use in gardening and by washing machines has increased, and that by toilets has decreased (Figure 56), data that are useful in evaluating opportunities for future recycled water consumption.

Figure 56 In-house water usage 1981-82 and 1998-2000 (Loh *et al.* 2003).



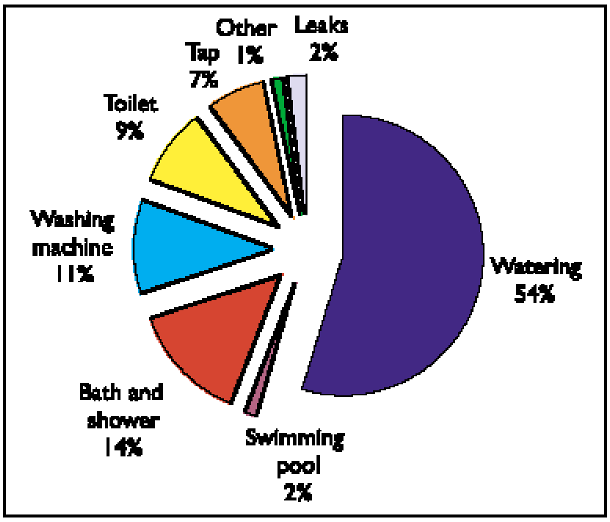
	Shower & Bath	Toilet	Washing Machine	Taps	Other
81/82	35%	32%	18%	15%	1%
98/00	33%	21%	26%	16%	3%

A significant difference was also noted in how water was used in single residences as compared to multi-residential use (Table 11, Figure 57).

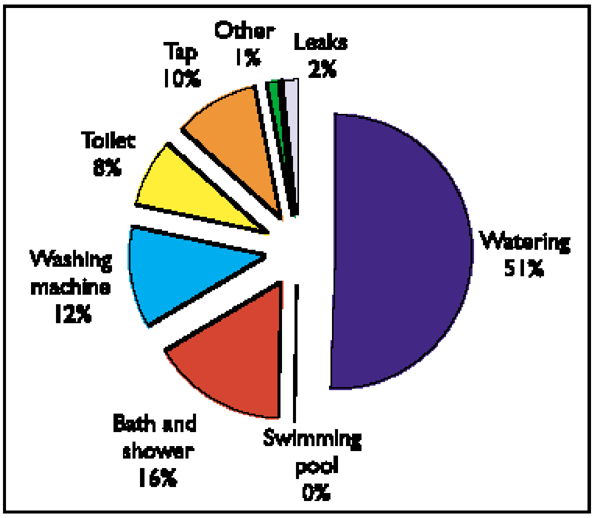
Table 11 Water use in single residences and buildings containing multiple residences, Perth, 1998-2000 (Loh *et al.* 2003).

	Single Residential Usage		Multi-residential Usage	
Appliance	L/house/day	L/person/day	L/house/day	L/person/day
Bath and shower	171	51	121	55
Washing Machine	139	42	94	43
Toilet	112	33	62	28
Tap	83	24	77	35
Other	18	5	11	5
Total in-house	*523*	*156*	*365*	*167*

Figure 57 Comparison of single residential and multi-residential household water use (Loh and Coghlan 2003)



Single Residential Household Water Usage



Multi-residential Household Water Usage

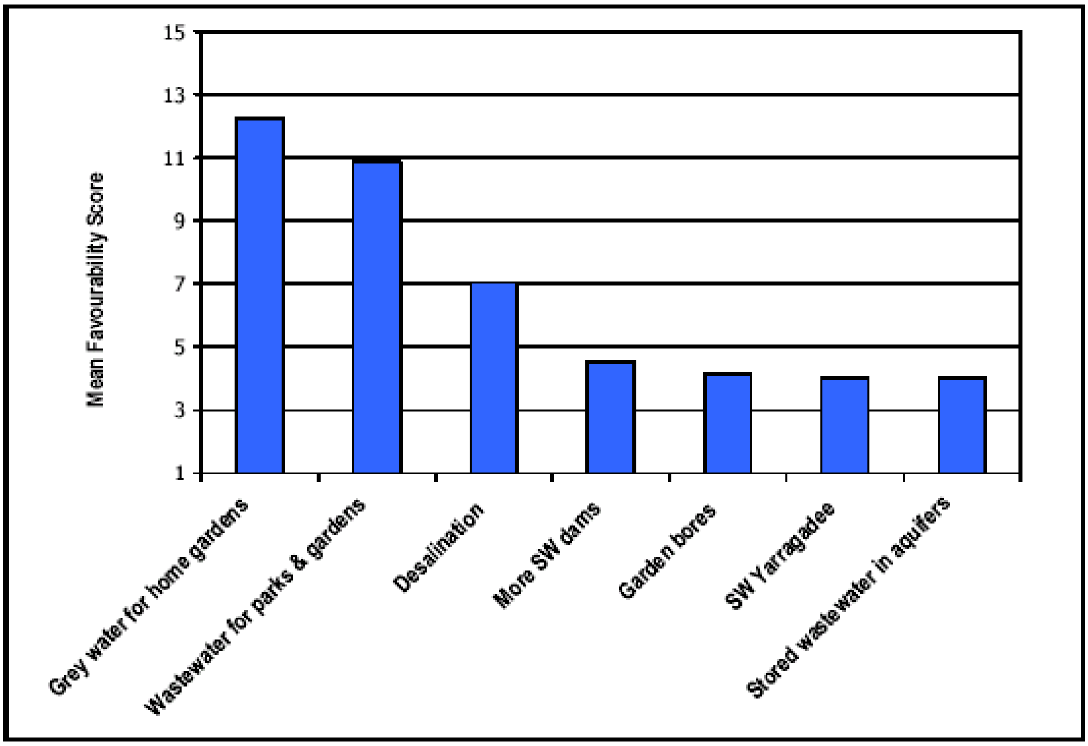
A recent study by Nancarrow *et al.* (2003) examined a proposal to supply Perth with 45GL of groundwater from the South West Yarragadee aquifer. Residents of the south-west (including Bunbury and Busselton, towns independent of the WA Water Corporation) were surveyed for their views and values. As the proposal involves taking water to Perth, Perth householders' views on the proposal were also examined.

There was strong disagreement with the water export proposal by the southwest community. Only 12% directly agreed with it, with 8% being unsure. Those originally opposed to the proposal were more inclined to change their minds if future certainty could be guaranteed. Less than a third of the Perth sample absolutely agreed with the water export proposal and less than half the total sample supported the proposal even given the possibility of total sprinkler bans (43% of the total sample) or increased water prices (47%). Support for the proposal markedly increased to almost two-thirds of the total sample if the future needs of the southwest could be guaranteed.

Overall, Perth respondents considered the export of Blackwood groundwater for Perth use to be less than fair to the people of the southwest and to be the least favoured future water resource, along with storing wastewater in aquifers for future use. Recycling options and desalination were the most favoured sources of the seven offered for consideration (Figure 58).

Having more knowledge of the issues associated with decision-making, ongoing management processes and water-use efficiency were likely to result in changed decisions by those surveyed.

Figure 58 Perth respondents' preferences (n=316) for future water resources for Perth (Nancarrow *et al.* 2003).



A particularly important study outcome is that economics-based arguments were least likely to affect decision-making by those surveyed. A mean attitudinal score concerning the ability of the experts and authorities to conduct investigations, plan for the future and make appropriate decisions indicated little trust and certainty in the community and any demographic differences were in degree rather than in opposition.

This observation should be of considerable importance to those undertaking the introduction of recycling schemes.

4.8 Tasmania

Development in Tasmania has centred on the major estuaries of the Tamar and Derwent Rivers and coastal areas of the northwest, northeast and south east of the state. Approximately 30% of the population still lives in rural areas with

- A highly concentrated population centred around Hobart, Launceston, Burnie and Devonport
- A large number of small towns and cities in the remainder or the state.

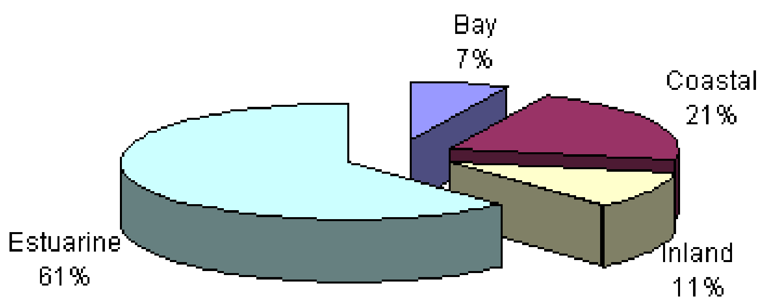
Local Government provides Tasmania's water and wastewater services.

Management of water quality in Tasmania is governed by the *State Policy on Water Quality Management 1997* (SPWQM) and the *Environmental Management and Pollution Control Act 1994*. Wastewater reuse or water recycling is a key waste management strategy used by producers of wastewater to reduce the disposal of liquid wastes to aquatic ecosystems. The three R's -reduce, reuse and recycle are key components of the key principles for limiting emissions from point source discharges such as sewage treatment plants.

The Tasmanian government has developed its *Environmental Guidelines for the Use of Recycled Water in Tasmania* to assist with facilitating water recycling, particularly for agricultural irrigation (Dettrick 2002).

Approximately 80% of Tasmania's wastewater has been historically discharged into inland, estuarine and bay waters, creating some challenges for the sustainable management of wastewaters (Figure 59).

Figure 59 Breakdown of Tasmanian Wastewater Receiving Environments by Volume (Dettrick 2003).



In systems with inland and estuarine discharges, it has been found that reuse with agricultural grade water is consistently around 10 times cheaper both in terms of capital and ongoing costs than upgrading STPs. Markets for recycled water are close to the regional townships, making recycling highly affordable.

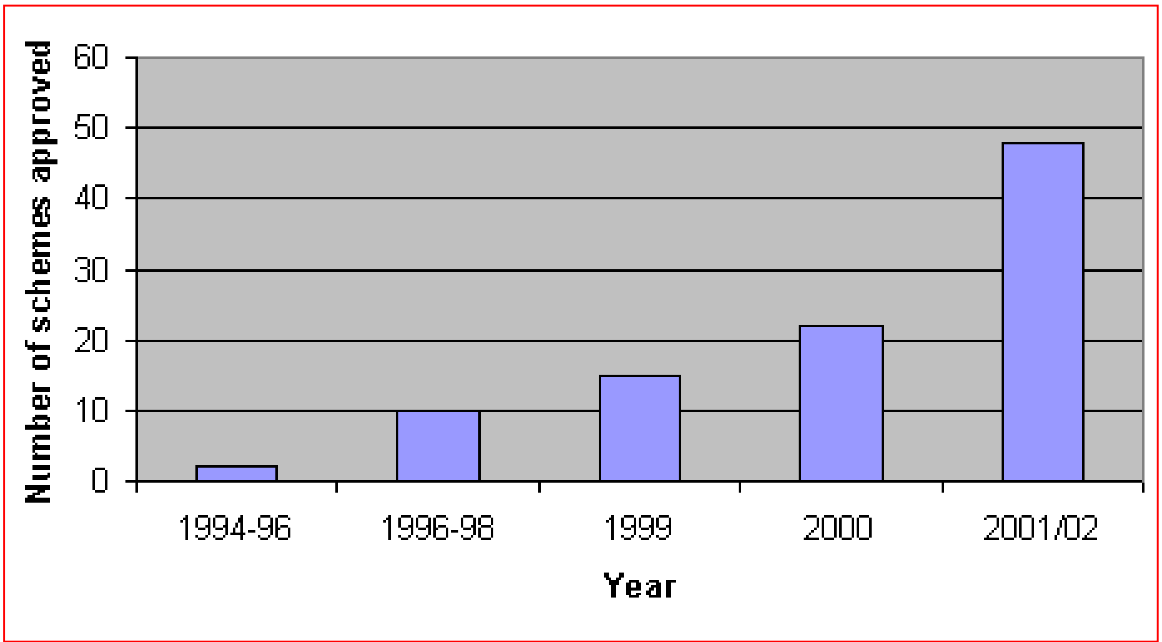
The major schemes at Brighton and the Coal River Valley in the drier south of the state have a potential use of at least 2.5 GL/year. Brighton is a small local government area with a low rainfall on the urban fringe of Hobart. The Brighton

STPs discharged into the Derwent River, rendering it unsuitable for primary contact due to sewage levels. At the same time, farmers were seeking access to irrigation water. The Brighton Council, with assistance of a NHT Coasts and Clean Seas program grant of $788,000, funded a recycled water distribution network, while local growers funded storage and irrigation infrastructure. The structures were in place within nine months of funding being announced and farmers were irrigating within 12 months. The expected outcomes were achieved, with reduced nutrient and bacterial loadings into the River Derwent. Gaining acceptance for wastewater irrigation was relatively easy in a dry area since there was a ready market demand, but it was learned that the price of wastewater needs to be on a sliding scale to allow farmers to invest heavily at the outset for a fast star-up. Involvement of all the stakeholders in setting up the project was essential. Barriers arose from lack of consistent national guidelines and lack of public awareness of risks involved, including lack of awareness by regulatory bodies.

The largest example of secondary treatment reuse is from the **Rosny Park STP** (2.7 GL permitted flow/year) and involves transportation to the Coal River Valley Irrigation District, which has over 500 farms with extensive horticulture, viticulture and turf growing. Commonwealth funding of $8,348,950 drove this project. The project irrigation area feeds a RAMSAR wetland, Pitt Water and Orielton Lagoon, was subject to review under the Commonwealth's Environment Protection and Biodiversity Conservation Act, the main issue being nutrient overload of the wetlands (Nott 2003).

The Natural Heritage Trust has facilitated the funding of approximately 30 additional water-recycling schemes in Tasmania between 2000 and 2002 (Figure 60).

Figure 60 Number of Water recycling Schemes approved in Tasmania by year (Dettrick 2003).



Key drivers for water recycling and reuse in Tasmania are:

- **Environmental impacts of discharge to inland and estuarine waterways**. This has become a significant driver in several sensitive inland and estuarine river systems such as the South Esk Basin, the Derwent Catchment, and the Mersey River where water quality is impaired by wastewater discharges, especially in the drier months. Discharges that remain after wastewater is stored and reused for irrigation water, are encouraged to be directed to natural storm flows, to better use the natural hydrological cycle to remove nutrients from river systems.

- **The cost and effectiveness of nutrient removal upgrades**. The cost to establish reuse schemes has been competitive with STP upgrades. There is also mounting evidence that on a mass load basis that even tertiary treatment may not be sufficient to protect sensitive inland water quality year round.

- **Lack of other water resources**. Recycled water is used for irrigating local amenity areas such as sports ovals and golf courses. The majority of reuse schemes in Tasmania will take place on agricultural land. Many water resources in Tasmania are already used for power generation, agriculture and potable water, so new agricultural enterprises can be assisted by water recycling.

It is likely that 70-80% of wastewater treatment systems in Tasmania will incorporate some form of water recycling by 2005. Under state policy, all new wastewater systems must include recycling as a central strategy to minimise or avoid discharges to aquatic ecosystems. Wastewater recycling is undertaken primarily by local government and by 2003, there were 55 water recycling schemes using treated effluent from municipal wastewater treatment plants. The drier Midlands of Tasmania represents the biggest opportunity for recycling wastewater, but also contains 80% of Tasmania’s potential and existing dryland salinity affected land. Areas around Evandale, Cressy and Perth, for instance, may have limited areas of land for reuse by irrigation. Reuse water from Launceston and Hobart will involve challenging marketing due to the lack of agricultural land in proximity (Dettrick 2003).

Tasmania is a relatively high rainfall state, so recycling has been primarily oriented to environmental outcomes and economic development of agriculture rather than saving potable water resources by substituting with recycled water when a drinking water standard was not needed.

4.9 Northern Territory

The Northern Territory government's reclaimed water policy, managed through the **Power and Water Corporation**, promotes efficient utilisation of reclaimed water while protecting public health, is socially acceptable, environmentally sustainable and commercially viable. All recycled water proposals are subject to the approval of the Chief Health Officer of the **Department of Health and Community Services** (DHCS). Power and Water will continue to monitor the health risks associated with the utilisation of recycled water, in particular the results of research associated with unrestricted and indirect potable reuse. Treatment, quality and monitoring is in line with ARMCANZ/ANZECC 2000. Although direct potable use will not be considered, indirect potable reuse is considered viable in the longer term, particularly where water supplies are based on non-renewable, low quality groundwater resources and could include aquifer storage and recovery of reclaimed water. The community shall be informed and supportive of any recycled water scheme. Preference is given to developing recycled water systems that have the potential to result in new industries and jobs for the local community, followed by those that have social benefits (eg irrigation of sporting fields). Use of recycled water is an important component of the total water cycle and its application will be considered as part of the hydrological cycle.

Recycled water applications are considered (independently of commercial viability) where significant health, social and environmental benefits can be realised through a reduction in effluent discharges to the environment. Reduction in per capita sewage flows and substitution of recycled water for existing water supplies are seen as integral components to achieving sustainability. The supply of recycled water for irrigation purposes requires the conjunctive approval of a 'land and water management plan' which addresses issues of salinity, sodicity, nutrient management and product safety by the **Department of Infrastructure, Planning and Environment** and the **Department of Business, Industry, Resources and Development**. Preference is given to customers who can provide an economically and environmentally sustainable demand and have the 'willingness to pay' for the service. Recycled water is supplied at a cost that is reflective of the costs in supply. The greater the level of treatment (above that required to discharge to the environment) the higher the cost of recycled water supplied.

Power and Water provided greater than 1,110 ML of recycled water in 2001-2 for irrigation purposes. On the sites where human contact is allowed, the water quality complied with the appropriate microbiological concentration as recommended by the National Guidelines.

There are a number of principal reclaimed water use projects. The **Darwin Golf Course STP** (450 ML/year), which was new in 2002, serves the Marrara Sports Complex and Darwin Golf Club. The Marrara Sports complex utilises the effluent direct from the golf course pond. Customer access to this supply is restricted between the hours from 11 pm to 5 am to ensure that no daytime watering occurs. In addition, prior to each irrigation cycle, the ring main that supplies the effluent is flushed (to sewer) with fresh effluent to reduce concerns associated with odour generation. However, Power and Water intends to upgrade the **Leanyer/Sanderson Waste**

Stabilisation Pond system in 2004-2005. The upgrade will include increased retention time, which will improve bacteriological water quality delivered to the both the Marrara and Darwin Golf Club sites.

At Humpty Doo, 10 ML/year of effluent from the **Humpty Doo Waste Stabilisation Ponds** is spray irrigated onto natural bushland adjacent to the ponds. No human contact is allowed and the area is fully fenced. The median recommended value for *E.coli* has been exceeded. However, safeguards include the site's remoteness, buffer distance from human dwellings and access restrictions. Power and Water intends to construct additional secondary ponds at the site in 2004 – 2005. These ponds will increase the total capacity of the ponds and enable the ponds to produce water quality <1,000 *E. coli* per 100 ml as per the "controlled access" recommendations in the guideline.

The **Pine Creek Waste Stabilisation Ponds** produce 8 ML/year recycled water of a high quality for use on the sports oval and rail corridor. The rising main from the Waste Stabilisation Ponds to the recycled water site is fitted with a clear water flushing system that effectively eliminates potential problems with odour generation during irrigation. Backflow prevention devices and air gaps are utilised to protect potable water supply integrity.

The **Katherine Waste Stabilisation Ponds** provide 45 ML/year recycled water of a high quality, principally because of the extended retention time obtained in the evaporation ponds. It is used on pasture and fodder harvested for a cattle feed lot.

At **Alice Springs**, negotiations have been undertaken between Power and Water, the Alice Springs Town Council and the Blatherskite Park Trustees regarding the management of the 580 ML/year system, used to irrigate open spaces, sports ovals, and a tree lot. The Trustees have undertaken to limit daytime watering hours where possible, provide a schedule of events when public access will occur to restrict irrigation during these times, restrict access to the park by locking the entry gates after certain hours, and improve signage around the site. Power and Water will soon be reviewing the management of the park in order to satisfy that public health is not being compromised. If the above measures are found to be inadequate or not properly enforced, Power and Water will consider restricting the availability of effluent to the park during certain hours.

Tree lots at **Kings Canyon** together with tree lots and resort grounds at **Yulara**, which is owned by the Ayres Rock Resort Corporation, also utilise reclaimed water. Restricted access and filtration/chlorination are practised where public access is considered possible.

Power and Water conducts annual audits of each recycled water site to ensure that operational practices comply with the requirements of the recycled water agreements and to the National Guidelines. The National Guidelines state that 'parasites such as *Ent. histolytica* cysts are completely removed by ponds with 20 days retention time'. In all cases except for the Humpty Doo Waste Stabilisation Pond system, the 20-day detention time requirement has been met (unreliable flow data for the year makes it impossible to confirm the 20-day retention time requirement for this site).

5 PRINCIPLES AND ISSUES OF WATER RECYCLING IN AUSTRALIA

5.1 Why recycle?

Whether recycling will be appropriate in a given situation depends on the availability of additional water resources, a desire or necessity to conserve rather than develop water resources, careful economic considerations, potential uses for the recycled water, the strategy of waste discharge and public policies that may override economic and public health considerations or perceptions (Mantovani *et al.* 2001).

In Australia, the recent droughts have highlighted the limited water resources in many areas.

- **Where resources are limited, a programme of declaring "Water Resource Caution Areas" should be introduced.**

Recent overseas experience has shown that recycling technologies and the costs of implementing them are changing quite rapidly, and the cost of recycled water produced by currently available advanced treatment technologies is only slightly higher than the cost of importing water, for example, to Southern California, and still significantly lower than alternative augmentation by desalting sea water (Wilf 1998)

A range of motivators may induce a focus on recycling. These may include: -

- A recent water supply crisis or drought
- Limitations being placed on treated wastewater discharges
- Environmental lobbying pressure,
- The comparatively high cost and/or limited availability of new water resources
- The potential to defer investment in new water resource infrastructure,
- Demand by potential users,
- The safety, dependability and reliability of supply of recycled water supplies

Ultimately, treated sewage effluent, stormwater and rainwater should be seen as resources, not as disposal problems. This is made clear in the California Water Code, which states

13550. (a) The Legislature hereby finds and declares that the use of ***potable*** *domestic* ***water*** *for nonpotable uses, including, but not limited to, cemeteries, golf courses, parks, highway landscaped areas, and industrial and irrigation uses, is a waste or an unreasonable use of the* ***water*** *within the meaning of Section 2 of Article X of the California Constitution if recycled* ***water*** *is available which meets …conditions, as determined by the state board, after notice to any person or entity who may be ordered to use recycled* ***water*** *or to cease using* ***potable water*** *and a hearing held pursuant to Article 2 (commencing with Section 648) of Chapter 1.5 of Division 3 of Title 23 of the California* ***Code*** *of Regulations:*
(1) The source of recycled ***water*** *is of adequate quality for these uses and is available for these uses…* (State of California 2003b).

- **Future water resources planning, including for the environment, should evaluate the potential for incorporating recycled water. As well as encouraging the use of recycled water by incentive schemes, water resources agencies should consider regulating for the mandatory use of recycled water for non-drinking water purposes where other water sources are over-stretched.**

5.2 Health

The obligation to maintain public health standards is basic to water supply services. Since the middle of the 19^{th} Century, any use of a contaminated water source has been contrary to a basic principle of drinking water supply. Historically, water supply systems and sewerage systems have been kept as separated from each other as possible. Water treatment and monitoring must provide consistently safe good quality water for all Australians. With growing pressure on existing potable supplies and the desire to reduce discharge of treated effluent to the environment, there could be increasing consideration to augment potable supplies with adequately treated wastewater (Hamlyn-Harris 2001a). Any recycling strategy that brings recycled water closer to direct human contact must be designed to assure public health.

There have been several notable water quality crises in recent years, the most significant of which was in Milwaukee, USA, in 1993 when about 400 000 residents became ill as a result of *Cryptosporidium* in the water of suburbs adjacent to one of the city's STPs (MacKenzie *et al.* 1994).

5.2.1 Contaminants

In October 1987, a major outbreak of gastroenteritis, estimated to have affected 6574 residents, occurred in the regional Victorian towns of Sunbury, Diggers Rest and Bulla. No microbial agent was clearly identified as a cause of this outbreak. A sanitary survey of the water supply at the time of the outbreak showed that one of the creeks suppling a weir, from which the water supply was being taken, was faecally contaminated. The water authority closed the systems using creek water, flushed the service reservoirs and issued advice that residents should boil all drinking water. The outbreak quickly ceased following these actions. As with many outbreak investigations, there were some difficulties in communication, particularly due to misleading information published in the media (Kirk, Rouch and Veitch 1999).

Sydney experienced a major water crisis following three events on July 2, August 24 and September 5 1998. High concentrations of *Cryptosporidium* oocysts and *Giardia* cysts were repeatedly observed in water samples collected in the distribution system, although no increase in waterborne disease was detected. The reported concentrations of both cysts and oocysts ranged from no detections to thousands of parasites per 100 L of finished water. Based on these monitoring data, three boil-water advisories were issued over a nine-week period. A formal government inquiry investigated the cause of the contamination (McClelland 1998). The reported levels of *Cryptosporidium* and *Giardia* in both raw and treated water were significantly higher than levels previously recorded. The reported levels caused the international scientific community to doubt the analytical accuracy. The episode has been estimated to have cost Sydney about

$70 million. In one author's opinion, reliance on poor-quality monitoring data created a water quality crisis when, in fact, no water quality problems or threats to public health existed (Clancy 2000). The possible presence of contamination in Sydney's water supply understandably caused great concern within the whole community.

The degree of alarm during the Sydney Water crisis emphasises the need for continuing education and public disclosure of information about the quality of a city’s water. This sensitivity will be all the more so where recycled water is involved.

Wastewaters contain two general types of hazards for humans. Microbial contaminants, largely present in faecal wastes and requiring inactivation to eliminate their potential to cause massive outbreaks of viral, bacterial and parasitic diseases from short-term exposures are the highest priority. Raw untreated domestic sewage contains varying levels of pathogens including bacteria, viruses, protozoa and helminths. The second risk comes from various chemicals, including pharmaceutical products, that end up in wastewater, and which may cause a range of ill effects should we be exposed to them for prolonged periods of time. Environmental contaminants, industrial chemicals, domestic chemicals and pharmaceuticals can also impact on treated effluent composition. Both sets of hazards require sound risk management systems for effective control. Hamlyn-Harris has summarised the health issues in two tables (Tables 12, 13).

Heath assurance standards for treated water and wastewater have historically involved the use of indicators such as faecal/thermotolerant coliforms or *Escherica coli*, which in water correlate quite well with the possible presence of bacterial pathogens, though their correlation with other classes of pathogens such as viruses and protozoa, is fairly poor. Physico-chemical water quality indicators such as turbidity, suspended solids and pH, are not, in themselves, health concerns. However, they can be used as a measure of the water treatment process performance as their presence may indicate the presence of contaminants of concern or they may mask, or shield, contaminants of concern and inhibit disinfection processes (Hamlyn-Harris 2001a) The risks of the various components of wastewater have been summarised (Table 14) by Shanableh and Rahman (2001).

Table 12 Physical parameters and pathogens that may impact on Health (Hamlyn-Harris 2001b)

Physical parameters	Pathogens	
	Viruses	**Bacteria**
BOD	Enteroviruses	Shigella
COD	▪ Poliovirus	Salmonella typhi
Total Organic Carbon (TOC)	▪ Echovirus	Salmonella (other)
Total Organic Halogens (TOX)	▪ Coxsackie A	Vibrio cholerae
Suspended Solids (SS)	▪ Coxsackie B	Escherichia coli
Compounds of Phosphorus	▪ Norwalk	E. coli O157 H7
Compounds of Nitrogen	Hepatitis A	Yersina enterocolitica
Dissolved Oxygen	Adenovirus	Leptospira
Hardness ($CaCO_3$)	Rotavirus	Legionella pneumophila
pH	Parvovirus	Campylobacter jejuni
Taste and Odour	Reovirus	**Protozoa**
Temperature	Astrovirus	Entamoeba histolytica
Total Dissolved Solids (TDS)	Calicivirus	Giardia lamblia
True Colour	Coronavirus	Balantidium coli
Turbidity		Cryptosporidium parvum
		Helminths
		Ascaris (roundworm)
		Trichuris (whipworm)
		Taenia saginata (tapeworm)

Table 13 Chemicals and algal components that may impact on health (Hamlyn-Harris 2001b)

Inorganics	Organic Compounds	Pesticides	Volatile Organics	Disinfection Byproducts	Algal Toxins	Pharmaceuticals	Endocrine Disruptors
Aluminium Ammonia Arsenic Asbestos Barium Beryllium Boron Bromate Cadmium Chloride Chlorine dioxide Chlorite Chlorate Chromium Copper Cyanide Fluoride Sulphide Iodine/iodide Iron Lead Manganese Mercury Molybdenum Monochloramine Nickel Nitrate/nitrite Phosphates Selenium Silver Sodium Sulphate Tin Zinc	Acrylamide Chlorobenzene Dichlorobenzenes Epichlorohydrin EDTA Hexachloro-butadiene Nitrotriacetic acid Alkyl tins Phthalates PAHs Styrene Trichloro-benzenes Vinyl chloride monomer Chlorinated dioxins PCBs	Aldrin/Dieldrin Atrazine Chlordane 2,4-D DDT and metabolites Heptachlor & epoxide Lindane Endosulfan Organo-phosphates Chlorpyrifos Carbamates Fungicides Pyrethroids Organic mercurials	Benzene Carbon tetrachloride Dichloroethanes Dichloroethenes Dichloro methane Ethylbenzene Tetrachloro-ethene Toluene 111-trichloroethane Trichloroethylene Xylenes	Halogenated furanones Haloacetic acids Haloaldehydes Haloketones Chlorophenols Chloropicrin Cyanogen chloride Formaldehyde Haloacetonitriles Chloral hydrate Trihalomethanes **Radionuclides** Radium- 226 and –228 Radon – 222 Uranium generated (Cs 137, Sr-90 etc) See also radio-pharmaceuticals	Microcystins Cylindro-spermopsin Saxitoxins Nodularin **Treatment byproducts from Algal toxins** Mycrocystin byproducts Cylindro spermopsin byproducts Saxitoxon byproducts	Radiopharmaceuticals Synthetic oestrogens/ Progesterones (oral contraceptives) – levonogestrel and ethynylestradiol Cardiovascular drugs ▪ Beta blockers ▪ Atenolol ▪ Anticholosterol ▪ Simvastatin Antibiotics ▪ Cephalexin ▪ Cefactor ▪ Amoxycillin Analgesics ▪ Paracetamol Sedatives ▪ Temazepam H_2 receptor agonists ▪ Ranitidine **Hormones** 17β estradiol Estron Testosterone	*These are a diverse group of chemicals and have been included under pesticides, organics metals, pharmaceuticals and hormones.*

Table 14 Risk-posing contaminants in wastewater (Shanableh and Rahman 2001).

Viruses – More than 100 virus types are known to exist in human waste (USEPA 1992). The exposure pathways for viruses include air, water, soil, dermal and food sources. Viruses can cause a variety of human, animal and plant diseases, can be highly infectious and are relatively persistent. Rowe and Magid (1995) explained, based on data presented by Sorber (1982), that inhaling even one *adenovirus* may be sufficient to infect 50% of subjects exposed. Viruses are generally regarded to be more resistant to disinfection than bacteria. Primary treatment of wastewater is generally ineffective at removing viruses, but secondary treatment can achieve 80-90% removal. Chlorination achieves significant removal of viruses but turbidity and other contaminants limit the removal efficiency. Tertiary treatment using liming and membranes is effective at removing pathogens including viruses.

Bacteria – Bacteria can cause a variety of diseases and can be highly infective. For *Shigella*, 10 organisms were found to be enough to cause infection (Rowe and Magid 1995). Bacteria are poorly removed by preliminary and primary treatment and large numbers of bacteria are discharged from secondary sedimentation tanks Disinfection is effective at destroying bacteria and the use of tertiary treatment can virtually eliminate bacteria.

Protozoa – Cysts can infect the intestinal tracts of humans and animals. As with bacteria and viruses, protozoa exist in all wastewater. Oral exposure to 1-10 cysts can cause infection (Rowe and Magid 1995). Significant removal of cysts can be achieved using primary and secondary treatment but effluents may contain large numbers of cysts. Heavy chlorine dosages and extended reaction times can inactivate cysts (WHO 1973, Rowe and Magid 1995).

Helminths – Nematodes and flatworms are generally found in warm climates. Helminths infect human intestines and repeated infections can cause serious disruption to intestine functions. Typical exposure is through ingestion of helminth eggs. Helminths are not effectively removed in conventional primary and secondary treatment systems.

Heavy Metals and Trace Organic Chemicals – Heavy metals and halogenated organic chemicals are generally contributed from industrial sources. Because of low concentrations in domestic wastewater, the accumulation of heavy metals in soils and the food chain to levels that can pose significant risk to human health and the environment requires time. Tertiary treatment involving liming ensures effective reduction of metals.

Boron, Nitrates and Salinity – Boron is an essential plant nutrient at low concentrations but toxic at levels higher than required by plants. Nitrates pose health problems for infants and excessive nitrogen loads can substantially reduce crop yields. High salinity can cause serious damage to soil structure and agricultural production. Soils with poor drainage characteristics and areas with high evapotranspiration losses can compound the negative impacts of salinity.

The same health assurance standards apply to storm water and water collected in household rainwater tanks. Urban stormwater may well have similar biological hazards to sewage. The urban areas, as well having a native bird and mammal population, also have a considerable population of feral animals and domestic pets, primarily cats and dogs. Similarly rainwater tanks can be contaminated by faecal droppings and various species that can enter the tank, apart from the risk of mosquito breeding and the potential increased risk of mosquito-borne diseases such as encephalitis and Ross River virus (Cunliffe 1998). Even with the provision of first flush diversion devices, it can be difficult to achieve drinking water biological standards in urban rainwater tanks (Coombes *et al.* 2000, Gardner 2002). However, the range of human pathogens in stormwater and rainwater may be restricted by host specificity, particularly viruses and to a lesser extent protozoa.

5.2.2 Micro-organisms

Natural attenuation of potentially pathogenic microbial populations can occur effectively in rainwater tanks, stormwater ponds, sewage lagoons and groundwater basins provided there is an adequate dwell time. This attenuation capacity forms a component of many treatment systems. Knowledge of the ability of the environment receiving the reclaimed water to remove any remaining pathogens present is essential to be able to predict any residual risk from the use of that reclaimed water. Soil, treatment ponds and groundwater have been shown to remove microbial pathogens from reclaimed water. The ability of these environments to remove the pathogens depends on the application method or use of the reclaimed water and the impact of one or more different disinfection processes. These disinfection processes include sunlight, temperature, desiccation, pH, chemicals, oxygen concentrations and the action of indigenous groundwater. Sunlight can have a significant impact on the decay of microbial pathogens in ponds and on the soil surface but has less influence in turbid water, shaded sections of soil or ponds, and beneath the soil surface. Sunlight, not surprisingly, has no influence in groundwater. Indigenous micro-organisms have been noted to have a significant impact on pathogen survival in ponds, soil and groundwater but their influence can be affected by other processes such as temperature, oxygen concentration, and moisture content. As well as influencing the activity of the indigenous micro-organisms, factors such as temperature, moisture content, pH and oxygen can also directly impact on pathogen survival through processes such as adsorption to soil and aquifer matrix, desiccation and inactivation via high temperatures. The documented variable success of these disinfection processes indicates that whilst these indigenous micro-organisms can significantly influence the removal of microbial pathogens from reclaimed water, and can be included in any management regime for the use of reclaimed water, more remains to be understood about how these processes act on different pathogens under varying conditions. Thus, these natural disinfection processes should only be used in conjunction with conventional treatment of reclaimed water (Toze 2003).

Where there is a concern about rainwater, UV light sterilisation can be added to rainwater tank supply systems.

It is not difficult for the community to generate concerns regarding the use of treated and recycled wastewater. For example, the possibility has been raised about skin infections arising from playing fields now being irrigated with recycled water. Caiger and Tuft (1999) reported a series of microbiological studies at Coffs Harbour, NSW, including a survey of soil pathogens in effluent on irrigated and control fields and testing of pathogens in effluent before and after chlorination and on delivery at the reuse site. The study also reviewed effluent disinfection and delivery procedures and historical results for chlorine residual and faecal coliform counts. To assess the extent of skin problems, an extensive survey of local doctors and hospital records was conducted. All relevant sporting groups were contacted and individuals were traced who were alleged to have contracted skin infections from sporting fields. The study found that soils in both effluent irrigated and control fields contained potential bacterial pathogens associated with skin lesions and that higher concentrations were linked more to poor drainage conditions encouraging anaerobic pathogens such as *Clostridium perfringens*. Information from local medical personnel, however, highlighted the prevalence of *Staphylococcus aureas* as the main causative organism of skin lesions in the city. This pathogen naturally occurs on skin and can opportunistically infect open wounds. It is not prevalent in soils or water. The 'epidemic' of skin lesions alleged to be associated with a particular sporting park was traced to one or two cases.

Stone (2002) conducted a survey between July and September 2002 of fifteen football clubs playing on sports grounds irrigated with recycled water in Western Australia, in which clubs were asked to keep a diary of cuts and abrasions, and found that of those teams that participated in the study, all the sports trainers reported no infections to any of the cuts and abrasions received by football players.

5.2.3 Chemicals

There have been growing concerns that environmental chemicals have potential to cause adverse health effects. A number of studies have implicated them with adverse changes in human health, while others have not shown any relationship. There has been considerable investigation of what chemicals can be found in sewage, recycled water and surface and ground waters. Science is now moving to identify whether these chemicals are of significance, and if so, what can be done about them. Lower analytical levels of detection have identified in sewage a number of chemicals causing concern in North America. These have included: -

- **steroid hormones**, excreted by humans, but which can cause feminisation in male fish and may interfere with pheremonally driven mating characteristics of the fish,
- **pharmaceuticals** which until recently if redundant in the home, were encouraged to be flushed down the toilet, a practice that should be discouraged. In addition, most pharmaceuticals are actually released after passing through the body—they are not always fully metabolised.
- **disinfection by-products**, such as N-nitrosodimethylamine (NDMA), a probable carcinogen, found in cosmetics, solvents, lubricants, polymers, chlorinated water and foods such as milk, cheese and beer, and previously in pesticides, herbicides, and plasticisers until more closely regulated,
- **other organic products** such as some detergent metabolites etc., some of which are toxic or oestrogenic

5.2.3.1 Endocrine-Disrupting Chemicals

It has been hypothesised that chemicals that interfere with the endocrine system may cause some of these health problems. This is a highly complex system and regulates a number of functions including development, growth and reproduction using chemical messengers (hormones) and feedback mechanisms. These endocrine-disrupting chemicals can affect drinking water and in Europe, the majority arise from wastewater. Representative endocrine disrupting chemicals include: -

- Hormones – 17 α-ethinylestridiole, and diethylstilbestrol
- Herbicides – atrazine, simazine, metoxychlor, and 2,4-D
- Insecticides – DDT, dieldrin, endosulphan and lindane
- Industrial chemicals, phthalates, bisphenol A, p-nonylphenol, PCBs, and tributyl tin
- Biological hormones – 17 β-estradiol, estriol, estrone, progesterone and testosterone
- Plant secondary metabolites

In rivers during dry periods when there is no net flow, such as the Hawkesbury in New South Wales, there may be abstractions equalling the input of water from wastewater plants. Under these conditions, drinking water intakes downstream of Penrith are accessing treated, though largely undiluted, wastewater. However, the overall conclusion from epidemiological data on adverse effects on human health is that low-level environmental exposure to endocrine disrupting chemicals has not yet been demonstrated to cause harm. There is evidence of impacts on aquatic fauna. The concentrations in domestic wastewater are many orders of magnitude lower than concentrations likely to cause detectable health effects in humans if this water is a component for reuse, even in drinking water (Falconer *et al.* 2003).

5.2.3.2 Disinfection by-products

Chlorination is used to disinfect treated effluents, and in the case of ASR, also serves to control biological clogging around injection wells. However, products of chlorination of water and wastewater are thought to be possible health problems, albeit at a far lower risk level to health than if the water were not sterilised. Chlorination produces a range of disinfection by-products by reacting with naturally occurring organic matter to produce products dominated by trihalaomethanes and haloacetic acids. Typical halogenated products of chlorination are shown in Table 15. Some of these halogenated disinfection by-products are carcinogenic in animals and are therefore possible human carcinogens. This has led to stringent guidelines and standards for these compounds in the USA, though Australian guidelines are less so.

N-nitrosodimethylamine (NDMA) was not detected when the limit of detection was 1000 parts per trillion (ppt), but that detection limit has been reduced to 1 ppt. It and its precursors have been identified in raw sewage, its origins being a chloramination by-product of disinfection, chemicals used to control root incursions into sewer pipes, or possibly from trade wastes from metal treatments used in the manufacture of circuit boards. Some dimethylamine cationic polymers, used to dewater sewage sludge, can be sources of NDMA precursors, while other cationic polymers do not generate NDMA precursors (Mitch, Gerecke and Sedlak 2003; Sedlak 2004). Access to some Orange County (California) groundwater wells, into which recycled water had been injected, was shut down for a time while the problem was reviewed (Mills, 2000). It has since been found that UV treatment, albeit at a magnitude greater than that necessary for disinfection, is effective in removing NDMA.

Table 15 Examples of Halogenated by-products of chlorination (Nicholson and Ying 2003).

Compound Class	Typical Compound	Approximate Percentage of Total Halogenated By-product Yield
Trihalomethanes (THMs)	Chloroform ($CHCl_3$)	35 (20 - 40)
Haloacetic acids (HAAs)	Trichloroacetic acid (CCl_3CO_2H)	30 (10 - 50)
Haloacetonitriles (HANs)	Dichloroacetonitrile ($CHCl_2CN$)	3 (<1 - 5)
Halogenated ketones	1,1,1-trichloroacetone (CCl_3COCH_3)	<1 - 1
Halogenated phenols	2,4,6-trichlorophenol	<<1
Chloral hydrate ($CCl_3C(OH)_2$)		3 (<1 - 5)
Cyanogen chloride (CNCl)		<1 - 3
Chloropicrin (CCl_3NO_2)		<<1
"MX"		<<<1
Higher molecular weight material	?	30

Orange County is replacing its former Water Factory 21 technology, based on lime clarification, reverse osmosis and chlorine disinfection with a $US450m membrane process using microfiltration, reverse osmosis and UV light with hydrogen peroxide to purify wastewater to a very high standard. Half of this water will be injected into 30 injection wells, while the remainder will go to spreading basins where it percolates naturally to the groundwater aquifer (Wedge 2003).

Brominated disinfection by-products can also arise from the oxidation of bromide, which is a natural constituent of water, to hydrobromous acid by chlorine used for disinfection, leading to the incorporation of bromine into the disinfection by-products formed, particularly in more saline waters Ammonia can affect the outcome by reacting with chlorine to form chloramines, reducing the formation of disinfection by-products.

Consequently, there has been a trend away from sterilisation of water by chlorination towards the use of chloramination, which forms lower levels of disinfection by-products compared with chlorine, though nitrogen-containing by-products such as cyanogen chloride can be formed.

5.2.3.3 Other Chemicals

Another chemical causing problems in groundwater has been perchlorate, a naturally occurring and man-made chemical implicated in disrupting thyroid metabolism, and used as an explosive in rocket fuel propellants. It was allegedly implicated in a massive spill into the lower Colorado River, and also has run into Californian groundwater from defence establishments. As a result of California establishing an interim standard in drinking water of less than 4 parts per billion (ppb), some groundwater wells supplying Los Angeles were taken off line, putting more pressure on the remainder which were increasingly being injected with recycled water (Conaugton, 2003).

A manmade chemical 1,4-dioxane, primarily used as an industrial solvent stabiliser that prevents the break-down of chlorinated solvents during many manufacturing processes such as electronics, pharmaceuticals and paper manufacturing has been one to have generated concern. It is also found widely in skin and hair care products such as shampoos, lotions and bath foam (Mills 2002).

Metal contaminants in municipal wastewater have not generally presented difficulties in Australia, though high levels of cadmium, copper, molybdenum, nickel, zinc and/or lead in recycled water can be a problem, particularly the accumulation of cadmium in tissues (Crook 1998). These issues are likely to be relatively unimportant in rural areas unless there is a local metal industry such as at Port Pirie, South Australia.

International links have been developed among water science researchers to progress perspectives on many of these recently identified chemicals. Informal "Emerging Technologies Conferences" are held without formal papers to encourage open debate based on sound science as to whether there are real problems and if so, what to do about them. There has been established an international Global Water Research Coalition (http://www.globalwaterresearchcoalition.net/) which provides details of new analytical techniques for chemicals that may be of concern. However, there is little epidemiology upon which to base concern (Bursill 2003).

Proponents of recycling need to be aware that there can be considerable differences in the quality of water that may be considered for recycling, as shown in Table 16 from Mitchell *et al.* (2002).

5.2.4 Water Quality Guidelines

Public Health responsibilities for wastewater and sewage treatment have resulted in regulations being based on classification systems. Both in the United States and in Australia, these regulations are the responsibility of state governments. There are inconsistencies between them. The California Department of Health Services has established "action levels" for approximately 50 compounds that have been identified for possible future regulation (DHS 2003). It recommends that if any water sources exceed the "action level", consumers should be informed of the contaminant and its health effects. If the concentration exceeds 100 times the "action level", use of that water source should be discontinued.

The Australian and States' Reclaimed Water Guidelines vary one from another, and generally place primary emphasis on bacteriological standards. There is only limited consideration of protozoa, viruses and chemicals, particularly those with possible biological activity. A comparative summary of Reclaimed Water Guidelines from the National Water Quality Management Strategy (NWQMS 2000), Victoria (EPA Victoria 2003), South Australia (DHS-SA 1999), Tasmania (Dettrick 2002) and

California's Title 22 is given in Tables 17 A-D. More specific details are given in the respective publications. Excessive emphasis on numerical guidelines can lead to a reactive style of water management rather than a preventive approach (Hamlyn-Harris 2001a).

The existing national guideline, *Guidelines for Sewerage Systems – Use of Reclaimed Water* (NWQMS, 2000), which does include a single treatment-based classification system, has no virus or parasite limits (GHD 2002a) and its approach is not now considered to be a sufficient basis for nationally consistent standards for the treatment and recycling of sewage. It is not directly applicable to grey water or storm water. The National Water Quality Management System does not provide for rainwater in tanks. Guideline strengths and deficiencies are summarised in Table 18 (Rathjen *et al*. 2003).

- **The National Water Quality Management Strategy *Guidelines*, developed in the 1990s, have strengths and deficiencies that should be independently appraised and addressed.**

The approach to standards in the water industry is changing. Water authorities have to provide greater assurance of water safety to consumers and industries. This has put more emphasis on risk management, quality assurance and process control within the Australian water industry. Managers are moving towards understanding the risks associated with processes and focussing quality control away from end-point testing and towards control of the critical operations earlier in the process. This is the philosophy behind Hazard Analysis and Critical Control Point (HACCP). The HACCP steps and principles are set out in Table 19.

In the 2003 revision of the *Australian Drinking Water Guidelines* incorporates a risk management approach that is based on HACCP principles. HACCP was originally developed for the space program in the US during the 1960s for the control of microbiological hazards in food. It has been applied to the food industry in Australia, particularly the meat industry, since the 1980s. The World Health Organisation/Food and Agriculture Organisation guidelines for HACCP *Codex Alimentarius* have been adopted internationally as the primary risk management system for the food industry. HACCP is, in essence, a system for managing risks through process controls to ensure a safe product. This involves describing the process with the aid of flow diagrams, analysing hazards (and assessing associated risks), determining Critical Control Points and critical limits and determining monitoring, corrective actions and verification procedures. The result is production with higher quality assurance and a greater opportunity to correct non-conforming (or potentially unsafe) product, minimising wastage and re-work and hence, reducing costs. This approach is particularly beneficial for public water supplies in which managing contaminated water in complex distribution systems is not simple (Hellier and Mullenger 2001).

The origins of the reclaimed water guidelines were primarily for the use of recycled water by land application for food production and amenity irrigation. They have a strong orientation to monitoring programs based on end-point testing. With increasing interest in indirect and potentially even direct potable substitution, a review of these standards has been considered essential.

Table 16 The quality of different classes of urban stormwater and wastewater and the requirements of selected urban water demands (Mitchell *et al.* 2002)

Quality Parameter	Class of Stormwater and Wastewater							
	Roof run-off* [14,19,20]	Rain tank [19,21]	Stormwater* [14,18]	Untreated greywater [15,16]	Untreated wastewater [16,17]	Treated wastewater [18]	Potable supply [22]	Urban garden watering, toilet flushing, car washing [23,24]
Thermotolerant coliforms, cfu/100 mL	<1–124	0-10	$0–6 \times 10^5$	$6–8 \times 10^6$	8×10^6		0	<10
Viruses, org/50L								<2
Parasites, org/50L								<1
BOD_5, mg/L			3–73	90–290	100–500	8–80		
pH	5.35-5.99	4.9-6.1	6.7–8.5	6.6–8.7	6.5–8	6.9–8.7	6.5–8.5	6.5–8.0
Total dissolved solids, mg/L	78-102	4-168	44–208	284–1700	250–850	520–4940	500	
Suspended solids, mg/L	0.75–204	0.4-178	13–1622	45–330	100–500	11–250		<5
Turbidity, NTU	0.75–6.5		12–34	20–>200			5	<2
Cadmium, µg/L	0.1–4	<2	0.2–46	<10		0–2	2	
Copper, mg/L	0.002–0.32		0.005–0.56	0.018–0.39	0.001–0.2	0.001–0.12	1	0.2
Iron, mg/L	<0.01	<0.01-0.1	2.4–7.3	0.094–4.37	0.3	0.03–1.6	0.3	1.0
Lead, mg/L	0.002–0.32	<0.01	0.007–2.04	<0.05–0.15	0.05	0–0.03	0.01	0.2
Manganese, mg/L			0.04–0.11	0.014-0.075	0.0003	0.02–0.08	0.1	0.2
Sodium, mg/L	4.4-12.9	3.17-16.5	12–116	29–230	70–300	41–1540	180	
Zinc, mg/L	0.02–1.1	0.4-5.3	0.026–2.4	<0.01–0.44	0.055	0.0–0.26	3	3
Total phosphorus, mg/L	0.034–0.49		0.049–2.14	0.6–27.3	4–30			
Total nitrogen, mg/L	0.65–2.84	0.3-3.6	0.50–12.6	2.1–31.5 (TKN)	20–85 (TKN)	6.1–44.2		
Nitrate, mg/L	0.1–0.87	<0.05-0.05	0.1–6.2	<0.1	5–30	0.1–19.5	50	

* Range calculated as ±2 standard deviation from mean, using Australian data only in Mudgway *et al.* (1997).
cfu: colony forming units
NTU: Nephelometric Turbidity Units
TKN: Total Kjeldahl Nitrogen
References in the table are in Mitchell *et al*. (2002)

Table 17A Comparison of Water Recycling regulations Class A recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class A (Highest Quality)				
QUALITY **Thermotolerant coliforms:<10 org/100ml (median)** Turbidity: ≤ 2 NTU (mean), 5 NTU (max) pH 6.5-8.5 (90 percentile) Cl_2 residual: 1mg/l after at least 30 minutes contact time or equivalent level of pathogen destruction Consider salinity controls	<10 *E. coli* org/100mL Turbidity < 2NTU (24 hr median), < 5 NTU (max) <10mg/L BOD <5mg/L Suspended Solids pH 6 – 9 (90 percentile) Cl_2 residual: >1mg/l after at least 30 minutes contact time where human contact, <1mg/L at point of use. <10 *E coli*/100mL, < 1 helminth/L, <1 protozoa / 50L, & <1 virus / 50 L	<10 *E. coli* org/100mL (median) Turbidity < 2NTU BOD < 20mg/L Specific removal of viruses, protozoa and helminths may be required. (Treat Class A reclaimed water to reduce the risk of infection of all types of human pathogens) Chemical content to match use.	**<10 median thermoltolerant coliforms / 100mL** pH 5.5 – 8.0 BOD < 10 mg/L Nutrient, toxicant and salinity controls	**<u>Total coliforms</u> <2.2 org/100mL (median over last 7 days)** <23 org/100mL (in any 30 days, maximum 1 exceedence) ≤ 240 org/100mL (at any time) <u>Tubidity: if using conventional filter loaded no greater than 12m/hr,</u> ≤ 2 NTU (24 hr median), ≤5 NTU (95% over 24 hr period), ≤ 10 NTU (at all times). Chemical dosing not required prior to filtration if influent:- ≤ 2 NTU (24 hr median), ≤5 NTU (no exceedences > 15 mins.) ≤ 10 NTU (at all times), and a back-up chemical dosing is available <u>If using membrane filtration</u>:- ≤ 2 NTU (24 hr median), ≤5 NTU (at all times)
PERMITTED USES Indirect potable groundwater recharge by spreading or injection Municipal with uncontrolled public access Residential non-potable Raw human food crops in direct contact with reclaimed water eg via sprays, irrigation of salad vegetables	Urban (non-potable) with uncontrolled public access Agricultural – *eg* human food crops eaten raw Industrial – open systems with worker exposure potential	Primary contact recreation; Residential non-potable – garden watering, toilet flushing, car washing, path/wall washing; Municipal use with public access/adjoining premises Dust suppression with unrestricted access Unrestricted crop irrigation	Indirect potable groundwater recharge by spreading or injection; Non-potable municipal irrigation (uncontrolled access); Urban non-potable (general household use); Fire and water protection systems; Agricultural – direct contact of reclaimed water with crops consumed raw; Stream augmentation and groundwater recharge; Urban use (garden watering and toilets); Aquaculture (human food chain); other uses subject to approval	Surface irrigation of food crops (including edible root crops) where the edible portion is in direct contact with reclaimed water; Surface irrigation of unrestricted golf courses, parks and playgrounds, school yards, residential landscaping; Recreational impoundment (unrestricted access); flushing toilets and urinals; Decorative fountains; artificial snow making; commercial car washes; structural fire fighting; unrestricted access industrial process water.
TYPICAL TREATMENT Tertiary with pathogen reduction. May need nutrient reduction for groundwater recharge.	**Tertiary treatment & pathogen reduction with sufficient log reductions to achieve above.** Where schemes pose a significant risk of direct off-site movement of reclaimed water, nutrient reductions to nominally 5mg/L total N and 0.5 mg/L total P will be required. Dept Health Services endorsement of plant	Full secondary + tertiary filtration + full disinfection. Coagulation may be required to meet water quality requirements	Coagulation, flocculation, advanced filtration and other best practice treatment processes to remove nutrients, sediments and other contaminants. Disinfection: MF, UV, ozonation and chlorination. Chlorination best practice if residual required to prevent bacterial regrowth	

* The Australian System (NWQMS 2000) does not use categories. The categorisation is expanded from SKM (2000).

† This summary is from SKM (2002).

Table 17B Comparison of Water Recycling regulations Class B recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class B (or 2nd highest quality)				
QUALITY Thermotolerant coliforms < 100 org/100mL (median) PH: 6.5 – 8.5 (90 percentile)	<100 *E. coli* org/100mL <20 mg/L BOD <30mg/L Suspended Solids pH 6 – 9 (90 percentile) Treatment includes Helminth reduction for cattle grazing use schemes	<100 *E. coli* org/100mL (median) BOD < 20mg/L Suspended Solids < 30mg/L Specific removal of viruses, protozoa and helminths may be required. (Class B-D use depends on use – *eg* Helminth *Taenia saginata* represents risk to cattle (beef measles) and should not be in reclaimed water used to irrigate pasture or stock water for cattle) Chemical content to match use.	<1000 median thermotolerant coliforms/100mL (<100 thermotolerant coliforms/100mL in special cases – stock drinking standard – applies for pastures and fodder crops (dairy and non-dairy) without withholding period pH 5.5 - 8.0 BOD < 50mg/L Nutrient, toxicant and salinity controls	**<u>Total coliforms</u> <2.2 org/100mL (median over last 7 days)** <23 org/100mL (in any 30 days, maximum 1 exceedence)
PERMITTED USES Indirect potable (surface water) Crops to be consumed raw but not in direct contact with reclaimed water (edible product separated from contact with effluent *eg* By peel or use of trickle irrigation or crops sold to consumers cooked or processed Pasture and fodder for dairy animals without withholding period Drinking water for all stock except pigs	Agricultural eg Dairy Cattle grazing Industrial *eg* Washdown water	Secondary contact recreation; Ornamental ponds with public access; municipal use with restricted access; Restricted crop irrigation; Irrigation of pasture and fodder for grazing animals; Washdown and stockwater; Dust suppression with restricted access; Fire fighting	Crops for human consumption; Crops to be consumed raw but not in direct contact with reclaimed water (edible product separated from contact with effluent *eg* By peel or use of trickle irrigation or crops sold to consumers cooked or processed; Pasture and fodder (no pigs or poultry); for grazing animals withholding period applies – 5 days for dairy (unless <100 thermotolerant coliforms/100mL applied), 4 hour for non-dairy; Non-potable municipal irrigation with controlled access	Surface irrigation of food crops where the edible portion (above ground) is not in direct contact with the reclaimed water Recreational impoundment Fish hatcheries
TYPICAL TREATMENT Secondary with pathogen reduction. Indirect potable (surface water) should comply with raw drinking water standards	Secondary treatment and pathogen reduction	Full secondary + disinfection	High rate processes such as activated sludge, trickling filters. Lagoon treatment with separate polishing lagoons is acceptable for < 1000 thermotolerant coliforms /100mL Disinfection – chlorination, UV and ozonation. Detention lagoons will not be sufficient if a concentration of < 100 thermotolerant coliforms/100mL is required.	

[*] The Australian System (NWQMS 2000) does not use categories. The categorisation is from SKM (2000).
[†] This summary is from SKM (2002).

Table 17C Comparison of Water Recycling regulations Class C recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class C (or 3rd highest quality)				
QUALITY Thermotolerant coliforms <1000 org/100mL (median) PH: 6.5 – 8.5 (90 percentile)	<1000 *E. coli* org/100mL <20 mg/L BOD <30mg/L Suspended Solids pH 6 – 9 (90 percentile) Treatment includes Helminth reduction for cattle grazing use schemes	<1000 *E. coli* org/100mL (median) BOD < 20mg/L Suspended Solids < 30mg/L Specific removal of viruses, protozoa and helminths may be required. (Class B-D use depends on use – *eg* Helminth *Taenia saginata* represents risk to cattle (beef measles) and should not be in reclaimed water used to irrigate pasture or stock water for cattle) Chemical content to match use.	<10000 median thermotolerant coliforms/100mL pH 5.5 - 8.0 BOD < 80mg/L Nutrient, toxicant and salinity controls	**Total coliforms <23 org/100mL (median over last 7 days)** <240 org/100mL (in any 30 days, maximum 1 exceedence)
PERMITTED Raw human food crops not in direct contact with reclaimed water, or crops sold to consumers peeled, cooked or processed Pasture and fodder for grazing animals (except pigs and dairy animals) with 4 hr. withholding period Pasture and fodder for dairy animals with 5 day withholding period Municipal with controlled public access (4 hr. withholding period) Ornamental water with no contact and restricted access Mines, dust suppression	Urban (non-potable): with controlled public access Agricultural: eg human food crops cooked/processed, grazing/fodder for livestock Industrial: systems with no potential worker exposure	Passive recreation, Municipal use with restricted access Restricted crop irrigation Irrigation of pastures and fodder for grazing animals	Agriculture (non-human food chain, *eg* forestry, cotton) Industrial processes (closed system) Non-human food chain aquaculture	Surface irrigation of ornamental nursery stock and sod farms with unrestricted public access Surface irrigation of pasture for grazing animals producing milk for human consumption. Surface irrigation of cemeteries, freeway landscaping and restricted access golf courses, Ornamental water with no decorative fountain, Non-structural fire fighting. Dust control Road/footpath cleaning Restricted access industry process water.
TYPICAL TREATMENT Secondary treatment and pathogen reduction	Secondary treatment and pathogen reduction	Primary sedimentation + lagooning or Full secondary (Disinfection if required to meet microbial criteria only)	Lagoon based systems No additional disinfection required	

* The Australian System (NWQMS 2000) does not use categories. The categorisation is from SKM (2000).
† This summary is from SKM (2002).

Table 17D Comparison of Water Recycling regulations Class D recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class D (or lowest quality)				
QUALITY Thermotolerant coliforms <10000 org/100mL (median) pH: 6.5 – 8.5 (90 percentile) For aquaculture, salinity TDS < 1000mg/L, < 10% change in turbidity (seasonal mean conc.), May need dissolved oxygen controls for fish, zooplankton	<1000 *E. coli* org/100mL <20 mg/L BOD <30mg/L Suspended Solids pH 6 – 9 (90 percentile	<10000 *E. coli* org/100mL (median) BOD < 20mg/L Suspended Solids < 30mg/L Helminths need to be considered for pasture and fodder. Chemical content to match use	No Class D	Total coliforms: No limit specified Suspended Solids: None specified but assume ≤ 39mg/L BOD: None specified but assume ≤ 20mg/L
PERMITTED USES Silviculture, turf, cotton etc. with 4 hour withholding period Aquaculture – non-human food chain Stream augmentation	Agriculture: Non-food crops including instant turf, woodlots, flowers	Restricted crop irrigation, irrigation for turf production, silviculture, non food chain aquaculture		
TYPICAL TREATMENT Secondary treatment and pathogen reduction (Pathogen reduction is site-specific for streams as required)	Secondary treatment	Primary sedimentation + lagooning or Full secondary		

* The Australian System (NWQMS 2000) does not use categories. The categorisation is from SKM (2000).

† This summary is from SKM (2002).

Table 18 National Water Quality Guidelines
– Current Situation and Future Requirements
(Rathjen *et al.* 2003)

Functional Use Areas			Water Sources: Potable Water	Rain Water	Stormwater	Greywater	Quality of Recycled Water: Highly Treated	Medium Treatment	Low Treatment
Potable Substitution Uses	Residential / Commercial Indoor	Toilet Flushing							
		Clothes Washing							
		Showering / Baths							
		Hot Water System							
		Drinking / Food Preparation							
	Residential / Commercial Outdoor	Residential Irrigation and other urban outdoor uses							
	Municipal Controlled Access	Parks & Sportsgrounds and Recreational Activities							
	Municipal Uncontrolled Access	Parks & Sportsgrounds and Recreational activities							
	Fire Protection Systems								
	Industrial Process Waters	Open Systems							
		Closed Loop Systems							
New Water Uses	Agriculture	Food sold unprocessed and in direct contact with recycled water							
		Food processed and not in direct contact with recycled water							
		Pastures							
		Non Food Crops							

Red	Guidelines Non Existent or Require Major Work
Amber	Guidelines Exist - Require Work
Green	Guidelines Well Established and Accepted

Table 19 Hazard Analysis and Critical Control Point (HACCP) steps (Cunliffe and Stevens 2003)

Step 1 Assemble HACCP Team The HACCP Team plan, develop, verify and implement the HACCP Plan. Generally comprises multi-disciplinary people (maintenance, operations, sanitation, quality control, marketing, chemists, microbiologists, etc.) knowledgeable of the process and product	
Step 2 Describe the Product A full description of the product is documented. This description man include water source; treatment processes, storage and distribution; and any special considerations to maintain product safety	
Step 3 Identify Intended Use The expected use of the product is documented including: how the product is to be used; consumer instructions for product use, and who the product is intended for.	
Step 4 Construct Flow Diagram Flow diagram must clearly indicate all process steps in the operation. The flow chart must state when the company's responsibility starts (bulk treated water, raw source water) and ends (at the meter box, at consumer tap) Steps prior to and after the organisation's direct responsibility should also be included.	
Step 5 Confirmation of Flow Diagram The HACCP Team confirms that the flow diagram is both complete and accurate as it is used in the hazard analysis. The best validation is to walk through and verify the set up of the system and processes. If this is not possible, those with operational knowledge of the system can validate the flow diagram.	
Step 6 Conduct a Hazard Analysis A significant hazard is none that must be prevented, eliminated or reduced to an acceptable level to produce a safe drinking water. Significant hazards; associated control measures; modifications to improve safety are identified as a basis for determining which control measures become critical control points	**Principle 1**
Step 7 Determine Critical Control Points (CCP) A CCP is a point, step or procedure at which control can be applied and a hazard can be prevented, eliminated or reduced to acceptable levels. The decision tree recommended by Codex may be used to determine is a process step is a CCP.	**Principle 2**
Step 8 Establish Critical Limits Critical limits are assigned to each control measure at a CCP. A critical limit defines the cut-off to ensure product safety. If a critical limit is not met, then the hazard is not controlled and corrective action is taken.	**Principle 3**
Step 9 Monitoring Monitoring is planned observations or measurements to provide a record. All critical limits have associated monitoring activity to ensure that the critical limit is met. If monitoring indicates that the critical limit has not been met, then corrective action must be taken.	**Principle 4**
Step 10 Establish Corrective Action Corrective actions ensure that the CCP is brought under control. Corrective actions can include: immediate action, responsibility for corrective action, disposition of product and root cause of the problem.	**Principle 5**
Step 11 Establish Verification Procedures Verification is the use of methods, procedures or tests to determine if the HACCP system is in compliance and confirms that the system follows the HACCP plan and that identified hazards, CCPs and critical limits are appropriate.	**Principle 6**
Step 12 Establish Documentation and Record Keeping Documentation is required as proof of compliance to the HACCP plan and provides a legal defence for due diligence. HACCP records should be dated and signed. Records should provide product traceability.	**Principle 7**

5.2.5 Rainwater tanks

For many people, rainwater tanks provide the only source of drinking water. The water from rainwater tanks is generally safe to drink and unlikely to cause illness for most users, but there are documented cases/outbreaks of disease from rainwater.

In 1999, students from three separate school groups on the mid-North Coast of NSW suffered vomiting and diarrhoea after drinking cordial made from water taken from a contaminated tank, with 129 from a total of 158 children becoming ill.

At a large construction site in Queensland, there were 28 cases of gastroenteritis among 200 workers. Organisms were found in stool samples and in samples of tank water, ice, and water fountains, attributed to frogs and/or mice. Live green tree frogs were found inside tanks and *Salmonella* had previously been isolated from frogs and cane toads. The cases ceased abruptly after control measures, including disinfection and flushing, were instituted.

In 1992, a mixed outbreak of Giardiasis and Cryptosporidiosis occurred in 89 people at a school camp after drinking water from an underground water tank that was contaminated by a leaking septic tank.

Rainwater is of variable microbiological and chemical quality. People with special health needs, (eg the immunocompromised) may wish to take extra precautions by using boiled, bottled or filtered water. There can be chemical deposition in highly industrialised areas or high traffic areas. Tanks are frequently poorly maintained by owners, and as previously indicated, may have inadequate mosquito control. (Cowie 2003)

Although in urban areas, a well-managed reticulated supply provides the safest source of drinking water, there is increasing support for harvesting and use of rainwater, encouraged in some states by subsidy programs. In new urban areas, this water source may be included in an alternative reticulation in the house for non-potable purposes such as, for example, for hot water supply. Coombes, Argue and Kuczera (2000) and Spinks *et al.* (2003) have established the efficacy of pasteurisation of rainwater through means of heating in the hot water system.

States are beginning to mandate the introduction or rainwater tanks in new developments. This raises a potential for increased liability for governments regarding the safety of their use. Many families still prefer to access rainwater for drinking purposes (some have no option), but a review of guidelines would be valuable.

- **In the light of increasing use of subsidies and the resulting increase in adoption of rainwater tanks as components of domestic water systems, the use of rainwater and rainwater tanks should be encompassed in the National Water Quality Management Strategy and the appropriate *Guidelines* series.**

5.2.6 Managing Health and Environmental Risks

Following discussions at Ministerial Council level, a Joint Steering Committee comprising representative of the Environment Protection and Heritage Standing Committee (EPHSC) the Natural Resources Management Standing Committee (NRMSC), the Office of National Health and Medical Research Council (NHMRC) and the Standing Committee and the enHealth Committee of the Australian Health Ministers Council (AHMC) is developing a new document, *National Guidelines on Water Recycling: Managing the Health and Environmental Risks*.

The focus will be on providing guidance for integrated protection of health and the environment. While this will involve recognising sensitive urban design as part of the context, the guidelines will not be to specifically address planning processes relating to water sensitive urban design. However, the guidelines are to be nationally recognised as authoritative, not merely a basis for harmonisation of the existing requirements in various jurisdictions, thereby overcoming the variation between jurisdictions. They need to address the deficiencies listed in Table 16.

The starting point for development of the *Recycling Guidelines* is to establish a generic risk management framework that can be applied to all combinations of recycled water sources and end-uses. The framework is being applied in assessing risks and setting guidelines in relation to priority combinations. The priority list is as follows: -

Rank	Source	End-use
1	Sewage or grey-water with 'large' scale treatment.	Residential garden watering. Car washing. Toilet flushing. Clothes washing.
2	Sewage or grey-water with 'large' scale treatment.	Recreational and open space irrigation in urban areas. Irrigation in agriculture and horticulture.
3	Sewage or grey-water with 'large' scale treatment.	Fire protection and fire fighting systems. Industrial uses, including for cooling water.
4.	Grey water with 'on-site' treatment.	Residential garden watering. Car washing. Toilet flushing. Clothes washing.
5.	Sewage or grey-water with 'large' scale treatment. Stormwater.	Aquifer storage.
6.	Stormwater	Recreational and open space irrigation in urban areas. Irrigation in agriculture and horticulture.
7.	Stormwater	Residential garden watering. Car washing. Toilet flushing. Clothes washing.
8.	Stormwater	Fire protection and fire fighting systems. Industrial uses, including for cooling water.

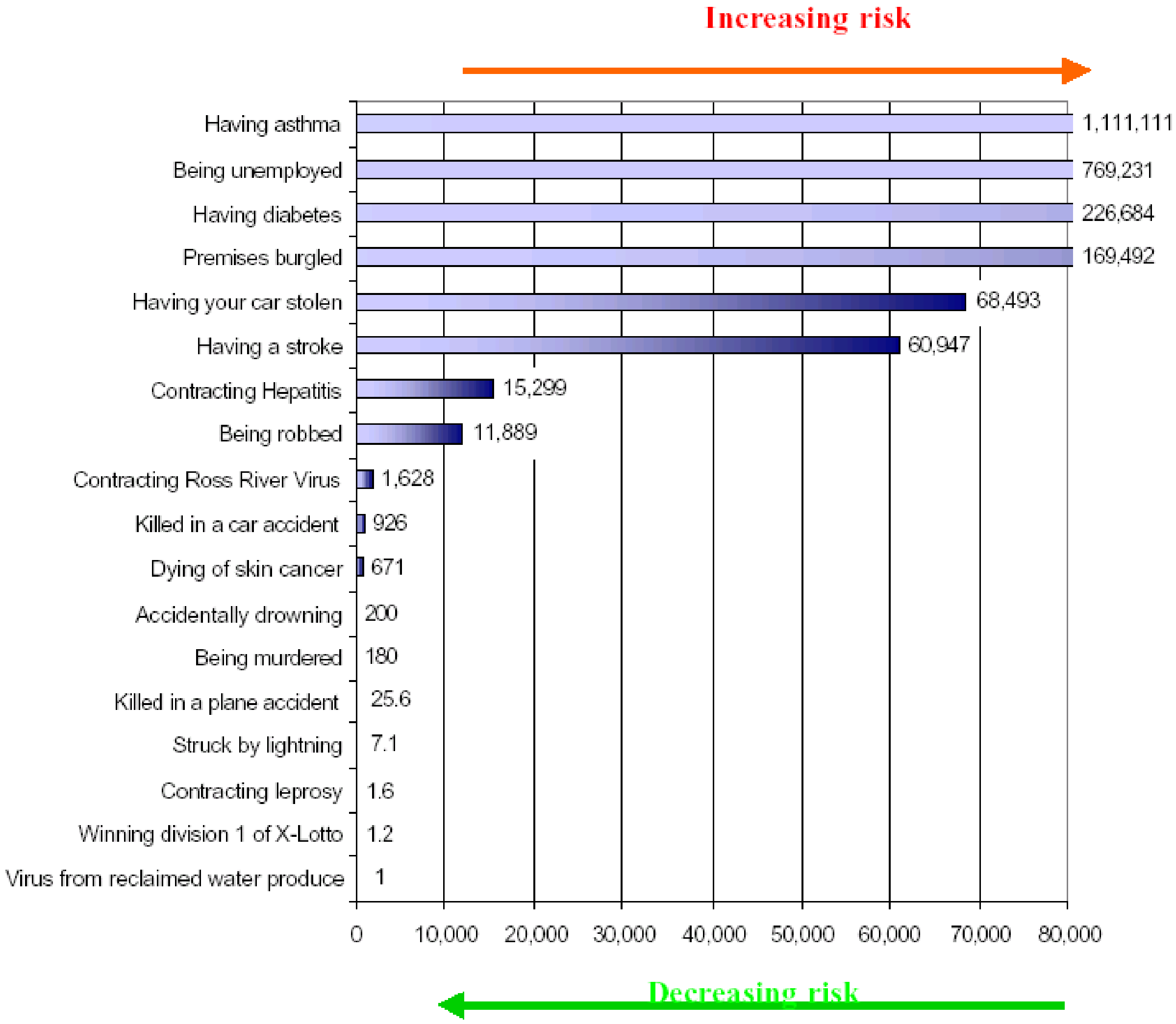
The framework for the guidelines is to be based on Hazard Analysis and Critical Control Point (HACCP) principles, building on the approach used in the 2003 revision of the *Australian Drinking Water Guidelines.*

Anderson *et al.* (2001) have discussed an approach whereby a uniform international approach might be adopted to assessing hazards and risk while providing flexibility for individual countries to vary requirements to suit local circumstances of affordability and risk. Australia's earlier progress towards developing the components of its National Water Quality Management Strategy has already received considerable recognition (for example Marsalek *et al.* 2002). Successful development of new *Recycling Guidelines* provides an opportunity to reinforce Australia's position as a leader in recycling implementation, demonstrating the potential to fulfil the suggestion by Anderson *et al*. (2002).

The bottom line is that the Australian community is far more sensitive to very small health risks that might flow from any hazards implicit in using recycled water than they are to other, much higher probability risks over which they perceive they have more personal control.

This has been elegantly demonstrated in a recent histogram prepared from Australian Bureau of Statistics figures (Figure 61).

Figure 61 Comparisons of the number of people likely to experience various events over a year from each ten million Australians. Source: Australian Bureau of Statistics and *Development of a risk assessment approach for evaluating wastewater reuse standards for agriculture* – (Ireland 2003).



- **Given the significance of the public health issues in reclaimed water management, it is important that the revision of the *National Guidelines on Water Recycling: Managing the Health and Environmental Risks*, based on Hazard Analysis and Critical Control Point (HACCP) principles, and building on the approach used in the 2003 revision of the *Australian Drinking Water Guidelines*, be finalised and agreed as soon as possible.**

- **Water authorities need to maintain an assurance of water safety to consumers and industries, including strong emphasis on risk management, quality assurance and process control.**

5.3 Community Acceptance

In addition to specific water quality requirements for each type of end use, there are significant social, institutional and legal issues related to using recycled water in both new applications and retrofit systems. The first obstacle is that of public acceptance. This is often described as the 'yuk factor', or the fear of 'toilet to tap'. Values rather than facts may lie at the base of public responses. The potential for adverse public opinion regarding the finished product may make industries reluctant to use recycled water, even with significant cost savings that could be passed to the customer. Recent emphasis on conservation and recycling of other products (eg plastics and paper) has developed a recycling ethic in the public that has been beneficial in expanding the acceptance of recycled water (Holliman 1998).

Although Australians increasingly recognise the importance of personal responsibility for the environment and conservation of our natural resources, and have accepted, for example, segregated household recycling schemes, people who feel positive about the benefits of recycling water are still reluctant to use recycled water themselves. There have been a number of studies on the community acceptability of recycled water. These studies, summarised in a forthcoming publication of Po, Kaercher and Nancarrow, and provided to the Prime Minister's Science, Engineering and Innovation Council (Rathjen 2003), are shown in Table 20.

Table 20. Respondents (%) Opposed to Recycled water for Specific Uses (Rathjen *et al.* 2003)

	ARCWIS (2002) N=665 %	Sydney Water (1999) N=? %	Lohman, Milliken (1985)* N=403 %	Milliken, Lohman (1983)* N= 399 %	Bruvold (1981)* N=140 %	Olson *et al.* (1979)* N=244 %	Kasperon *et al.* (1974)* N=400 %	Stone & Kable (1974)* N=1000 %	Bruvold (1972)* N=972 %
Drinking	74	69	67	63	58	54	44	46	56
Cooking at Home	-	62	55	55	-	52	42	38	55
Bathing at Home	52	43	38	40	-	37	-	22	37
Washing clothes	30	22	30	24	-	19	15	-	23
Toilet flushing	4	4	4	3	-	7	-	5	23
Swimming	-	-	-	-	-	25	15	20	24
Irrigated dairy pastures	-	-	-	-	-	15	-	-	14
Irrigated vegetable crops	-	-	9	7	21	15	16	-	14
Irrigated vines	-	-	-	-	-	15	-	-	13
Orchard irrigation	-	-	-	-	-	10	-	-	10
Irrigated alfalfa Hay	-	-	-	-	-	8	-	9	8
Home garden irrigation	4	3	3	1	5	6	-	6	3
Irrigated parks	-	3	-	-	4	5	-	-	3
Golf course irrigation	2	-	-	-	4	3	2	5	2

*cited in Bruvold (1988) – these studies were conducted in the US.

Apart from those described earlier in Queensland, there are many other examples around the world where local communities have rejected recycling proposals because of a failure to take into account the various factors that such communities see as important. The reasons for failure are commonly a lack of coordination between the authorities involved in planning health, water supply and environmental management, and inadequate community consultation on the issues. Part of the problem is probably due to the "top down" expert-based approach to water planning where experts develop solutions and then consult the community. The recent study by Nancarrow *et al.* (2003) examined a proposal to supply Perth the South West Yarragadee aquifer demonstrated the probability of little trust and certainty in the community concerning the ability of the experts and authorities to conduct investigations, plan for the future and make appropriate decisions. Success stories often show the recycling agenda being driven by community organisations that are able to encourage integration between the various arms of Government. These observations indicate that sustainability cannot be achieved through technical and administrative means alone. The active participation and "ownership" of households and consumers in the decision-making process is essential.

Australian populations in cities and regional centres differ from each other and also have different water perceptions to those overseas. This is well illustrated by the differing attitudes of people in South Australia to rainwater collection from those in the other states. Adelaide people have chosen to install rainwater tanks because historically, their water supply, then unfiltered, had a relatively unattractive taste and appearance, so 'most people had one' to get what was perceived as 'fresh rain water'. In Sydney, the community is split with regard to its interest in installing a rainwater tank in home gardens (Roseth 2003). Those who would consider installation perceive that there are environmental, cost and water saving benefits; those who are not interested are concerned with the aesthetic attributes of rainwater tanks, and with cost associated with their installation and maintenance.

Roseth (2003) also concludes that the community will accept the use of recycled water not because it is inherently good, but because it is an inevitable initiative, which, along with other initiatives will safeguard future water supply. Associated with the acceptance is considerable concern about the health and safety of recycled water, particularly when using it for personal purposes. Definition of the problem with regard to water provision and use needs to be undertaken in consultation with the community in that city.

Groups assessing a water supply problem need to undertake an evaluation of the existing attitudes of people to water. To what extent do some think that water supply is a basic obligation of government to provide without question, or others perceive it as a finite resource which has be husbanded, and for which every member of society has some responsibility? The group needs to develop an approach to the introduction of different options for use or recycled water, with a staged process suggesting less personal initially, but moving towards an increasingly personal use as the community becomes more comfortable. For example there has been a high degree of acceptance of the concept of recycled water use in Rouse Hill for garden and toilet use. The availability of recycled water for clothes washing has been introduced more recently. There are no proposals for direct drinking use. There is also a need to differentially target groups according to age, ethnicity, education level and local circumstances and political stances (McKay 2003).

There needs to be a definition of the proposed pricing strategy for the potable water and the recycled water and to carefully consider the perverse incentives and how much price differentials affect attitudes. Setting the price at or near the price of potable water may encourage people to use potable water for all purposes 'to be on the safe side'. Alternatively, setting the price of recycled water very low to gain acceptance may result in that water no longer being valued as a scarce resource, and being used over-generously, as appears to have happened at Rouse Hill.

Consideration also needs to be given to perceptions of equity issues. The hazard and political opportunism presented by environmental or net worth discrimination, as demonstrated in San Diego where the perception was created, albeit without foundation, that treated wastewater from wealthy northern neighbourhoods would be distributed to poorer urban communities, which would be forced to drink 'the effluent of the affluent' (Sheik 2003).

In encouraging the development of innovative approaches to water cycle management in new housing developments, the likely impacts on the developers, the real estate agents responsible for marketing the development, and the home buyers all need to be considered.

The availability of recycled water including storm water to build into water features has a significant impact on land values. A standard unimproved building block with a waterfront to a pond or lake feature will attract an additional market value increment of 20-30%. Where such features are built into a development, they are usually maintained by the developer for some time, but ultimately pass to local government. Local government can be reticent to have such features included in developments because of the additional maintenance costs, including for water quality monitoring in the water features that will be faced in due course. Although there is also evidence of land agents having been uncomfortable marketing properties with recycled water, there has been little obvious impact on the potential buyers (Mitrevski 2003).

A development consultant advised of approvals for such developments taking over two years to complete in Victoria. Many developers would be likely to conclude that innovative solutions on that approval time-frame are "just too hard".

- **The processes that have to be undertaken and the approvals obtained for subdivisions with creative water supply and effluent treatment provisions can be very cumbersome, involving multiple interactions with a number of different agencies at state and local government level, and serve to inhibit innovation. Approval processes should be streamlined among agencies.**

Having established the wider use of recycled water, it also behoves the suppliers to maintain the confidence of consumers. This is especially important in ensuring the compliance with regulations to ensure that not only is there adequate processing quality assurance in place, but that there are no cross-connections. Education of the plumbing profession, other agencies likely to be undertaking engineering works in the vicinity of water supply lines, and of the consuming public is essential to the maintenance of successful recycled water use. This is further discussed in section 5.9.

Even though no health impacts were recorded from the 1998 Sydney water quality ‘crisis’, the unfolding events demonstrated the public, media and political sensitivities to any perceived threat to health from contaminated water supplies. Incidents such as any of the 20 cross connection incidents reported in California since 1991(Safewaterreuse 2003) could prejudice acceptance of current schemes and new proposals. Although some countries such as Japan have adopted the use of dual water supply installations without regulated period inspection for cross-connection, ensuring continued credibility of recycled water use requires that such a policy should not be allowed to develop in Australia.

The Gold Coast City Council appears to be following an exemplary path in determining the future water needs of the Pimpama-Coomera area and any necessity for use of recycled water.

However, we do need to understand what brings communities to accept recycled water, we need to improve community understandings of the options available and we need to develop better tools for engaging communities at the planning stage of specific schemes so that community-owned decisions are achieved.

The following points have to be considered: -

- Opposition to change is a normal response when people are being introduced to new concepts,
- A range of outreach / awareness / education programs should be put in place together,
- Involving the public as well as regulators, early in the discussions and in the decision-making process, is essential,
- Independent sources are likely to be necessary to ensure trust,
- Specific community groups affected by different impacts of the proposal should be independently targeted,
- Contact in small group gatherings is better than large public meetings,
- Word of mouth is a very effective form of communication for residential customers,
- Any deficiencies of information should be promptly filled –if the proponents do not do so, someone else surely will.
- Approval from the public and from elected officials may reinforce each other,
- Conversely, opponents and opportunistic nominators for election may also reinforce each other to their mutual advantage
- Efforts should be made to minimize disruption during the construction phase of the project to minimize any negative impacts before service begins.
- Customers need to develop an awareness that recycled water is also a limited resource,
- The cost of public consultation is small in relation to the engineering and other costs that make up the total cost of the project

- **The community is sensitive to the security and safety of its water supplies. Any developments and changes in its provision must be undertaken in consultation with the community. The active participation and 'ownership' of households and consumers in the decision-making processes is essential. Better tools should be developed for engaging communities in the planning of specific schemes.**

The use of unplanned indirect potable recycling occurs more widely than is generally recognised in Australia, particularly in the Murray Darling Basin. As increasing constraints on water resources become evident in some areas, consideration may have to be given to introducing planned indirect potable recycling, as has been carried out in California.

- **There is scope for greater use of planned indirect potable water recycling, but any introduction should be brought about only with community commitment.**

- **Ensuring public confidence and support is fundamental to future recycled water initiatives.**

5.4 Costing and Pricing

There is currently great variability in pricing of water in Australia, including recycled water. Examples are given of current prices in Table 21.

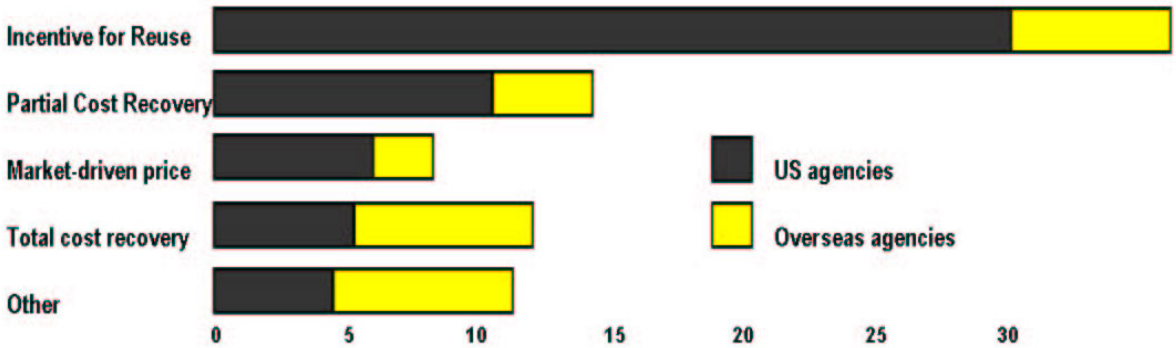
Table 21 Location, use, and price of water from Australian recycling projects, together with price of two drinking waters for human consumption in 2003.

Location	Use	Class	Price, /kL	Reference
RECYCLED WATER				
Northern Adelaide Plains, SA*	Irrigated horticulture/vegetables	A	7-15c	Ringham (2003)
Sydney – Rouse Hill, NSW	Residential supply for toilets, home gardens, washing	A	28c	Sydney Water and IPART (2003)
Geelong, Victoria†	Various agricultural and horticultural irrigation uses	C	35-58c	Byrnes (2004)
Springfield, Qld.,	Residential supply for toilets, home gardens	A	43c	Hall (2003)
Southern Vales, SA*,	Vineyard irrigation	B/C	53c	Templeman (2003)
Olympic Park/Newington, NSW,	Public facilities and Residential supply for toilets, gardens, washing	A	83c	Listowski (2003), IPART (2003)
DRINKING WATER				
Sydney Water Corporation Drinking water	Human consumption (reticulated bulk supply)	-	98c	IPART (2003)
Ride citrus/mandarin sports water	Human consumption (in 500 mL bottles)	-	$6,600.00	*Choice*, Jan/Feb 2004, p27-29

* Marketed to users by pipeline company – water obtained without charge from water treatment agency. All other cases, water marketed by water treatment agency.
† Schemes use private infrastructure for transfer of recycled water.

Worldwide, prices do not generally reflect the recovery of the full costs of amortised capital and operating costs (Mantovani *et al.* 2001). Furthermore, the environmental costs are not taken into account either. Mantovani *et al.* (2001) illustrated from their survey the principal rational for determining the price at which water would be sold (Figure 62).

Figure 62 Principal rationale for price determination (n=79) (redrawn from Mantovani *et al.* 2001)



Mantovani *et al.* (2001) found that of 29 water agencies that provided responses on what they charged for recycled water *vis à vis* the potable water price: -

- Five US and 2 international agencies charged >75% of the potable price
- Two US and 3 international agencies charged 50-75% of the potable price,
- Two US and 3 international agencies charges 25-50% of the potable price, and
- Five US and 7 international agencies charges <25% of the potable price

Early new users may need additional incentives to get the project started. In an Australian example, the first participants in the Northern Adelaide Plains Scheme involving recycled water being delivered from the Bolivar STP by Water Reticulation Services Virginia were signed up for water in the winter season at 7 c/kL, and in summer at 12 c/kL. The property locations of those signing up determined the most economical layout of the delivery system. Other growers, finding a pipe passing their door, then sought to access the supply, but are now charged a higher delivery price for recycled water to offset their opportunistic accessing of a pipeline system designed to serve the original participants.

Only 12 of 79 respondents sought to recover their costs. The reasons why the prices of recycled water were cross-subsidised by other components of the water business were stated to be: -

- Avoiding potable water capital costs by using recycled water to meet new or growing water demands (Luggage Point, Brisbane (Q), is a good Australian example),
- Avoiding costs to treat and dispose of large quantities of effluent (Christies Beach STP - Southern Vales (SA) pipeline),
- Availability of government financial assistance for water reuse (Australian NHT Coasts and Clean Seas Program),
- Local policy objectives

A variety of issues need to be taken into account.

If the price is set too low, users are likely to regard recycled water as an unlimited resource and use it in a profligate manner, as has occurred at Rouse Hill. On the other hand, if the price is set close to the price of potable water, customers with some insecurity about using recycled water will use potable water for all purposes “to be on the safe side”.

- **Regulators and water agencies, in defining pricing strategies for potable water and recycled water, must carefully consider any perverse incentives and how price differentials may affect water-user attitudes.**

In a drought environment in which there were restrictions on the potable supply, users might even be prepared to pay more than the potable price to ensure continuity of supply.

This highlights the importance of actually establishing the size of the likely market for recycled water before commencing the project. Unless use is made mandatory, to get commitment the water agency will inevitably have to quote a supply price to attract firm customers. Mantovani *et al.* (2001) found that only 27 of 62 recycled water respondents had actually conducted a market survey before initiating the project. Some of the remainder has less than ten customers and felt that a market survey was unnecessary.

- **Recycled water projects must not be initiated without establishing the market for the recycled water produced.**

Mills and Asano (1998) have identified sixteen components that need to be considered in surveying the potential market for recycled water. These are listed below, with parenthetic comments illustrating Australian experience or potential issues to address.

1. Specific potential uses of recycled water,

    (The objective of developing the market needs to be clearly defined – is it driven by the recognition that there are very limited water supplies to support new development [for example, the Gold Coast Pimpama-Coomera investigation], is it primarily to encourage savings by substituting for potable water use [the Illawarra Wastewater Strategy to replace potable water at Bluescope Steel], is it primarily driven as a disposal to land project with opportunities to encourage economic development [Werribee – Balliang], is it an environmental improvement project [Tasmanian local government schemes], or is there a risk of developing projects in the hope that a market will appear from somewhere?)

2. Location of users,

   (Piping infrastructure and pumping are major costs impacting on the economics of a scheme. Distribution costs are in proportion to the user markets. Proximity of the Northern Adelaide Plains vegetable growers to the Bolivar STP has been an encouraging component of that scheme, whereas finding markets adjacent to plants in Launceston and Hobart is likely to be difficult.),

3. Recent historical and future quantity needs (because fluctuations in water demands, at least three years' past use data should be collected),

   (The impact of industry adjustment and technological change has had a significant impact, for example, on Hunter Water's ability to maintain markets)

4. Timing of needs (seasonal, daily and hourly water demand variations),

   (Industrial markets are much more regular in their demands than seasonal irrigation markets, and more nearly match the relatively even supply of sewage effluent provided storm surges can be minimised.)

5. Water quality needs

   (Water quality should be fit for its intended purpose, though it may well ultimately be more economical to generate all the water to advanced Class A to provide greater diversity of market opportunity if no major "lead market" is evident.)

6. Water pressure needs

   (Recycled water in South Australia is supplied by the Virginia Water Reticulation Services to growers unpressurised, with growers then having to install their own storage, pumping and distribution system, whereas the Willunga Basin Pipeline Company supplies recycled water pressurised to growers who maintain only a filtration and distribution system, but their water price is higher, albeit also because the scheme was totally funded without external grants and subsidies.)

7. Reliability needs – how susceptible is user to supply interruptions,

   (Better continuity of supply resulted in Gladstone (Q) industries moving to recycled water in the recent drought, demonstrating the potential importance of recycled water to critical industrial processes. Slightly more flexibility may be possible for irrigation users, particularly amenity users, and in that part of the growing season where there is adequate natural rainfall – for example, Virginia Water Reticulation Services requires all growers to have sufficient storage capacity for supplying three days demand in the absence of continuity of supply so that plant maintenance can be undertaken. Supplying peak demands to meet the expectation of dual supply markets may present difficulties– the Rouse Hill community in hot weather already consumes recycled water derived from 77% of peak sewage inflows to the Rouse Hill STP.)

8. To what extent is the user likely to want to dispose of residual recycled water after use,

   (An incentive for potential industrial users of the developing Kwinana Water Recycling Project in Perth is the ability to discharge surplus water and industrial effluents [subject to Trade Waste requirements] into the Cape Peron outfall.)

9. Identification of on-site treatment or plumbing retrofit needed to accept recycled water,

   (These issues and their costs were a significant component of developing the stormwater recycling schemes by the Salisbury Council in Adelaide for Michells, Holdens etc. Research showed that while it may not yet become necessary, Michells could establish an in-house wetland-based treatment program following their industrial use of the recycled stormwater. Where the customer faces significant retrofit costs, there may be attraction in a discounted cost for the first couple of years as an incentive to access a recycling scheme. Where recycled supply is being offered to existing potable water-using industries which will need retrofitting, the most economical approach is to target a small number of potentially large consumers close to the recycling plant.)

10. Internal capital investment and operating and maintenance costs for on-site facilities to accept recycled water,

    (Where there is a combined market of agricultural users who can accept lower quality recycled water, and specific industrial users who demand a higher quality water, it may be more attractive for the water authority to recycle to a base standard, with those users with specialised needs purchasing recycled water relatively inexpensively and installing their own additional treatment plant. The contrast may be noted between the BP-Amoco Refinery at Luggage Point, where Brisbane Water prepared a recycled water of very high standard for its principal customer, with the Eraring Power station in Newcastle which accepts a lower quality recycled water from Hunter Water and provides additional treatment "in-house" to meet its needs for water very low in Total Soluble Salts.)

11. Needed monetary savings on recycled water to recover site costs or the desired pay-back period and rate of return on capital,

    (This issue in Australia has revolved around considerations of private and public benefit, and the extent to which environmental costs and benefits, which may be difficult to quantify, affect the equation. This then can influence the extent of grant funding, such as from the NHT Coasts and Clean Seas Program, which may be invested.)

12. Present source of water, who supplies, and at what cost?

    (Although Australia has in recent years separated the water resource management and supply functions, they have remained within government, even in the case of Adelaide where the service functions are subcontracted from the SA Government's SA Water Corporation to the private sector. This allows governments to maintain an effective integrated policy overview of water and wastewater services, in contrast to much of North America where the water supply and sewage treatment/recycling services may be provided by unrelated private sector companies leading to greater regulatory difficulties (Mantovani *et al.* 2001). There have been examples where a wastewater district implementing a recycling program was sued by a local water district on the basis that the availability of recycled water in the community caused a drop in potable water sales, reducing the revenue to support the loan commitments made to establish the potable water supply infrastructure (Mills and Asano 1996). But are we also likely to see competing suppliers, for example in South Australia between Salisbury Council and SA Water Corporation, which could have a similar effect on capital management? Are the costs of potable supply any more near to the true costs of supply than the recycled sources?)

13. When would user be willing to start taking recycled water?

    (Is attraction to use recycled water going to need financial incentives [eg Rouse Hill], and can the level of incentive be correctly judged? Alternatively, is the market influenced by there being no alternative source of supply [eg Kwinana Industrial Area]?)

14. Future land use trends that could eliminate recycled water use, such as conversion of farm lands to urban development

    (This is a potential problem for many schemes, particularly where the plants are close to the edge of cities. Werribee, Victoria, is an example of an area now undergoing rapid development. There may be scope to plan an orderly evolution of the use of recycled water from land-based agricultural use to industrial use.)

15. For developing user projects, when would access be required, and what is the current status and schedule for the development?

    (It has previously been highlighted that many overseas projects have over-estimated the likely market demand. Examples in Australia include the establishment of an industrial precinct with reticulated recycled water at Springfield by Ipswich Water, but yet to attract industrial uptake.

16. After informing user of potential project conditions, a preliminary indication of the willingness of the user to accept recycled water.

    (Accurate forecasts of the recycled water market are necessary to avoid unrealistic cost-recover projections for new projects (Mantovani *et al.* 2001). An example where this will be important is the ambitious scheme by Sydney Water to seek to market from 2008, up to 100ML/day of recycled water from the 53km Glenfield-Liverpool-Malabar pipeline, with potential markets identified for about half the flow.)

Currently, there is also great variability in the costing of recycled water in Australia. Examples are given in Table 22.

Table 22 Estimated costs of producing recycled water from various sources

Location	Use	Class	Price /kL	Reference
Parafield, SA	GH Michell & Sons Australia Pty Ltd, woolscouring	Stormwater	30c (operating cost only)	Pitman, 2003
Springfield, Q	Amenity, schools, oval, residential	A	$1.45	Consultant – (Hall 2003)
Olympic Park/Newington, NSW	Public facilities and Residential supply for toilets, gardens, washing	A	$1.60 (operating cost only)	Listowski 2003
Melbourne	Integrated hydrological system, residential development	A	$2.50	Private sector development consultant, pers. comm.
Melbourne – Eastern STP	Integrated amenity and residential use	A	>$3.00	GHD 2002a
Rouse Hill NSW	Residential supply for toilets, home gardens, washing	A	$3-00 to $4-00 Initially, $7-00	de Rooy & Engelbrecht 2003, de Rooy 2003

Costing and pricing mechanisms of recycled water are not transparent. It is likely that neither the true cost of potable nor recycled water is reflected in current prices. In the case of a number of recycling schemes, the treated water is provided by the water treatment authority without charge for distribution to recycled water users, so the distributing company is only required to service the capital and operating costs of the distribution system. A lack of integration in potable water, sewage, stormwater and groundwater resource management can result in irrational use of resources and failure of market forces. Externalities such as impacts on the environment are generally not costed. (Externalities are the costs or benefits that impact society but are not included in the market price of a good or service - pollution is an example of a negative externality, education is an example of a positive externality benefit when members of society other than students benefit from a more educated population. Externality is one type of market failure that causes inefficiency.) CoAG principles now allow for externalities to be built into water prices, though the NCC has made only limited incursions into examining the progress states are making with externalities.

- **The cost of externalities should to be built into drinking water, sewage treatment and recycled water prices as provided for under the CoAG water reform principles.**

Often the cost of capital has not been accounted for in determining recycled water costs or prices. There has been dependence on grants to cover the shortfall between willingness to ask users to pay and the actual costs of a project.

Such grants become *de facto* provisions for externalities, notably through the Coasts and Clean Seas Program that had been instrumental in establishing several coastal STP reuse projects in the 1990s, but which went into recess in 2002.

The gap between recycled water costs and alternative supplies can be very project specific, but costs can be something like $25/ML for water from a channel or river versus $400 to $800/ML to distribute recycled water. Potable water is typically retailed at $300 to $700/ML. Hence while including externalities in the price of alternatives to recycled water will result in price increases, it is unlikely that the gap will be easily closed (SKM 2002).

A disincentive for adoption of recycled water with dual supply systems by developers has been the custom to impose a charge component representative of the capital invested in the water resources facilities (‘headworks charges’), but with no reduction in the size of this charge when up to half of the water in a development may be derived from a recycling source rather than all from potable reservoirs.

- **‘Headwork charges’ imposed by water agencies for provision of water supplies to new subdivisions should relate to the nature of the supply systems being adopted and to the proportionate use being made of the ‘headworks’ in the total water supply system rather than being applied as a flat charge.**

An interesting example is that of the Bolivar STP in Adelaide. It has been estimated that about 4 000 Ha of seagrass has been destroyed in consequence of effluent discharges from STPs into St Vincent Gulf. Costanza *et al.* (1997) have estimated the value of seagrass to be $US 19,004/Ha/year, putting the value of the benefits forgone at $US 76m (say $A100m at early 2004 exchange rates). Though it is perhaps ‘drawing a long bow’, this figure may be compared with the $55 million of capital invested in the Bolivar DAFF plant and the Virginia reticulation scheme to reduce nutrient discharges to St Vincent Gulf via the outfall channel (Ledger 2003).

There are inconsistencies between governments in the management and regulation of their water resources and water services. An integrated water cycle management anomaly has been evident in the National Water Reform Agenda, which examines the effectiveness and efficiency of Australia’s water and wastewater services, but excluded recycled water from its considerations (Campbell 2003). This anomaly was amended in 2003.

The States’ Regulators’ Forum has given little attention to water. Some states, including Victoria, South Australia and Western Australia have had no effective price regulation (Owens 2003), and the Western Australian regulator was unable to access objective financial data (Parry 2003). The Victorian Essential Services Commission is assuming a role of water pricing regulator from 2004, while a new Economic Regulation Authority has been set in place in Western Australia.

- **Industry regulators should have an obligation to examine costs and prices as well as service standards, but should also review water prices from a perspective of total water cycle management.**

There can be a conflict of interest within government with regard to water management, flowing through into pricing strategies. Water resource managers may be seeking to restrain per capita consumption by increasing the cost of water in two or multi-tiered pricing structures beyond a certain threshold level of consumption. (Aggressive leak detection programs to restrain total water use can be helpful there too.) However, state-owned water utilities can have an obligation to maximise returns to their principal shareholder, the state governments, with one option for achievement being through selling more water. A movement into recycled water may undercut revenue streams from more profitable potable water sales. The extent of the dividend from SA Water to the South Australian Treasury after tax of 119% in 1998-9 and 124% in 1999-2000, subsequently drew unfavourable comment from the National Competition Council (NCC 2001).

- **Governments must resolve at whole-of-government level the conflicts of interest that may be extant at portfolio level in environmental management, resource provision, revenue generation and water pricing objectives.**

The evidence from North America, where water supply management agencies have in some areas been allowed to develop independently of wastewater management agencies, often serving areas that are not concomitant, is that the approach has led to inefficient use of the water resources from a total water cycle perspective.

- **Any separation of responsibilities for the ultimate management of water and wastewater resources as has developed in USA, should be discouraged in Australia.**

As well as identifying a market for recycled water, it is essential that those wishing to access the newly found availability of recycled water for processes, particularly agricultural production, have addressed the market demand for the additional produce so generated. This is a potentially important component of such schemes as the Werribee – Balliang pipeline scheme. Horticulture Australia Ltd, the R&D arm of the horticulture industry, and Land and Water Australia are currently exploring the scope for increased horticultural production from the potential availability of additional recycled water (Chapman 2003; LWA 2003).

There is a risk that a potentially large reuse projects initiated with economic development as a primary driver, for example increased horticulture, if not tied to a reduction in potable water demand, will offer little in net resource and environmental benefits. Water conservation, demand management and reuse opportunities need to be considered together in the development of pricing policies and investment decisions.

A view has been expressed that any water can be made safely potable if strained through enough money.

5.5 Legal matters

A range of legal issues may arise in the production and use of recycled water. Mantovani *et al.* (2001), referring also to Richardson (1985), discussed the theories governing liabilities that might be applicable to marketing and delivering recycled water for reuse.

Negligence may arise, either on the part of the water treatment authority, or on the part of the user in production if they have failed to take reasonable precautions to protect others from foreseeable risks of harm. This may result from

- failure to reach treatment standards,
- improper use standards (for example using B class recycled water for amenity use outside of, say, the approved period 10pm to 6am when public contact would be assumed to be minimised)
- inadequate monitoring and surveillance provisions special circumstances raising foreseeable dangers even when products reached normally accepted standards.

Strict liability (liability without fault) may arise for injuries caused by defective products without proof of negligence. Imposition of strict liability represents a policy judgement by society that an activity, while having sufficient value that it should not be prohibited, is sufficiently hazardous that the one engaging in it should bear the entire risk of loss (Feitshans, 1996). This could arise if the recycled water failed to reach the prescribed quality standards or if standards used to judge the quality were flawed (as was suggested by some as having occurred in the 1998 Sydney *Cryptosporidium* 'water crisis').

Warranty issues may arise if recycled water is treated as a commodity and damage occurred resulting from its use. These may also arise if recycled water has been used in processes which have been described as using what has been assumed to mean potable water, for example in human food production.

Within Australia, government agencies (including local government) are almost always responsible for the oversight of recycling programs, and most legislation governing water issues is likely to 'bind the Crown'.

Contracts become important in managing the access to, distribution and use of recycled water. Issues to be considered include any obligations for: -

- the recycler to guarantee supply (many supply authorities will not do so),
- the recycler to guarantee agreed compositional and delivery standards (*eg* maximum salinity, minimum pressure or within agreed parameters),
- the customer to receive the supply as part of the plant's effluent management program,
- the customer to have adequate storage capacity to allow supply to be withheld for a period due to maintenance or emergency needs,
- the supplier to have the right to discharge elsewhere if a processing problem arises affecting water quality?
- the customer to comply with any special conditions such as excluding public access or irrigating only at certain hours (Figure 63),
- the customer to accept whatever limits are placed on use of the recycled water,

- the customer to accept that the product is fit for his/her purpose,
- any agreed sharing of risks, for example for third party damages,
- Duration of contract
- Provision for contract termination
- Rights of supplier to enter the user's site
- Financial arrangements, water price, price review procedures, facilities for payments
- provision for mediation in the event of dispute,
- definition of the jurisdiction where any disputes might be resolved
- appropriate insurance being required (and available).

Figure 63 Special conditions may have to be complied with such as excluding the public at certain hours – Shire of Wickham, WA (WA Water Corporation).

There have been difficulties in potential recycled water users obtaining public liability insurance for production systems involving use of the water. This problem has on occasion obliged the water authorities to undertake the use of the water themselves, for example by running their own farm enterprises (Langdon 2003).

There is evidence that within the Australian Trade Practises Act of Australia there is a residual liability to the water supply authority. Risks are mitigated by warnings and education campaigns. In contrast, in California, Title 22 restricts liability to meeting the water quality regulations (Gregory 2003).

- **Any residual liabilities to the water supply authorities within the Australian Trade Practises Act should be clarified, along with meeting the necessity for any additional legislation that might be needed to protect water utilities from lawsuits if they are in compliance with federal and state legislation.**

The continuing identification of new chemicals with lower and lower maximum permissible concentrations (MPCs) will be of concern to water authorities, whether their product is potable water from catchments believed to be pristine, or it is recycled using the most recent technology. Future legislation may impose cleanup liabilities for contamination resulting from activities that were entirely legal at the time they occurred. Careful evaluation of all activities by regular environmental audit is an excellent way to ensure that there are no procedures that may, if untreated, generate liability. With appropriate follow-up and corrective action, it can greatly reduce the potential for civil liability and virtually eliminate all potential for criminal liability (Feitshans 1996). This is the basis of the HACCP process.

A bill was introduced into the US 108th Congress House of Representatives in January 2003 with the intent of protecting water utilities from lawsuits if they are in compliance with federal and state legislation. The basis of its introduction was that setting drinking water standards is a complex public policy determination requiring careful analysis and balancing of the maximum safe level for each drinking water contaminant and the technological capability of removing the contaminant while assuring that drinking water is affordable. The setting of these standards was not appropriate for individual juries deciding individual cases in separate states, but was fundamentally a scientific issue, and that claims for monetary damages brought against water providers under common law based on alleged contamination of drinking water threatened to undermine the science-based uniform national system of water quality regulation. However, the legislation would still allow lawsuits against utilities that are not in compliance with the relevant water legislation or if in the case of unregulated contaminating substances, the utility could be liable if it knew or should have known that the substance was likely to cause injury at the levels found and it was feasible to remove the substance to a safe level (Miller, 2003).

Recently, the Australian position with respect to water rights has been clarified with water entitlements being disaggregated from land titles, becoming separate tradeable instruments. This gives to a water titleholder the right to sell water, either temporarily or permanently, independently of the land title. The security of access to surface or groundwater has been an important underpinning for new agricultural economic development. However, the position as to entitlement to recycled water is far less well defined, and access to recycled water does not appear to be a readily tradeable instrument. Lack of clear title may inhibit investment. Growers only currently access water on the basis of a contractual relationship with the supplier, usually on an annual or season basis - a relationship unlikely to encourage major capital investment in improved irrigation practices. If the supplier has access to the water from a water authority, that too may be only by a limited contractual agreement.

Colorado has set in place state regulation to administer the beneficial use of reclaimed wastewater, with surface water, ground water and wastewater all being subject to controlled appropriation (Mantovani *et al.* 2001). In some cases, the water rights encourage reuse rather than disposal, for example the rights held by the Denver Water Department to import water from west of the Continental Divide to the front range are contingent on frugal usage including successive reuse (McEwen 1998).

A similar issue is likely to arise with stormwater. Although the harvesting of stormwater in rural areas is subject to States controls, albeit quite inconsistently, through implementation of policies on constructions such as farm dams, and the proportion of catchment run-off that may be harvested, the urban position seems less clear. In the case of the Salisbury Council in South Australia, it has been given a permit to store groundwater using ASR, and then given an incremental increase in its groundwater entitlement by the Northern Adelaide and Barossa Catchment Water Management Board as a consequence. The Council then markets the recovered water.

A further issue that needs to be clarified is the legal right to lay infrastructure in the form of recycled water mains as an urban service similar to the right available for laying services for potable water, sewerage, stormwater drainage, electricity, gas and telecommunications. There is evidence that the existing legal position in parts of Australia may be unclear, particularly if the service is being laid by a private sector entity from, say a water treatment plant to an industrial site, and where a licence may be required from, say, local government (Marks 2004).

- **The issue of water rights, as they apply to urban stormwater and to water recycled from wastewater effluent, and the right to lay infrastructure to deliver these waters, should be addressed.**

5.6 New Technologies

5.6.1 Membrane Technologies

Several new treatment and disinfection technologies are offering significant benefits over those previously employed, and are being increasingly adopted. Membrane processes such as microfiltratioin and reverse osmosis are increasingly being used, Luggage Point, Wollongong, Olympic Park and Singapore being examples. These techniques offer significant advantages for pathogen removal, enhanced organics removal and with appropriate choice of membranes, removal of salts and dissolved solids. With an appropriate product train, recycled water suitable for use in boiler applications can be achieved. However, care must be taken in the management of the membranes as their efficiency can be considerably reduced and life shortened by “poisoning”, for example by chlorine (Barr 2003). Other uses include as a source of dilution flow to add to high salt treated effluent streams to make them more attractive for agricultural use, as is being considered at Black Rock, Victoria. The cost of membranes is continuing to fall, run times have increased and the lives of membranes have been lengthened. Operating pressures have been reduced, thereby lowering operating costs for power (Florida Reuse Committee 2003).

Membrane technologies have been adopted by the CRC for Waste Management and Pollution Control in its production of a compact wastewater management system suitable for office and apartment buildings and portable installations and now licensed to Zeolite Australia, with an initial installation being made at Flemington Racecourse in Melbourne to generate water to be used for grounds maintenance in place of the existing potable supply.

However, if the recycled water is taken to a compositional standard equivalent to that required for potable or industrial boiler use by reverse osmosis, some 15% of the volume will be lost, as it is carrying the salt stream which has to be discharged (Langford 2003). An STP serving a population of 50,000 people would generate a waste stream of 1.8 ML/day which would require disposal (Griffiths 2003). If otherwise free of nutrients and undesirable chemicals, it may be possible to discharge this stream to ocean, but in the case of inland plant use, it is likely that an evaporation basin similar in principle to those at Noora or Stockyard Plains in the Murray Darling Basin salt interception schemes would be required. This raises other issues, such as whether relatively impermeable sites are available, allowing effective evaporation and potentially commercial use of harvested salt or whether there is a risk that the salt brine will infiltrate into aquifer systems.

5.6.2. Membrane bioreactors

This technology involves use of membrane filters such as microfiltration or and ultrafiltration membranes as a substitute for sedimentation and filtration in the conventional suspended growth biological systems of secondary treatment. Such technologies are becoming attractive where the biological reactor is large but the hydraulic capacity is small. Output water from these units can then be passed through reverse osmosis for final disinfection. The use of submerged membrane bioreactors has been reviewed by Adham *et al.* (2001). They noted four alternative commercial suppliers of the technology. Such systems have generally been installed in small capacity industrial plants, and for use in small communities operating up to 300 kL/day (e.g. Magnetic Island, near Townsville), but have recently been developed up for larger-scale plants in Canada and Egypt at up to 10 ML/day. After a survey of existing installations, cost comparisons were made between one brand of submerged membrane bioreactor, and oxidation ditch and conventional activated sludge technologies, each as a pre-treatment to reverse osmosis. The study was at the conceptual design level for 1 MGD capacity, with the capital amortised over 20 years at 8% interest rate. The outcome of the study is given in Table 23.

Table 23 Summary of capital and operating costs for a submerged membrane bioreactor compared with oxidation ditch and activated sludge process streams (Adham *et al*. 2001).

Treatment Alternative	Capital cost $	Amortised capital cost ($US/yr)	O&M cost ($US/yr)	Total cost ($US/yr)	Total cost. ($US/1000gal)	Total cost ($US/kL)
Zenon submerged membrane bioreactor	$5,068,627	$516,000	$267,000	$783,000	$2.15	$0.57
Oxidation ditch	$5,587,800	$569,000	$307,000	$878,000	$2.40	$0.63
Activated Sludge	$5,933 520	$606,000	$282,000	$867,000	$2.38	$0.63

Management of membrane fouling is an important issue in the operation of membrane systems. Chaudhary *et al.* (2003) have recently experimented with using powdered activated charcoal to reduce direct organic loading in a membrane system used after biological treatment. Initially, organic removal was due to adsorption onto the powdered activated charcoal, but subsequently was due to biological degradation by microbial communities growing in suspension in the reactor and on the powdered activated carbon. There appears to be scope for developing further ways in which membrane technologies can be developed for wastewater processing.

5.6.3 Disinfection alternatives

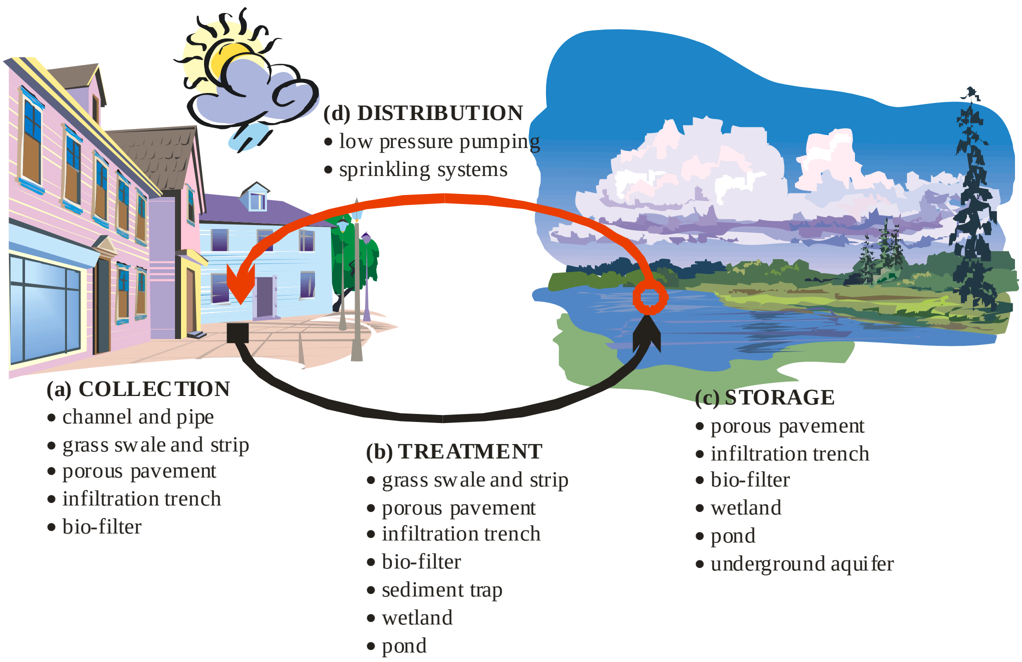
Ultraviolet (UV) Irradiation is an effective disinfection method that does not create disinfection by-products such as those associated with chlorination and chloramination. It can destroy some toxic material such as NDMA (Florida Reuse Committee 2003). Ozonation has been adopted in a number of recent systems, but can be difficult to use consistently. At Rouse Hill, an additional superchlorination step was subsequently added to the process train. (Engelbrecht 2003).

As additional chemicals with potential risks are being isolated, there has been a tendency to add additional steps to process trains (Sedlak 2004).

5.6.4 Stormwater

In a comprehensive study, 85 stormwater harvesting schemes have been identified in use or being developed in Australia. Sixteen of these have been reviewed in detail from perspectives of regulation, system components, design, construction, maintenance and operation, implementation issues, costs and benefits and performance, with a critique of current practices, knowledge gaps and research needs (Hatt, Deletic and Fletcher 2004). The components that can make up a stormwater harvesting and management system have been succinctly illustrated (Figure 64).

Figure 64 Components of a Stormwater Harvesting and management system encompassing various options for collection, treatment, storage, flood protection and distribution of the recycled stormwater for use (Hatt, Deletic, and Fletcher 2004).



Much of the increasing interest in stormwater harvesting, treatment and reuse is associated with the wider adoption of Water Sensitive Urban Design in new urban developments. Stormwater re-use system design should satisfy end use requirements and address the multiple objectives that these systems often have, which can include both flood mitigation and water reuse objectives. Current WSUD systems are not primarily oriented to delivering high water quality with reliability of treatment and the ability to cope with high variability of intake. Construction tolerances in integrated stormwater treatment and reuse systems are generally finer than in conventional systems. It was also noted that one of the most frequently encountered issues was the lengthy negotiation, assessment and approval processes for such developments, ascribed to lack of pertinent experience and policies on the part of the water industry and the relevant authorities. It was concluded that further innovative techniques were needed for the collection, treatment and storage of stormwater, with further research into performance modelling for evaluation purposes.

- **The current *Australian Guidelines for Urban Stormwater Management* (ARMCANZ/ANZECC 2000) do not give adequate consideration to the harvesting and use of urban stormwater as an additional resource and they should be revised.**

5.6.5 Use of Wetlands

While recognising the progress being made with physico-chemical processes, there appears to be a renewed interest developing in biological systems based on wetlands for wastewater treatment. This is especially so in country areas where space constraints are not a problem, but also in systems designed for harvesting and treating stormwater. Examples include effluent application to land to produce a treated effluent that meets discharge standards, known as the FILTER system (Jayawardane *et al.* 2001, Gardner *et al.* 2001), and the Advanced Pond System™ being marketed by NIWA Australia, the Australian commercial arm of a New Zealand Crown Research Institute, the National Institute of Water and Atmospheric Research. This system uses ecologically engineered natural processes, aims to achieve near-tertiary treatment (in terms of nitrogen and phosphorus removal) and superior removal of pathogens and indicator bacteria (NIWA 2004).

Reclaimed storm water from wetland systems can be combined with treated effluent to produced a final product to distribute in non-potable recycling systems as is done at Olympic Park and will be done at Mawson Lakes.

Constructed wetlands provide a low cost alternative to tertiary Biological Nutrient Removal plants and thus may be more appealing for small communities where the cost of upgrading treatment works can be prohibitive. The treated wastewater from these wetlands (a scarce resource during the dry season and in arid regions) can also be used to irrigate crops, playing fields, parks and gardens or golf courses. During the wet season these wetlands can be used as a water storage area and for groundwater recharge. The water discharged from constructed wetlands can be of acceptable quality to flow into estuarine and riverine environments.

Constructed wetlands can also provide a habitat for biodiversity and improve landscape amenity, though in the case of the Salisbury Council’s Parafield Airport wetlands, they have had to be fenced to exclude birds due to the need to discourage competition for air-space between planes and birds at the airport. As many natural wetlands are only seasonally inundated, during the dry season wildlife has to seek alternative refuges. Wetlands constructed for effluent treatment can mitigate the loss of wetlands that have occurred in the past through ignorance of their importance or the scarcity of water due to extraction for agricultural purposes (Greenway 2003).

- **The importance of effluent treatment facilities should be recognised for their potential complementary role in biodiversity conservation.**

Emergent macrophytes are an essential component of most constructed wetlands and play a major role in facilitating physical and biological processes in pollutant removal. These macrophytes, however, are restricted to shallower water usually less than 50 cm deep and not all species can tolerate permanent flooding. Surface Flow Wetland Systems for the treatment of steady flow wastewater treatment plant streams, exhibit little variation in water levels and are usually designed for a depth of 30-50 cm water. Thus sedges and reeds tolerant of permanent inundation need to be planted. By contrast huge fluctuations in water levels occur in stormwater wetlands necessitating a range of shallow (<10 cm) and deeper (50 cm) macrophyte zones. The shallower zones will completely dry out during low rainfall periods therefore plant species that can tolerate wetting and drying cycle should be selected for these areas. Several alternative models, encompassing surface flow wetlands, subsurface flow wetlands, and a combination of both are illustrated by Greenway (2003).

The removal of human pathogens is paramount to municipal wastewater reuse. Constructed wetlands can be designed to maximise the removal of any potential health risks. When used for reclaimed water, ponds are used either for short-term storage, for treatment or for polishing the reclaimed water. The efficiency of the treatment process is highly dependent on the design and operation of the pond system. Treatment of the effluent in ponds usually relies on a combination of physicochemical and biological factors such as sunlight, temperature, sedimentation, pH, hydrogen sulphide, and biological influences. Importance is often given to the action of micro-organisms along with aquatic algae and plants to reduce the pathogen load in the effluent as it passes through the ponds. The effectiveness of the treatment process can rely on retention time of the water in the ponds, climatic conditions and seasonal variation, and the quality of the effluent entering the pond (Toze 2003),

The mechanisms operating in wetlands have been summarised by Greenway (2003) in Table 24.

Table 24 Role of Constructed Wetlands in Effluent Treatment (Greenway 2003).

Pollutant	Treatment Process
Suspended Solids and BOD	Sedimentation is facilitated by the vegetation. Finer particles adhere to the bio-film surfaces of the vegetable or gravel substrate. Microbial degradation of organic particulates
Nutrients	Direct uptake by plants and micro-organisms. Inorganic nutrients converted to organic biomass. Microbial processes facilitate the removal and transformation of nutrients, especially nitrogen removal.
Metals	Microbial bioremediation of metals. Metals immobilised by adsorption onto sediments or by precipitation. Plant uptake and bioaccumulation.
Hydrocarbons	Microbial hydrocarbon degradation
Pathogens	Natural UV disinfection. Natural bio-control by microbial predators in the wetland ecosystem. Adsorption to fine particles and sedimentation. Natural death and decay.

Problems with the ability of waste stabilisation ponds to decrease coliform and bacteriophage numbers have occasionally been noted, often related to inadequate retention time. Bacteriophage inactivation can be influenced by differential responses to varying sunlight spectral wavelengths. Pond systems do appear to be more effective at removing the ova of the larger pathogens such as the helminths, with the removal method predominantly through sedimentation (Toze 2003).

Maintenance of wetlands used for water remediation is critical to guarantee reliability of treated water quality, but evidence has been observed of neglect in some systems since their construction (Hatt, Deletic and Fletcher 2004).

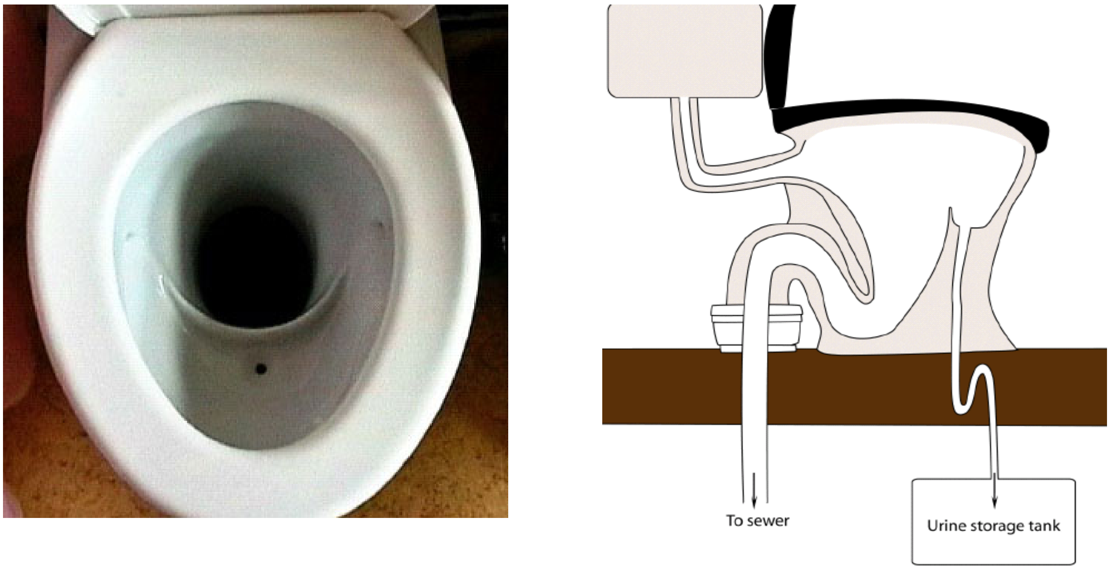
- **Following the observed neglect of some wetland water remediation systems and the need to guarantee reliability of treated water quality, mechanisms must be established at the time of funding and construction of new projects to ensure sound management systems are set in place and maintained.**

5.6.6 Waste stream separation

A common ideology to ecological villages or ecological sanitation (EcoSan) is to separate at source and close nutrient and water loops within societies, not only to reduce drinking water demand, but in general, to be more sustainable (Balkema *et al*., 2002). Hence, low flush toilets, such as vacuum on demand systems using less than 0.5 L/flush and even dry (zero flush) composting toilets have been implemented, often with urine separation. Urine-separation not only allows the collection of 50-85% of the major plant nutrients currently present in sewage, within less than 1% of the wastewater volume (Kirchmann and Pettersson, 1995; Jönsson, 2002), but it also reduces the odour and pollution (leachate) issues associated with collecting / composting human faeces. There are both dual flush and vacuum urine-separating toilets produced in limited numbers, principally in Sweden and Germany (Ashbolt 2004).

Greater potential awaits a technological advance to concentrate urine nutrients (such as with Australian membranes), thereby reducing the transport costs back to agriculture and replacing industrial fertilisers. Stored urine is hygienically safe, and is cost effective for local utilisation within 200km of the zone of production (Jönsson, 2002), and maybe far greater distances with dedicated pipelines. Practical experiences with urine sorting toilets exist mainly in Sweden with more than 3000 installations (Figure 65).

Figure 65 Details of urine separating toilet (Gardner 2003).



One problem remains with separating toilets, namely that men are often reluctant to sit down for urinating, despite the unavoidable spreading of urine in the bathroom. A possible solution is the domestic use of waterless urinals, some of which have been developed in Australia. The logistics and economics of collecting and distributing urine would not be without difficulty, and it is doubtful if Australia would immediately adopt this technology.

5.7 Energy consumption

The energy used in wastewater plants, provided there are no major pumping costs after the conclusion of the treatment, represents 3-5% of the daily power consumption of an ‘equivalent person’ (EP) living in an urban environment (Griffiths 2003).

However, energy consumption for operating wastewater plants can vary depending on the technology used, particularly with regard to the final high level treatment which may be imposed if the effluent is to be recycled to equivalent to potable standard. The energy input in operating sewage treatment plants is almost entirely the electrical energy driving the plants. Sydney Water (2002), which has a wide range of technologies in its 27 plants, and is one of the largest power consumers in New South Wales, averaged 362.9 kilowatt hours per megalitre (kWhr/ML) of sewage treated in 2000-1, but by 2001-2, this had increased to 418.9 kWhr/ML. The increase was ascribed to significant treatment process upgrades at Cronulla STP, additional pumping due to wet weather events in February 2002, commissioning of a stabilisation grade A biosolids facility at Malabar STP and increase in sewage connections to the Rouse Hill STP, a plant with advanced treatment facilities required for the local domestic recycled water scheme.

The plant power consumption requirements for operating a Biological Nutrient Removal STP have been calculated by Griffiths (2003) and are presented in Table 25.

Table 25 Energy requirements for an aerobic BNR wastewater treatment train (Griffiths 2003)

Unit process	Energy consumption (kWhr/ML)
Inlet Works	10
Aeration	230
Pumping	70
Aerobic digestion	10
Sludge dewatering	30
Ultra violet disinfection	50
Miscellaneous	20
TOTAL	420

Griffith notes that many plants lack adequate aeration control, and as a result may have aeration power consumption 100% above the minimum necessary, and suggests that this is the simplest area where economies of power consumption may be achieved.

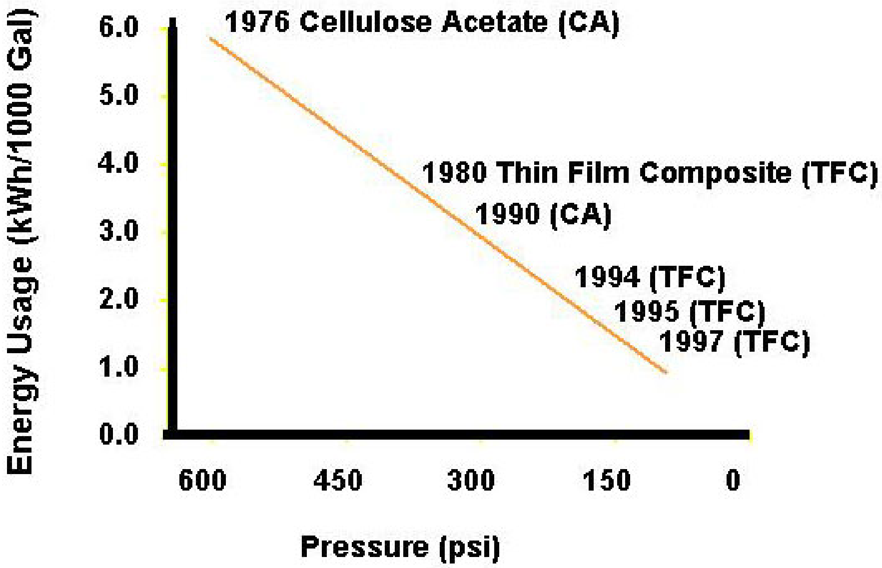
A variety of processes have been proposed for reclamation of product water from wastewater. Generally these consist of several unit processes to provide a "multiple barrier" to the survival and discharge of viruses, pathogens, toxic compounds and compounds that may interfere with the longevity, health or reproduction of the consumer. Typical unit processes for water reclamation can include some of the following;

- Tertiary dual or single media filtration
- Biological activated carbon treatment
- High lime treatment
- Ozone Treatment
- Micro-filtration
- Ultra-filtration
- Nano-filtration
- Reverse Osmosis

The tertiary filtration of the product water from an advanced biological wastewater treatment system requires additional head for flow through the filter. With appropriate operation, the filters have been demonstrated to achieve significant removal of cysts such as *Cryptosporidium* and *Giardia*. Dual media filtration is in fact the main, or only, barrier provided against cysts in many water treatment plants drawing from non-secure catchments. The tertiary filters also can serve as a polishing stage for the secondary treatment process. Tertiary filters can remove remaining suspended solids from the effluent from a biological nutrient removal plant to reduce the effluent phosphorus concentration from 0.3 mg/L to less than 0.1 mg/L as phosphorus. An effluent of this quality can be discharged to inland waters without promoting algal growth. The reduced suspended solids will also result in improved effectiveness of any ultra-violet disinfection systems provided (Griffiths 2003).

The energy costs and pressure requirements of membrane filtration systems have reduced considerably in recent years as illustrated from the Californian Water Factory 21 (Figure 66).

Figure 66 Relationship between energy usage and operating pressure has declined over time in Californian Water Factory 21 as membranes have developed (adapted from Mills 2003).



The various membrane based filtration systems can be used individually or as a pre-treatment step prior to further, finer membrane filtration. The energy requirements for membrane filtration naturally increase with decreasing pore size. Energy requirements for individual and combined systems are presented in Table 26. Many advanced Australian membrane plants are typically using a combination of microfiltration and reverse osmosis.

Table 26 Membrane filtration energy requirements (Griffiths 2003).

Membrane type	Pretreatment	Energy consumption (kWhr/ML)	Product recovery
Microfiltration	-	110	92-96%
Ultrafiltration	-	170	88-92%
Nanofiltration	Microfiltration	410	74-83%
Reverse Osmosis	Microfiltration	820	74-82%

The energy requirements can potentially double or treble during the production of a recycled water supply equivalent to drinking water standard. The extent of recovery losses, discussed earlier, is also evident.

Biological treatment is likely to continue to be the main form of effluent treatment, with future plants maintaining the most use of biological systems and minimizing energy requirements while producing the highest quality effluent suitable for its intended purpose (Griffiths 2003). This will often result in a limited use of membranes in the low pressure processes (microfiltration and ultrafiltration), coupling the high degree of solids removal and positive barrier to pathogens they provide with the complementary capabilities of conventional biological and physical/chemical processes (Leslie, Lozier and Law 2003).

If drinking water standard product is to be produced, a major energy component is that of pumping it to the point of entry to the use system. Most sewerage systems make maximum use of gravity flow, and are generally at a low point in relation to the market being served. If a drinking standard water is to be returned indirectly to the potable system by pumping to a water reservoir before the appropriate water treatment is applied, it is likely that the pumping will involve a considerable lift as the reservoir will have been sited to obtain maximum head. Griffith quotes an example of 60 km distance and a lift of 120 m, which was estimated at 4,600 kWhr/ML.

However, the energy cost of transmission for recycled water may well be less than many current water resources supply tasks. For example, SA Water in obtaining 35-85% of Adelaide's water, depending on seasonal conditions, by pipelines from the River Murray at Mannum and Murray Bridge, uses a pipeline 48 km long and involving a lift of 418 m over the Mount Lofty Ranges (Griffin and McCaskill 1986). Direct return of potable water may be a more attractive option from the energy cost viewpoint, though unlikely to be acceptable to the community in the near future.

The economic benefits of securing markets as close as possible to the site of recycling are self-evident, with a small number of customers each with a large, fairly constant demand, being the most attractive from the wastewater processor's viewpoint. With pumping costs being a major cost of wastewater processing costs, the attraction inherent in having smaller treatment and recycling plants close to markets is also apparant, rather than having very large STPs remote from potential marker where the economics of processing scale may be more than offset by the greater transmission losses and pumping costs. These issues are further highlighted with older sewerage systems that suffer from major levels of infiltration during rain events.

- **In view of the energy and greenhouse costs associated with pumping and the provision of large piping infrastructure, particularly where recycling is intended, further consideration be given to the choice of STP options in new subdivisional projects between pipeline connection to an existing large but distant treatment works *vis à vis* the adoption of locally based small disaggregated treatment plants.**

- **Incentives for new industries that require steady supplies of large volumes of water of less than drinking water quality should be developed in association with any proposals for new sewage treatment works to minimise supply costs and maximise savings of potable water.**

Ozone generation where used in the product train, must typically be carried out on-site with a likely energy requirement of 200 kWhr/ML. If a ten-fold increase in UV disinfection is imposed to destroy chemicals such as NDMA, as recommended by the Californian Health Services Department, there is a considerable impact on total energy use as shown in Table 25, with the approximately 500 kWhr/ML effectively doubling the energy demand for the process train. Where Chlorine is used, it is typically imported, so the embodied energy in its manufacture is assigned to the manufacturer rather than the STP.

Gold Coast Water, in developing options for the Pimpama-Coomera area (Gold Coast Water 2003b), assumed an energy use of 800 kWhr/ML, but noted that independently sources data shows that this could range from 500 kWh/ML for an oxidation ditch BNR plant at Thorneside to 1,000 kWhr/ML for a compartmentalised plant such as at

Nambour. It was assumed for the options study that in future wastewater treatment plants, an energy cost of 550 kWhr/ML would prevail.

For the purposes of its calculations, it made a number of assumptions, as shown in Table 26

Table 26 Energy costs for various water and wastewater treatment functions (Gold Coast Water 2003b)

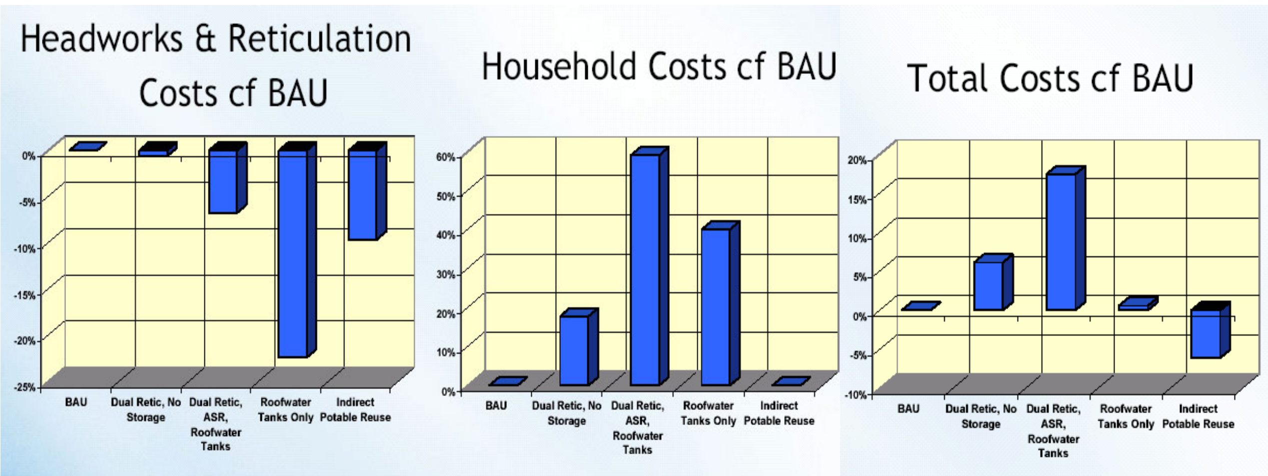
Function	Energy use (kWhr/ML)
Water pumping station	40-450
Sewage pumping station	140
Conventional water supply treatment	50
Recycled water treatment (membranes)	200
Dual membrane filtration plant	400
Wastewater treatment	500-1000
Household pressure pumps (for rainwater tanks)	230-3100

Assumptions were also made about the efficiencies of pumps, which represent a major energy cost of operating water and wastewater plants. Water supply pumps were assumed to be 90% efficient, open impeller wastewater pumps were assumed to be 70% efficient, while household pressure pumps were assumed to be 17.5% efficient. Motor losses of 20% were also assumed.

It will be seen that compared with other components that might be used in an integrated water supply system involving both the provision of drinking water and the provision of recycled water from effluent treatment plants, stormwater sources or household rainwater tanks, a major increase in energy requirement occurs if pressurised rainwater tanks with domestic pumps are introduced into the equation. This can arise, for example, in using rainwater for the hot water system. Gardner (2002) noted this same disadvantage in 'Healthy Home®**'** project.

The costs of alternative options (Figure 67) considered by Gold Coast Water, whilst having specific design characteristics for the location, nevertheless give some indication of the comparative costs of alternative approaches to water provisions for Pimpama-Coomera (Gold Coast Water 2003b).

Figure 67 Comparison of "whole of life (capital + operating and maintenance) cost components of supply options compared to the "Business as usual" (BAU) option (Gold Coast Water 2003b).



It can be seen that those options involving rainwater tanks involve significantly higher whole of life costs, reflecting the high power requirements for operating systems with relatively energy inefficient pressurisation systems for use with rainwater.

5.8 Greenhouse gas emissions

The input power costs can also be used for calculating the input greenhouse gas emission costs of various options.

However, greenhouse gases, notable methane, can also be generated from the supply-train sewage treatment processes where biological systems are being used. These can be offset if the methane is used as a biogas source for operating co-generation plants, which can be an energy input to the STP and/or a minor revenue stream by supplying surplus electricity to the grid. This is already practised in a number of locations such as the Oxley Creek STP in Brisbane, at Melbourne Water's plants and at SA Water's plant, operated by United Water at Bolivar rather than releasing or flaring off these gases. Sydney Water generates 13m. kWhr of power from its Malabar and Cronulla STPs, representing 3.3% of its total power demand.

Gold Coast Water among its other design parameters, chose an objective of a 20% reduction in Greenhouse Gas emissions over "business as usual". After identifying seven options for high-level development, details of which are given in Table 27, and assuming a greenhouse gas emission rate of 1.08 $kgCO_2/kWhr$, based on the Swanbank Power Station as the source of electrical power, it was possible to calculate the emission differences between various options. These are shown in Figure 68. The greenhouse gas emission contribution for the wastewater, stormwater, roof water and potable components making up the total water supply are shown in Figure 69.

Table 27 Characteristics of seven options chosen for high-level evaluation compared with "Business as usual" (BAU) (Gold Coast Water, 2003)

KEY	OPTION							
ELEMENTS	BAU	1	2	3	4	5	11	12
Reclaimed Water Service for		Laundry*, external toilet & fire fighting	External, toilet & fire fighting	External, toilet & fire fighting	External, toilet & fire fighting		External, toilet & fire fighting	
Seasonal storage	No	Yes	No	Yes	No	No	No	No
Rainwater for				Bathroom, laundry & hot water	Bathroom, laundry & hot water	Bathroom, laundry, hot water, toilet & external	Bathroom, laundry & hot water	
Wastewater service	Conventional	Smart	Smart	Smart	Smart	Smart	Smart	Smart
Notes		Recycled water to NSW Standards					Onsite tank for recycled water storage	Indirect potable reuse
Common Elements		Yes	Yes	Yes	Yes	Yes	Yes	Yes

* Note – Recycled water in Option 1 was to be treated to NSW standards as a consequence of its proposed use in laundries.

Figure 68 Greenhouse gas emissions from each of the seven high level options for water and sewage services for the Pimpama-Coomera region (Gold Coast Water 2003).

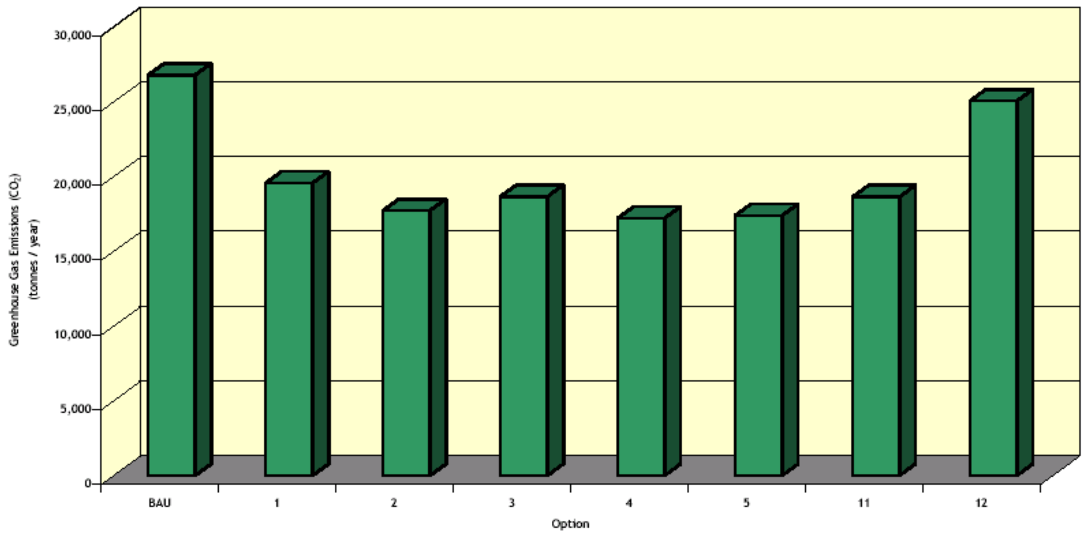
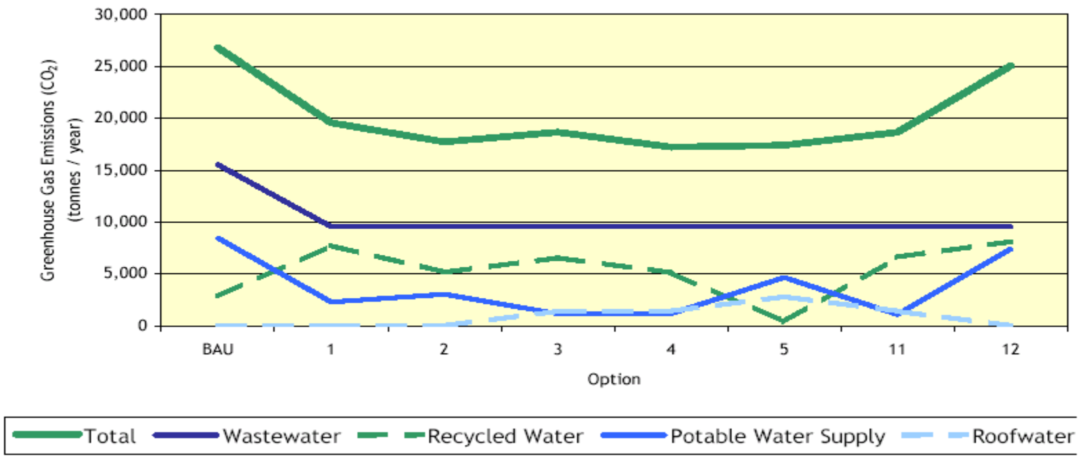


Figure 69 The greenhouse gas emission contribution for the wastewater, stormwater, roof water and potable components making up the total water supply (Gold Coast Water 2003).



From these figures, it is evident that a consideration of capital costs, operating costs, energy costs, and greenhouse gas emissions involves trade-offs. These have to be considered in the particular circumstances of any scheme being developed to integrate recycled water including stormwater and rainwater with a conventional mains drinking water system drawn from traditional catchment and groundwater sources.

5.9 Infrastructure

The major risk to the successful development and wider adoption of water recycling in Australia is that of loss of public confidence. The established level of confidence is likely to be very 'brittle' and will be easily lost with an 'incident' that is perceived to put health at risk. Therefore a Hazard Analysis is likely to identify Critical Control Points in infrastructure construction and maintenance. Overseas evidence of cross connection being a problem is still being recorded. At Rouse Hill, the major risk/issue associated with the commissioning and ongoing operation of the scheme has been the quality of plumbing work done by private plumbers between the Sydney Water main and the final house fittings. Rouse Hill is being developed by a multitude of different developers/builders over several decades. Each builder and plumber potentially working in the Rouse Hill area is given a comprehensive guide to recycled water standards and requirements. However, typically for a house in Rouse Hill to be connected to the dual water supplies there could be three plumbing contractors employed over time to complete, variously, the horizontal service lines under unformed roads; the vertical line to the meter and from meter to the house; and finally the internal house plumbing. These arrangements in practice have realised a range of plumbing errors that would have caused cross-connections between the two supplies. A random audit of properties undertaken before the scheme was commissioned found many examples of unacceptable plumbing work. About fifty direct cross-connections and several hundred significant plumbing errors were identified and rectified through this work. Despite a large effort in this area there have been two post-commissioning incidents of an unacceptable cross-connection (de Rooy and Engelbrecht 2003).

These experiences confirm the need for appropriate training of plumbing contractors with the introduction of dual plumbing systems for drinking water and recycled water.

The Master Plumbers and Mechanical Services Association of Australia (MPMSAA) has developed a GreenPlumbers® program working with the community, Local Government and Industry, to promote more environmentally sustainable ways of operating. To complement this initiative, GreenPlumbers® training programs have been designed to assist plumbers and sales staff in understanding their roles in relation to Environmental and Public Health. Over 500 accredited GreenPlumbers® have completed their training, and many more are currently signed up to participate in future workshops (Greenplumbers 2003).

Despite this initiative, a significant issue at Rouse Hill has been the need for an ongoing effort to educate and advise customers about the ‘conditions of use’ for recycled water and to deal with various minor non-conformances with plumbing. For example the special tap fitting (removable handle and reverse thread connector) has sometimes been removed/replaced with standard taps. Educating builders, plumbers, new residents and visitors about the system is a significant task. There is an ongoing concern about the potential for customers (following a great Australian tradition) doing unauthorised handyman work and making a mistake leading to a cross-connection that may not be detected for some time (de Rooy and Engelbrecht 2003).

The Master Plumbers and Mechanical Services Association of Australia and its research partner, RMIT University – Faculty of Engineering, have reviewed the National Plumbing and Drainage Codes (AS/NZS 3500) and State plumbing regulations to investigate possible changes that would be required to better facilitate rainwater harvesting and domestic water reuse (Workman, Herbert and Tink 2003). Their report highlighted the over regulation and complexity of the plumbing industry, noting that there is no national regulatory body, whilst at State level there are a large number of regulatory stakeholders such as water authorities, water retailers, local government municipalities, environmental protection authorities, and health departments, all of which have mixed views on domestic water harvesting, recycling and re-use.

Some of the issues arising from differences between the National Plumbing and Drainage Code and State based regulations that they identified were: -

- the definition of class A quality recycled water and domestic use
- the inconsistent definition of rainwater
- treatment of sewage water and rainwater and how the two systems are managed
- non return values where multiple sources of water are used (backflow prevention)
- marking of pipes containing waters of different quality
- provision in new house construction or extensions to facilitate selective reuse of greywater, or selective supply from rainwater
- harnessing of rainwater tank supplies to houses
- provision of multiple sources of water for the same use, (eg supply of washing machine from tank with mains as a backup)

Coombes and Kuczera (2003) have suggested that rainwater tanks provide greater economic benefits to the community than the traditional water supply and stormwater management options in the majority of cases have considered. This view is also being reflected in the recent introduction of subsidy schemes and in some new developments, an obligation to include rainwater tanks as a supplementary water resource. New urban developments are likely to require increasingly complex water management systems with appropriate infrastructure. Although the Australian standard is quite specific for above-ground rainwater tanks, further clarification is suggested for underground tanks. Noise issues and the relative inefficiencies of pumping systems (discussed earlier) need to be addressed. There is no standard for using rainwater for hot water systems, though such installations are being proposed for new developments such as at Aurora, Victoria, and have historically been used in country areas. The standard could be reviewed to accommodate a single tank being used for a multiplicity of domestic uses. The standard prohibits the convergence of stormwater and sewage water to a possible on-site domestic treatment plant for reuse, though on a broader scale, this is now being addressed in community-level developments. (Examples at Olympic Park, Mawson Lakes and Roxby Downs have been discussed earlier.) There is no provision in the standards for the separation of greywater from sewage, though his has been widely practised manually in some cities during the recent drought. As the greywater volume generated domestically is about three times that needed for toilet flushing, there is potential for it to be used for that purpose provided a retention time of no more than 24 hours can be achieved, with the surplus by then disposed of. Practical monitoring requirements need to be defined, as current requirements, as demonstrated in Canberra, are prohibitively expensive. The current code for on-site wastewater management (AS/NZS 1547:2000) does not address issues of sustainable reuse. An alternative used in parts of Europe is to combine stormwater/rainwater with greywater (sullage) into a single treatment and holding system that can provide sufficient water for toilet flushing and garden irrigation, reducing by half the current average demand on the domestic drinking water supply system. In general terms, it has been concluded that the national Plumbing and Drainage Code AS/NZS 3500 covers in great detail the performance standards and acceptable solutions for plumbing installations but does not cover water sustainability measures of which recycling forms a part (Workman, Herbert and Tink 2003).

There is also considerable variation in state-based regulation of infrastructure. Each State/Territory individually regulates on-site installations including auditing and compliance. The groundwork should be laid to allow the development of a service industry for maintenance or in-house recycling systems in high-rise office and apartment buildings, particularly where hydraulic conductivity of local water and/or sewage mains is likely to be restricted. There are some current regulatory loopholes, for example single buildings in NSW with more than one residential unit but less than 2,000 people, discussed earlier. Each State has its own examination and licensing board for plumbing practitioners. While there is a national regulation for plumbing approval/compliance MP52, many states do not enforce this at installation or point of sale. A comparison (Table 28) has been prepared showing the variations between the states and Territories (Workman, Herbert and Tink 2003).

Table 28. State/territory based structures for plumbing (Technical Solutions) (Workman, Herbert and Tink 2003).

New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	ACT	Northern Territory
On site Regulations Sydney Water Act 1994, Hunter Water Corporation, Sydney Water Corporation, Aust. Inland Energy and Water, other water authorities and local councils, NSW Code of Practice Plumbing and Drainage, Different authorities call up different versions of AS/NZS3500 **Wastewater** (additional regulatory groups include NSW EPA, Sydney Health, local government.) **Occupation Licensing** NSW Dept of Fair Trading	**On site regulation** Plumbing Industry Commission (PIC), All work must comply with AS/NZS 3500 **Wastewater** **(**Additional regulatory bodies include Victorian EPA, Dept Health/Human Services, Local Government.) **Occupation Licensing** PIC with processes supported by the Australian and New Zealand Reciprocity Association Agreement	**On site regulation** Building Codes of Queensland Local Government Councils regulate plumbing works **Wastewater** (Additional regulatory groups include Qld. EPA, ecoaccess, local government.) **Occupation Licensing** Plumbers and Drainers Examination Licensing Board	**On site regulation** South Aust. Water Corporation administered by Development Services Branch **Wastewater** (Additional regulatory groups include Department of Human Services, local government.) **Occupation Licensing** Commissioner for Consumer Affairs	**On site regulation** Water Corporation of WA. Technical regulatory role with transfer of Plumbing Licensing Board and the Office of Water Regulation **Wastewater** (Additional regulatory groups include local government) **Occupation Licensing** Water Corporation will transfer to Plumbing Licensing Board	**On site regulation** Dept of Infrastructure, Energy and Resources (legislation and regulations), Local Government councils (issue permits and certification of completion of plumbing works.) **Wastewater** (Additional regulatory groups include local government.) **Occupation Licensing** Plumbers and Gasfitters Registration Board.	**On site regulation** Building, Electrical & Plumbing Control (BEPCON), ACT Dept. Urban Services **Wastewater** (Additional regulatory groups include Environment ACT and Urban Services.) **Occupation Licensing** Plumbers Drainers and Gasfitters Board	**On site regulation** The Building Advisory Services branch of Lands, Planning and Environment **Wastewater** (Additional regulatory groups include local government.) **Occupation Licensing** Plumbers and Drainers Licensing Board, administered by Dept of Industries and Business.

Source – Commonwealth Dept. Industry, Science and Resources (2000) "Future options for Plumbing and Drainage Regulation in NSW February 2002 – NSW Interagency Committee on Plumbing Regulation Reform

Stringent educational efforts towards contractors and customers alike are needed to minimise any health risks of non-complying infrastructure installations.

- **Encouragement needs to be given to the evaluation of 'in-house' wastewater treatment systems with concomitant recycling in high-rise office and apartment buildings, and for the establishment of a service industry to manage such installations.**

- **Infrastructure standards pertaining to water services, particularly plumbing and drainage regulations, should be examined to achieve standardised outcomes across Australia.**

- **Education of the plumbing profession, other agencies likely to be undertaking engineering works in the vicinity of water supply lines, and of the consuming public, is essential to the maintenance of successful recycled water use.**

5.10 Research and Development

Dillon (2000) reviewed the then current research and development being undertaken into water reuse at the first Water Recycling Australia symposium, organised by the Australian Water Association Water Recycling Forum and held in Adelaide in October 2000. In that year, there were more than 16 research projects with a total annual expenditure of at least $2.9M. However there were significant gaps in comparison with the research needs survey. The largest needs identified were on: -

- factors affecting public acceptance of recycled water,
- potential public health impacts,
- summaries of existing research,
- economics of reuse and
- environmental impacts.

These corresponded quite closely with research priorities developed by several research organizations in USA and Europe (Dillon 2000). Furthermore, with a few exceptions, much of what was then classified as research was investigations of a localised nature that added neither to scientific knowledge nor enabled the new information to be employed at other sites. In short, Australia needed to think more deeply about types of water and reuse opportunities to pursue, so as not to commit precious water resources and large capital investments on projects with short term gains that in the long-term reduce water security for cities (Dillon and Ellis 2004).

A motion arose out of the first Water Recycling Australia Conference ‘to establish a national research program in water reuse, and… should aim to establish a sound scientific base for guidelines, codes of practice, decision making on appropriate technology and training, improve methods for evaluating the economics of reuse projects in relation to alternatives, provide more useful information on society's valuation of reuse and risks, and justifiably improve both public confidence and economics of reuse projects’.

It is evident that research is being undertaken into water recycling on an increasingly collaborative basis. New research programs, including the Australian Water Conservation and Reuse Program, have been developing since the time of the first Water Recycling Australia Conference, and these are outlined below. A second Water Recycling Australia conference was held in Brisbane in September 2002.

5.10.1 Australian Water Conservation and Reuse Research Program

The **Commonwealth Scientific and Industrial Research Organisation** (CSIRO) is leading the establishment of the **Australian Water Conservation and Reuse Research Program** (www.clw.csiro.au/priorities/urban/awcrrp), which has a range of co-participants including the Water Services Association of Australia, the Academy of Technological Sciences and Engineering, Horticulture Australia Ltd, Land and Water Australia, and GreenPlumbers, a registered name of the Master Plumbers and Mechanical Services Association of Australia. The components of this program are: -

The big picture

Inventory of water conservation and reuse activities and issues in Australia.

John Radcliffe, CSIRO and Australian Academy of Technological Sciences and Engineering, Adelaide.

Australian water-sensitive urban design: recent developments, new knowledge.

Tim Fletcher, Belinda Hatt and Ana Deletic, CRC for Catchment Hydrology, Monash University, Melbourne

Integrated water management: Australian case studies.

Grace Mitchell, CSIRO, Melbourne

Social acceptance

Factors affecting public perceptions of water reuse.

Murni Po, Juliane Kaercher, Blair Nancarrow, CSIRO Perth

Health and risk assessment

Health aspects of water conservation and reuse, and proposed new national guidelines.

Tony Priestley, CRC Water Quality and Treatment, CSIRO, Melbourne

The fate of viruses and other pathogens: understanding health risks in non-potable reuse of stormwater and reclaimed water.

Simon Toze, CSIRO, Perth

Quantitative risk assessment workshop, covers health guidelines on water reuse.

Ted Gardner, Qld Department of Natural Resources and Mines, Brisbane

Implementing new technology

Innovative management systems for domestic scale harvesting of rainwater and stormwater, reuse of grey water, and on-site treatment of effluent.

Clare Diaper, CSIRO, Melbourne

Review of National and State plumbing codes and changes required (to facilitate the above).

Ray Herbert, Gary Workman, Greg Tink, GreenPlumbers, MPMSA and RMIT University, Melbourne

Agricultural and Environmental Issues

Endocrine disruptors and pharmaceuticals.

Guang-Guo Ying and Rai Kookana, CSIRO, Adelaide

Impacts on crop quality from irrigation with reclaimed water.

Murray Unkovich, Daryl Stevens, Guang-Guo Ying & Jim Kelly, Adelaide University, CSIRO & ARRIS Pty Ltd, Adelaide

Impacts on soil, groundwater and surface water from sustained irrigation with reclaimed water.

Daryl Stevens, ARRIS Pty Ltd, Adelaide

Water reuse for horticulture: guidance for irrigators and industry development, management methods to improve water use efficiency and sustainability.

Jim Kelly, National Water Reuse Coordinator, Horticulture Australia; Anne-Maree Boland and Andrew Hamilton, Department of Primary Industries, Victoria, Melbourne; Murray Chapman, Land and Water Australia,

Economics and contractual arrangements

Economics of water conservation and reuse, including externalities and life cycle costing.

Darla Hatton MacDonald, CSIRO, Adelaide

Position paper on economic, institutional, policy and regulatory barriers to efficient urban water management in Australia.

Darla Hatton MacDonald, CSIRO

Manual of contractual arrangements for reuse projects, supplier/buyer relationships.

Andrew Sherman & Astrid Di Carlo, Russell Kennedy Solicitors, Melbourne

International Links

American Water Works Association Research Foundation, Water Reuse Foundation, Global Research Alliance, the European Commission via Oz-AQUAREC, UNESCO, and WHO.

5.10.2 Integrated Concepts for Reuse of Upgraded Wastewater in Australia (Oz-AQUAREC)

Oz-AQUAREC (www.uow.edu.au/eng/cme/research/ozaquarec) is the Australian collaborative arm of AQUAREC (see below), led by the **University of Wollongong**. Oz-AQUAREC is funded by a grant of $644,375 from the Australian Department of Education, Science and Training Innovation Access Program (International S&T Competitive Grants no. CG030025).

AQUAREC is an international project ***Integrated Concepts for Reuse of Upgraded Wastewater,*** supported by the European Commission under the 5th Framework Programme and contributing to the implementation of the Key Action 'Sustainable Management and Quality of Water', contract number: EVK1-CT-2002-00130.

Members of the Oz-AQUAREC team are: -

Dr. Andrea Schäfer (Project Leader) -University of Wollongong (NSW).
Dr. Stuart Khan (Project Manager) -University of Wollongong (NSW).
Mr. Mike Muston -Muston & Associates (NSW)
Dr. Stewart Russel -University of Wollongong (NSW)
Assoc. Prof. Will Price –University of Wollongong (NSW)
Dr. Simon Toze –CSIRO Land & Water (WA)
Assoc. Prof Greg Hampton –University of Wollongong (NSW)
Dr. Rebekah Brown –Monash University (VIC)
Dr. Peter Dillon -CSIRO Land and Water (SA)
Andrzej Listowski –Sydney Olympic Park Authority (NSW)

The EU AQUAREC project seeks to coordinate water recycling efforts to overcome obstacles to implementation that are encountered worldwide.

The central questions involve finding ways to manage the risks from pathogens and micropollutants, and in particular to deal with uncertainties; strategies for selecting and implementing technical options; appropriate water quality indicators; processes for user/public consultation; regulations, guidelines and best practice frameworks.

The underlying goal is to move water provision systems towards sustainability, balancing the protection of water resources, economic and regional interests, and the interests of water users.

Australia will apply the outcomes of the EU partners to Australia and contribute the extensive water recycling experience from Australia and its goal of understanding the constraints of water recycling technology and management.

Anticipated outcomes of the project include:

1. Increased implementation of sustainable water use practices (such as recycling);
2. Availability of nationally coherent guidelines and standards for water recycling with an increased incorporation and understanding of micropollutants and pathogens and related indicators. Assistance provided to operators with analytical tools for monitoring purposes;
3. Increased involvement and trust of the community and other stakeholders in decision-making through a transparent and participatory process developed by this project;
4. Better understanding, in a form accessible to operators, of conditions and weak points producing system failures. This will include the removal of micropollutants during conventional and advanced treatment processes;
5. Better understanding obtained through a social/environmental impact assessment of the appropriate roles in wastewater management of recycling and the alternatives;
6. A critical understanding of existing water recycling schemes to provide lessons from the experience in a form readily available for new projects.

In summary, the project will make a significant contribution to more sustainable water management, technically and economically more successful recycling initiatives, and reduced hazards to human health and the environment. Overall, these outcomes will help alleviate critical water problems facing Australia.

5.10.3 CRC For Water Quality and Treatment

This Cooperative Research Centre, which was established in its present form in July 2001, had as its core participants Australian Water Services Pty. Ltd, Egis Consulting Australia, Orica Australia Pty Ltd, United Water International Pty Ltd., Curtin University, Griffith University, Monash University, RMIT University, University of Adelaide, University of NSW, University of Queensland, University of SA, CSIRO, the Water Services Association of Australia and a number of State water agencies. The Centre has three component programs, *viz*:

- Health and Aesthetics, encompassing Epidemiology, Toxicology and People’s Perspectives,
- Catchment to Customer, dealing with Catchments, Storage and Measurement, Treatment Technologies, Distribution Systems and Sustainable Water Sources, and
- Policy, Regulation and Stakeholder Involvement, Education, encompassing Strategic Directions, Policy and Regulations, Rural and Regional Water Supplies, Education and Training, Commercialisation and Communication.

This Cooperative Research Centre is playing a significant role linking water suppliers, water regulators and water researchers across the country and has formal links with similar groups internationally. The Centre played a significant role in developing the new Australian Drinking Water Guidelines and its Chief Executive is chairing one of the three working groups developing new Guidelines for Recycled Water, picking up greater emphasis for their use in an urban environment. The Centre has a strong research emphasis on heath issues, the pathogens potentially associated with water supplies and recycled water, public perceptions about these issues, the monitoring of water quality and treatment technologies and new water reclamation processes. Student training and mentoring is an important role for the Centre in recycled water issues. The Centre is linked to other water-related CRCs through the CRC Water Forum

5.10.4 CRC for Waste Management and Pollution Control

This Cooperative Research centre, established for 7 years in 1997, has had a research focus on innovation in treatment of wastewater and solid waste. As described earlier, it has been responsible for the development of membrane based packed-sized treatment plants suitable for office and apartment building applications and for use in recycled water production from sewer mining applications. Its technologies have been commercialised through a venture Waste Technologies of Australia and are now being marketed in the private sector.

5.10.5 State Government sponsored linkages

State agencies are increasingly identifying research topics relating to water recycling topics. Queensland has identified 31 topic proposals in the economic, social, technical, educational, environmental, institutional and health aspects of "water renewal" (Gibson 2002) on behalf of the **Consortium for Integrated Natural Resources Management** (CIRM), a formal linkage mechanism between three Queensland government departments (Natural Resources and Mines, Primary Industries and the Environment Protection Agency), the University of Queensland, Griffith University and CSIRO. South Australia has set up a similar linkage, the **Centre for Natural Resource Management** (CNRM) linking the SA Department of Water, Land and Biodiversity Conservation, Primary Industries and Resources SA, the South Australian Research and Development Institute, CSIRO, the University of Adelaide, Flinders University, and the University of SA.

5.10.6 Individual Research Projects

Significant research relating to water recycling is also being carried outside the collaborative structures described above, including in CSIRO, the **University of Technology, Sydney**, the **University of NSW** and the **University of Melbourne** with separate funding from the Australian Research Council, water agencies, Research and Development Corporations and elsewhere.

5.10.7 PMSEIC Working Group Report

The PMSEIC Working Group (Rathjen 2003) suggested that in view of the large costs and long life of urban infrastructure, research in recycling should be encouraged, targeting funding from the Australian Research Council and other areas. The Cooperative Research Centres have provided an effective vehicle for encouraging the Australian water industry to invest in research. A number of successful CRCs have continuing and strengthening support from industry, and the work from these Centres is being taken up by the industry. There may be a further opportunity to encourage the Australian urban water industry to support a new CRC that works at the whole of water cycle system level for developing and evaluating integrated water cycle plans and water sensitive urban developments for Australian cities. The Working group noted that several research groups were operating in this area, and there might be significant advantages in helping bring them together and enhance the research effort.

However, from the above summaries, it is evident there has already developed very considerable collaboration over the past three years and it may be more fruitful to encourage that collaboration rather than trying to re-establish new collaborative structures.

The PMSEIC Working Group identified a range of technological opportunities (Table 29) that have potential for the future. Some of these areas already have a degree of research investment, albeit strengthening of them could be advantageous. Other areas have little investment but hold promise if pursued.

- **Encouragement should be given to further collaboration among research agencies working on aspects of integrated water cycle management, particularly effluent and stormwater recycling, and the more effective incorporation of rainwater into domestic supply systems**

- **Continuing research be supported into treatment processes that will lead to progressive improvement in costs and efficiency of advanced wastewater treatment based on the opportunities suggested to the Prime Minister’s Science, Engineering and Innovation Council (summarised in this review in Table 29).**

- **Investment in innovative community scale water recycling projects should be stimulated**

Table 29 Technology Opportunities in Collecting and Treating Various Types of Water (Rathjen *et al.* 2003)

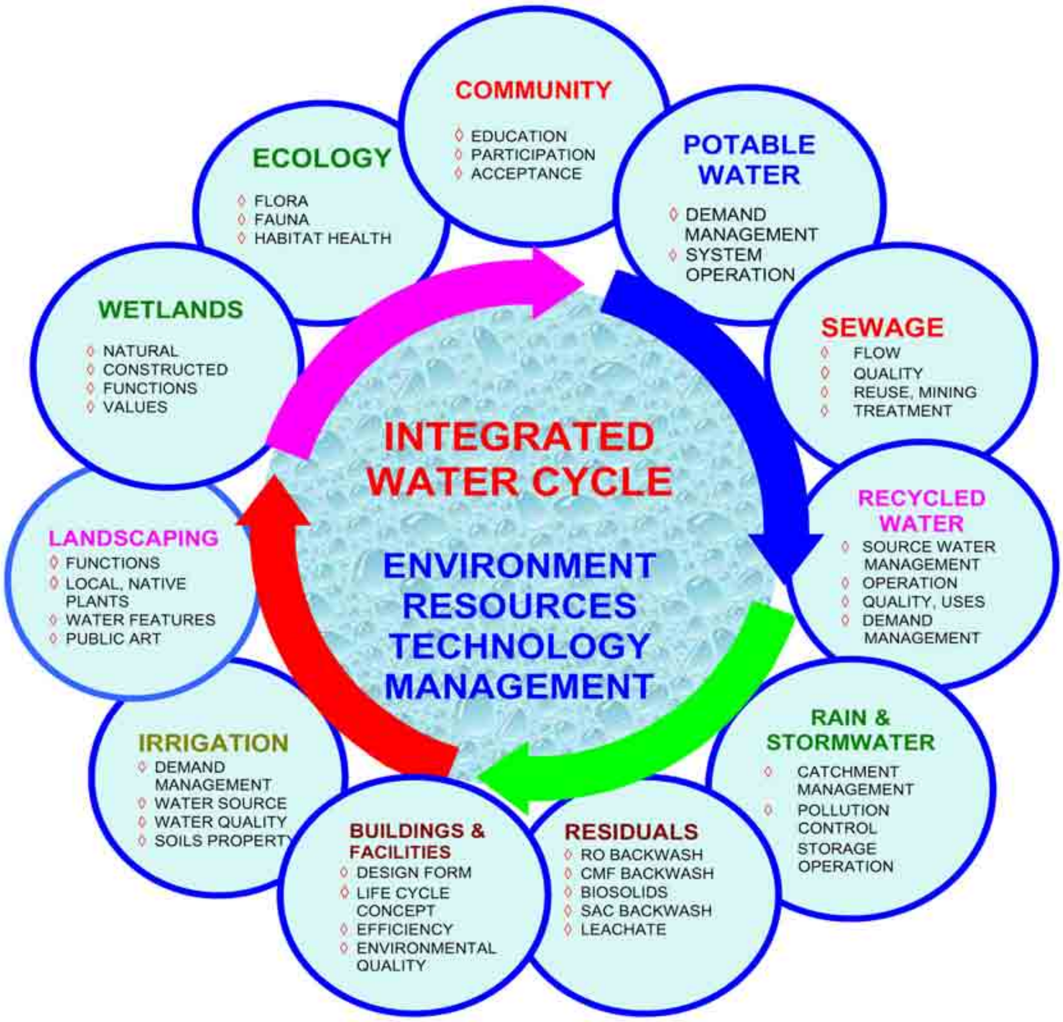
Water Source ⇒	Roofwater	Stormwater (urban runoff)	Greywater	Blackwater (toilet wastes)	Saline Water (sea or brackish)
Technological Approach	First flush diversion Storage tanks POU filters UV disinfection	Storage lagoons Aquifer storage and recovery (ASR) Coagulation/ flocculation/ filtration Disinfection	Membrane bioreactors Adsorption Disinfection	Remove blackwater from water based transportation system Treat separately for pathogen destruction and energy and nutrient recovery	Reverse osmosis membranes Multi stage flash evaporation
Barriers to Implementation	Cost Storage space Reliability of filtration/ Disinfection	Ability to capture and store large scale intermittent flows in urban areas Cost of 3rd pipe distribution Fragmented water institutions Plumbing codes, Unscientific environmental and health regulations Lack of awareness of subsurface storage options	Cost and reliability of small to medium scale treatment and disinfection processes Lack of knowledge of fate of constituents in soil and groundwater Lack of science-based regulation Huge range in detergent sodium and phosphorous concentrations	Large investment in existing toilet technology Public acceptance Low cost of water, energy and nutrients Lack of regulation for subsurface storage Lack of regulation and servicing industry for composting options	Cost Brine disposal
Technological Breakthrough Required	Devices to warn of system failure and contamination Smart storage	Cheaper 3rd pipe systems Novel storage techniques Demonstration of subsurface water quality improvements to potable standards	Cheaper, more reliable treatment/disinfection technologies On-line systems to detect system failure and apply Management Framework	Attractive and functional designs for waterless or low volume collection and transportation systems Enhanced energy recovery through thermophilic anaerobic digestion Process for nutrient recovery and concentration	Reduce costs through enhanced membrane performance and/or lower power costs through enhanced energy recovery
Timescale for Application	1-5 years Short term	2-10 years Short to medium term	5-20 years Medium to long term	10-50 years Long term	5-20 years Medium to long term

5.11 Integrated Water Cycle Management

The ultimate key to effective management of water resources, including the provision of water for urban areas and for irrigation is through the effective use of catchments and groundwater, combined with the harnessing of stormwater, the collection of roof water into rainwater tanks, and the recycling of wastewater effluent within a framework of ensuring there is sufficient water provided for the environment to allow the effective continuation of the ecosystem services on which we all depend. Anderson (2003) has hypothesised how these concepts and associated evaluation methods can be brought together and have the potential to reduce the ecological footprint of water, sewerage and drainage systems by more than 25%.

The components of the water services system have been illustrated conceptually as shown in Figure 70.

Figure 70. A concept of the Integrated Water Cycle as the basis of effective water resource planning and water services management (Listowski 2003).



- **There is currently a community awareness of the need to better manage Australia's water resources. Wastewater effluent, stormwater and rainwater should be seen as complementary water resources of value rather than problems to be disposed of. This provides a platform for greater consideration of water recycling opportunities.**

- **Ensuring public confidence and support is fundamental to future recycled water initiatives.**

6 CONCLUSIONS

The following brings together the principal conclusions presented in this review.

6.1 The Community's Expectations for Water

- The community is sensitive to the security and safety of its water supplies. Any developments and changes in its provision must be undertaken in consultation with the community. The active participation and 'ownership' of households and consumers in the decision-making processes is essential. Better tools should be developed for engaging communities in the planning of specific schemes.

- There is currently a community awareness of the need to better manage Australia's water resources. Wastewater effluent, stormwater and rainwater should be seen as complementary water resources of value rather than problems to be disposed of. This provides a platform for greater consideration of water recycling opportunities.

- The term 'drinking water' is recommended as preferable to 'potable water' since the community at large better understands it.

- Similarly, the term 'water recycling' is suggested as the preferred term to be adopted for generic water reclamation and reuse in Australia.

6.2 Water Resource Planning and Management

- An understanding of the entire hydrologic cycle, with a convergence of understanding of the expressions *Water Sensitive Urban Design* (WSUD) and *Integrated Water Cycle Management*, should form the basis of future water resource planning and management in Australia.

- Where resources are limited, a programme of declaring 'Water Resource Caution Areas' should be introduced.

- Future water resources planning, including for the environment, should evaluate the potential for incorporating recycled water. As well as encouraging the use of recycled water by incentive schemes, water resources agencies should consider regulating for the mandatory use of recycled water for non-drinking water purposes where other water sources are over-stretched.

- There is scope for greater use of planned indirect potable water recycling, but any introduction should be brought about only with community commitment.

- The issue of water rights, as they apply to urban stormwater and to water recycled from wastewater effluent, should be addressed.

6.3 National Water Management Strategy Guidelines

- The *National Water Quality Management Strategy Guidelines*, developed in the 1990s, have strengths and deficiencies that should be independently appraised and addressed.

- Given the significance of the public health issues in reclaimed water management, it is important that the revision of the *National Guidelines on Water Recycling: Managing the Health and Environmental Risks*, based on Hazard Analysis and Critical Control Point (HACCP) principles, and building on the approach used in the 2003 revision of the *Australian Drinking Water Guidelines,* be finalised and agreed as soon as possible.

- The current *Australian Guidelines for Urban Stormwater Management* do not give adequate consideration to the harvesting and use of urban stormwater as an additional water resource. They should be revised to do so.

- In the light of increasing use of subsidies and the resulting increase in adoption of rainwater tanks as components of domestic water systems, the use of rainwater and rainwater tanks should be encompassed in the National Water Quality Management Strategy and the appropriate *Guidelines*.

6.4 Building the Urban Environment

- The processes that have to be undertaken and the approvals obtained for subdivisions with creative water supply and effluent treatment provisions can be very cumbersome, involving multiple interactions with a number of different agencies at state and local government level, and serve to inhibit innovation. Approval processes should be streamlined among agencies.

- 'Headwork charges' imposed by water agencies for provision of water supplies to new subdivisions should relate to the nature of the supply systems being adopted and to the proportionate use being made of the 'headworks' in the total water supply system rather than being applied as a flat charge.

- Encouragement needs to be given to the evaluation of 'in-house' wastewater treatment systems with concomitant recycling in high-rise office and apartment buildings, and for the establishment of a service industry to manage such installations.

- Incentives for new industries that require steady supplies of large volumes of water of less than drinking water quality should be developed in association with any proposals for new sewage treatment works to minimise supply costs and maximise savings of potable water.

- Infrastructure standards pertaining to water services, particularly plumbing and drainage regulations, should be examined to achieve standardised outcomes across Australia.

- Education of the plumbing profession, other agencies likely to be undertaking engineering works in the vicinity of water supply lines, and of the consuming public, is essential to the maintenance of successful recycled water use.

6.5 The Economics of Recycling

- The cost of externalities should to be built into drinking water, sewage treatment and recycled water prices as provided for under the CoAG water reform principles**.**

- Industry regulators should have an obligation to examine costs and prices as well as service standards, but should also review water prices from a perspective of total water cycle management.

- Regulators and water agencies, in defining pricing strategies for potable water and recycled water, must carefully consider any perverse incentives and how price differentials may affect water-user attitudes.

- Recycled water projects must not be initiated without establishing the market for the recycled water produced.

6.6 Issues for Water Agencies

- Water authorities need to maintain an assurance of water safety to consumers and industries, including strong emphasis on risk management, quality assurance and process control.

- In view of the energy and greenhouse costs associated with pumping and the provision of large piping infrastructure, particularly where recycling is intended, further consideration be given to the choice of STP options in new subdivisional projects between pipeline connection to an existing large but distant treatment works *vis à vis* the adoption of locally based small disaggregated treatment plants.

- Following the observed neglect of some wetland water remediation systems and the need to guarantee reliability of treated water quality, mechanisms must be established at the time of funding and construction of new projects to ensure sound management systems are set in place and maintained.

- The importance of effluent treatment facilities be recognised for their potential complementary role in biodiversity conservation.

6.7 For the Future

- Governments must resolve at whole-of-government level the conflicts of interest that may be extant at portfolio level in environmental management, resource provision, revenue generation and water pricing objectives.

- Any separation of responsibilities for the ultimate management of water and wastewater resources as has developed in USA, should be discouraged in Australia.

- Any residual liabilities to the water supply authorities within the Australian *Trade Practises Act* should be clarified, along with the necessity for any additional legislation that might be needed with the intent of protecting water utilities from lawsuits if they are in compliance with federal and state legislation.

- Encouragement should be given to further collaboration among research agencies working on aspects of integrated water cycle management, particularly effluent and stormwater recycling, and the more effective incorporation of rainwater into domestic supply systems

- Continuing research be supported into treatment processes that will lead to progressive improvement in costs and efficiency of advanced wastewater treatment based on the suggestions made to the Prime Minister’s Science, Engineering and Innovation Council (summarised in this report in Table 29).

- Investment in innovative community scale water recycling projects should be stimulated

6.8 Community Confidence

- The circumstances are right to encourage Australians to better manage their water resources. The adoption of opportunities to make better use of recycling should be encouraged.

- Ensuring public confidence and support is fundamental to future recycled water initiatives.

EFFLUENT REUSE DATA FOR AUSTRALIAN STATES AND TERRITORIES

(Sewage Treatment Plants with no recycling are excluded from the listing)

EFFLUENT REUSE DATA – SYDNEY, NSW – 2001-2

(Sources: Sydney Water, Sydney Olympic Park Authority,)

SYDNEY WATER GEOGRAPHIC AREA	LOCATION	Annual Flow (ML)	Treatment Type	% Re-Use	PURPOSE
Blue Mountains	Blackheath	410	S + MF	1	*
	Glenbrook	1500	$T^{add\ P}$ + D	1	*
	Mt Victoria	50	$T^{add\ N,P}$ + D	2	*
	Winmalee	6480	$T^{add\ N,P}$ + D	1	*
Georges River & Southern Beaches	Cronulla	22400	T + D	1	*
	Fairfield (Storm plant) Glenfield Liverpool (= Malabar)	188000	P S + D S + D HRP	2	* STP onsite reuse for the 3 STP's
Illawarra	Bellambi	9630	P, CAS + D	3	*
	Bombo	1720	S, Denit, D	5	*
	Gerringong-Gerroa	*300*	*T + MF + D*	*80*	Aorangi Farm (2003 figures)
	Port Kembla	6520	P, CAS + D	<0.5	*
	Shellharbour	8010	S + D	3	*
	Wollongong	*6490*	*S + D*	*14*	(estimate for 2004)
Lower Hawkesbury	Hornsby Heights	2100	$T^{add\ P}$ + D	22	*
	West Hornsby	6110	$T^{add\ P}$ + D	3	*
Middle Hawkesbury Nepean	Castle Hill	2950	$T^{add\ P}$ + D	11	Golf Course
	North Richmond	510	$T^{add\ P}$ + D	<0.5	*
	Penrith	8560	$T^{add\ P}$ + D	5	Recreational - Hickey's Reserve
	Picton	490	$T^{add\ P}$ + D	97	Carlton Farm
	Quakers Hill	12300	$T^{add\ N,P}$ + D	1	Golf Course
	Richmond	1250	T + D	63	Golf Course, University Irrigation
	Riverstone	710	$T^{add\ P}$ + D	26	*
	Rouse Hill	3070	$T^{add\ N,P}$ + MF + D	8	"Third pipe" non-potable domestic systems
	St Marys	14150	$T^{add\ N,P}$ + D	8	Dunheved Golf Course
	West Camden	3250	$T^{add\ P}$ + D	8	*
Sydney Harbour Northern Beaches	Bondi	53700	HRP	2	*
	Northern Suburbs(NHead)	134900	HRP	1	*
	Warriewood	7000	S + D	8	*
Upper Nepean	Warragamba	240	S + D	19	*
	West Camden	3250	$T^{add\ P}$ + D	8	*
SYDNEY OLYMPIC PARK AUTH.	**LOCATION**	**Annual Flow (ML)**	**Treatment Type**	**% Re-use**	**PURPOSE**
Homebush - Newington		800	CA,MF,RO	100	"3rd pipe", gardens, non-potable domestic,

* Note: All STP's have a component of reuse for onsite plant processes. Details of offsite reuse is indicated in purpose

Treatment Key:- **P** – Primary. **HRP** - High-rate primary. **S** - Secondary. **T** - Tertiary. **add N,P** – indicates an additional removal rate of Nitrogen and Phosphorous. **D –** Disinfection. **CAS –** Chemically assisted sedimentation. **MF** – Microfiltration.

EFFLUENT REUSE DATA – NEWCASTLE, NSW – 2002-3

(Source: Wendy Yeomans, Hunter Water)

HUNTER WATER	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	RECYCLING PURPOSE
Cessnock	Branxton	459	OD/EA	15	Woodlot, agriculture (pasture for non-dairy cattle)
	Cessnock	1570	TF	4	Golf course, agriculture (pasture for non-dairy cattle) [plus an additional 30-60% indirect agricultural reuse]
	Kurri Kurri	1340	EA	8	Golf Course, Horticulture [plus 2% recycled within the WWTW]
	Paxton	27.0	EA	26	Woodlot
Maitland	Farley	1610	EA	10	agriculture (pasture for non-dairy cattle) [plus an additional 30-60% indirect agricultural reuse]
	Morpeth	3720	EA	4	Golf Course, agriculture (pasture for non-dairy cattle) [plus 2% recycled within the WWTW]
	Shortland	2340	EA	1	STP
	Dora Creek	1080	EA	95	Industrial – Power generation
	Edgeworth	6150	EA	12	Golf course, industrial (coal washery)
Port Stephens	Raymond Terrace	2110	EA	2	STP
	Karuah	75.9	EA	99	Reuse enterprise – feed crops (eg lucerne) and future woodlots

Treatment Key:- AL=Aerated lagoon; AP=Aerated Pond; CA=Activated sludge; DAFF Dissolved Air Floatation & Filtration; EA=Extended aeration; IFAS=Integrated Fixedfilm Activated Sludge; MR= Microfiltration; OD=Oxidation ditch; OP=Oxidation pond; RO=Reverse Osmosis; TF=Trickling Filter

EFFLUENT REUSE DATA – COUNTRY NEW SOUTH WALES – 2000

(Source: Water Directorate (2000)

COUNCIL	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Albury	Waterview	2400	CA	100	Woodlots, Lucerne, Wetlands
Armidale-Dumaresq	Armidale	2200	TP	50	Pasture - flood irrigation
Ballina Shire	Ballina	1100	TF+PC	2	Irrigated Sports Field, Racecourse
	Lennox Head	700	BB	7	Golf Course
Bathurst City	Bathurst	3100	TF+BB	1	STP process water
Bega Valley Shire	Bega	400	TF+OD	97	Irrigated Dairy Pasture
	Bermagui	180	PC	17	Golf Course
	Eden	360	BB	22	Golf Course
	Merimbula	1700	TF+PT	7	Golf Course
	Tathra	180	PC	50	Golf Course
Berrigan Shire	Berrigan	130	TF	79	Showground
	Finley	300	TF	50	Golf Course
Bland Shire	Ungarie	40	PC	37	
	West Wyalong	380	TF+PC	79	Golf Course, Sports Fields, Parks
Blayney Shire	Blayney	230	PT	100	Mine process water
Bogan Shire	Nyngan	270	OP	50	Pastures – private irrigator
Bombala Shire	Bombala	180	TF	0	Timber mill process water, Pastures
Bourke Shire	Bourke	330	OP	97	Pasture irrigation
Brewarrina Shire	Brewarrina	150	TF	90	Irrigated Lucerne
Cabonne Shire	Canowindra	150	TF	78	Sports fields, Golf Course, Race Course
	Eugowra	50		90	Irrigated pasture
Central Darling Sh.	Wilcannia	90	OP	55	Golf Course
Cobar Shire	Cobar	150	AL	14	Golf Course, Landscaping
Coffs Harbour City	Coffs Hbr.	3800	TF+PT+AL	1	Sports fields, Golf, Race Course, Roads
	Moonee	180			*(connected to Woolgoolga)*
	Sawtell	1700	BB+PC+PT	1	Golf Course, Bowling Club
	Woolgoolga	590	TF+PT	1	Sports Field, Hydroponics
Coolah Shire	Coolah	90	OP	83	Golf Course
Coolamon Shire	Coolamon	110	TF	21	Golf Course, Sports fields
	Ganmain	50	OP	100	Irrigated pastures
Coonabarabran Sh.	Coonabarabran	290	TF	1	STP process water
Coonamble Shire	Coonamble	370	TF	14	Racecourse
Cootamundra Shire	Cootamundra	560	AP+AL	47	Golf, Sports fields, Ovals, Parks
Corowa Shire	Corowa	720	TF	83	Trees, flood irrigated pastures
Culcairn Shire	Henty	30	PC	100	Sportsgrounds, Parks
Deniliquin Shire	Deniliquin	770	TF	100	Private irrigators
Dubbo City	Bumblegumbie	1900	TF		Tree plantation (STP closing)
	Troy Junction	1900	CA	54	STP, pastures, animal fodder
Dugong Shire	Dugong	330	TF	55	Private irrigator
Eurobodalla Shire	Bateman's Bay	1360	OD	4	Golf Course
	Moruya	320	EA	25	Golf Course
Forbes Shire	Forbes	680	TF	15	Irrigation for hay mills
Gilgandra Shire	Gilgandra	260	TF	95	Tree plantation
Glen Innes Municipal	Glen Innes	600	TF	5	Golf Course
Goulburn City	Goulburn	2600	TF	84	Pastures, Tree plantation, Race Course
Grafton City	Grafton	450	TF+OP	33	Tea Tree plantation
Gundagai Shire	Gundagai	220	TF	23	Golf Course
Gunnedah Shire	Gunnedah	885	TYF	73	Cotton farm
Harden Shire	Harden	180	TF	100	Golf, Sports fields, Public gardens
Hastings	Dunbogan/Camden	720	TF	2	Dune stabilisation
	Kew Kendall	180	EA	97	State Forest, Golf Course
	Lighthouse Beach	180	PC	8	Golf Club
	Port Macquarie	3800	PT	0	School sports fields
	Wauchope	360	PT	16	Golf course, farm – beef cattle
Hawkesbury City	Hawkesbury	-	-	-	Beef pastures, STP, Fodder, Trees
Holbrook Shire	Holbrook	120	TF	4	Racecourse, Cemetery

EFFLUENT REUSE DATA – NEW SOUTH WALES – 2000 (continued)

COUNCIL	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Hume Shire	Burrumbuttock	9	OP	100	Tree plantation
Jerilderie Shire	Jerilderie	140	TF	74	Racecourse, green space
Junee Shire	Junee	430	TF+PC	56	Golf course, Sports fields, High School
Kempsey Shire	Fredrickton Kempsey South Kempsey West S-W Rocks	90 330 1100 540	PC TF+PC TF PC	56 20 2 13	Golf Course, pasture Golf Course Racecourse Golf Course
Kyogle Shire	Bonalbo Kyogle Woodenbong	40 270 30	PC TF PC	50 7 55	Golf Course Pasture Golf Course, School agricultural farm
Lachlan Shire	Condobolin	370	TF+PC	16	Golf Course, STP
Leeton Shire	Whitton	30	OP	100	STP
Lismore City	Lismore East Lismore South Nimbin	1400 1600 30	PT TF EA	Tr. 74 66	STP Tea Tree Plantation Pasture
Lockhart Shire	Lockhart	100	TF	100	Sports fields, Showground, Parks
McLean Shire	Yamba	400	TF+BB	15	Golf Course
Manilla Shire	Manilla	170	TF	100	Pasture, Lucerne
Mid Coast Water	Taree-Dawson R Taree Tea Gardens Wingham	1900 810 720 410	EA TF PC TF+BB	53 4 3 69	Dairy and Beef pastures Tree plantation (Flooded Gums) Golf Course via ASR Dairy and Beef pastures
Moree Plains Sh.	Moree Mungindi	 90	 PC	 100	Cotton Pastures
Mudgee Shire	Gulgong Mudgee	150 1000	PT TF	100 30	Pastures, Sports fields Fodder (downstream of discharge)
Murray Shire	Mathoura Moama	45 400	TF OP	 50	Pastures (uncommissioned) Pastures
Muswellbrook Sh.	Denman Muswellbrook	170 1300	BB+PC TF+PC	100 97	Golf Course, Sports fields Golf, Sports, Power Sta. dust suppression
Narrabri Shire	Narrabri	750	TF	100	Irrigated cotton
Orange City	Spr.Hill/Lucknow Orange	32 3900	EA TF/EA	100 100	Pastures, Council tree nursery Gold Mine – industrial use
Parkes Shire	Parkes	700	TF	4	Golf Course
Parry Shire	Kootingal	230	OP	0	Orchard (Turtles blocking pipes)
Pristine Waters	Corindi Beach Coutt's Crossing	30 30	EA BB		Pastures, Bananas Golf Course
Queanbeyan Coun.	Queanbeyan	2300	EA+TF	4	STP, Nursery
Scone Shire	Scone	580	TF+BB	87	Sports, Golf, Races, agriforestry
Shoalhaven City	Bombaderry Nowra	1100 2000	TF TF+OD	1 72	Tea Tree plantation Dairy pastures
Temora Shire	Temora	400	TF	100	Sports, Landscaping, Golf, STP, Cemetery
Tenterfield Shire	Tenterfield	300	TF	67	Golf Course
Tumut Shire	Batlow Tumut	190 500	TF TF	13 6	Golf Course Golf Course
Tweed Shire	Banora Point Kingscliff Tyalgum	2600 540 14	PC+EA TF+PT EA	4 19 100	Golf Course Tea Tree Plantation
Wagga Wagga City	Forest Hill Uranquinty Kooringal Narrung St	136 90 2000 4500	PC OP TF+CA TF+EA	29 100 15 2	CSIRO Forestry experiment Irrigated lucerne Golf, Sport,Cemetery,Truck wash, STP, trial STP, Racecourse, Cricket oval
Warren Shire	Warren	270	TF	8	Sports fields
Weddin Shire	Grenfell	190	TF	26	Sports fields, Parks
Wentworth Shire	Dareton	100	TF	100	Golf Course
Yass Shire	Yass	490	TF+PC	50	Fat lamb pastures, Golf Course
Young Shire	Young	700	TF	10	Golf Course

Treatment Key:- AL=Aerated lagoon; AP=Aerated Pond; BB=Bathurst Box; CA=Activated sludge; EA=Extended aeration; OD=Oxidation ditch; OP=Oxidation pond; PC=Pasveer Channel; PT=Port Macquarie Tank; TF=Trickling Filter

EFFLUENT REUSE DATA – VICTORIA – 2001-2

(Source: S Costello, EPA Victoria)

AUTHORITY	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Melbourne Water	WTP –Werribee	150000	CA/OP/Cl	4	STP. Tourism,
	ETP – Carrum	140000	OP, CA+BNR	1	STP
Barwon Water	Aireys Inlet	106	OP	100	Forestry
	Anglesea	288	CA	28	Golf Course
	Apollo Bay	380	CA	4	STP
	Black Rock	19900	CA+Cl	6	Agriculture, floriculture
	Lorne	359	CA	4	STP
	Portarlington	412	OP	100	Forestry
	Winchelsea	44	OP	100	Forestry
Coliban Water	Bendigo	7410	CA (BNR)	13	Grazing
	Heathcote	150	OP	100	Golf Course
	Keyneton	510	TF/OP	18	Grazing
	Rochester	260	OP	100	Grazing
	Echuca	2000	OP	100	Cropping
East Gippsland Water*	Bairnsdale	1340		91	Pasture
	Dinner Plain	30	OP	80	Forestry
	Lakes Entrance	690	TF/OP	97	Golf Course, Grazing
	Lindenow	16	OP	100	Environmental Water
	Mallacoota	112	OP	100	Golf Course, Grazing
	Metung	70	OP	100	Pasture
*Reuse percentages include discrepancies due to evaporation	Omeo	30	OP	100	Pasture
	Orbost	310	OP	71	Pasture, Forestry
	Paynesville	333	OP	100	Grazing, Golf Course
Gippsland Water	Drouin	430	HRTF	30	Beef pastures
	Heyfield	130	OP	100	Beef pastures
	Maffra (domestic)	470	OP	100	Beef pastures
	Mirboo North	99	OP	100	Golf Course, Beef pastures
	Stratford	140	OP	100	Beef pastures
	Willow Grove	15	OP	85	Dairy pasture
Glenelg Water	Casterton	120	Im/OP	100	Grazing, Forestry
	Coleraine	84	Im/OP	100	Grazing
	Hamilton	1020	TF/OP	61	Forestry, Grazing, Gold Course
Goulburn Valley Water	Alexandra	230	OP	19	Grazing
	Bonnie Doon	100	AL	6	Grazing
	Broadford	250	AL	66	Grazing
	Cobram	870	OP	68	Grazing
	Eildon	100	TF	26	Grazing
	Kyabram	620	TF	16	Dairy pastures
	Mansfield	420	OP	40	Grazing
	Marysville	60	OP	72	Forestry
	Mooroopna	1470	OP	37	Dairy pastures
	Nagambie	170	OP	51	Forestry, Pastures
	Nathalia	150	OP	90	Forestry, Grazing
	Numurkah	460	OP	30	Forestry, grazing, dairying
	Seymour	700	TF/OP	42	Grazing, Golf Course
	Shepparton	6800	OP/AT	42	Forestry, Grazing
	Tatura	1500	HROP/OP	40	Forestry, Cropping, Dairying
	Tongala	510	OP	82	Cropping, Dairying, Washdown
	Upper Delatite	51	OP	8	Grazing
	Wallan	280	OP	41	Grazing
	Yea	124	OP	50	Grazing
Grampians Water	Ararat	850	TF/OP	41	Viticulture
	Birchip	60	OP	100	Pasture
	Charlton	80	OP	100	Pasture, Forestry
	Dimboola	130	TF	100	Pasture, Forestry
	Donald	126	OP	100	Forestry

EFFLUENT REUSE DATA – VICTORIA – 2001-2 (continued)

AUTHORITY	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Grampians Water (Continued)	Edenhope	130	OP	100	Pasture
	Halls Gap	180	OP	100	Pasture, Golf Course
	Horsham	1300	CA	100	Pasture, Golf Course, cropping
	Murtoa	66	Im	100	Pasture
	Nhill	170	CA	100	Pasture
	Sea Lake	63	OP	100	Pasture
	St Arnaud	180	Im/TF	100	Pasture
	Stawell	440	TF	100	Pasture, Forestry, Grapes, Golf, Parks
	Warracknabeal	160	TF	100	Pasture
	Wycheproof	50	OP	100	Pasture
Lower Murray Water	Koorlong	1120	OP	100	Forestry
	Mildura	2270	CA	100	Forestry, Pasture
	Red Cliffs	220	TF	100	Golf Course
	Robinvale	190	OP	100	Pasture
North East Water	Barnawartha	12	OP	37	Plantation
	Beechworth	510	OP	29	Grazing
	Bellbridge	30	OP	66	Grazing
	Benalla	580	AL	38	Cropping
	Bright	300	OP	6	Golf Course
	Chiltern	110	OP	29	Grazing
	Corryong	204	OP	16	Grazing
	Rutherglen	372	AL	49	Recreational
	Tallangatta	161	TF	67	Grazing
	Wangaratta	2050	OP	26	Forestry, Cropping
	Wodonga	2000	BNR	9	Golf Course, Sports ovals
	Yackandandah	90	OP	20	Grazing
	Yarrawonga	500	TF	14	Cropping
South East Water	Blind Bight	91	OP	100	Nursery
	Cranbourne	200	OP	77	Nursery
	Hastings	1360	OP	5	
	Koo Wee Rup	120	OP	86	Forestry
	Lang Lang	80	OP	41	Nursery
	Longwarry	130	OP	67	Dairy pastures
	Mornington	4800	CA	Tr.	Forestry
	Pakenham	1450	OP	48	Turf grass, fodder
	Rosebud	3040	OP	Tr.	Nursery
South Gippsland Water	Wonthaggi	1150	OP	Tr.	Forestry
	Yarram	230	?	100	Pasture
South West Water	Camperdown	240	TF	100	Grazing
	Cobden	150	CA/OP	100	Grazing
	Mortlake	91	OP	100	Pasture
	Port Campbell	55	OP	100	Pasture
	Terang	260	TF	100	Grazing
	Timboon	44	OP	100	Pasture
Western Water	Gisborne	450	PC/OP	38	Recreational
	Melton	2950	CA/OP	100	Agricultural
	Parwan South	1030	OP	100	Agricultural
	Riddell's Creek	99	OP	59	Agricultural
	Romsey	220	TF/OP	100	Agricultural
	Sunbury	2850	CA (BNR)	4	Agricultural and recreational
	Woodend	210	OP	56	Recreational
Westernport Water	Coronet Bay	110	CA	100	Irrigated horticulture
	Cowes	1060	CA	3	Golf Course
Yarra Valley Water	Brushy Creek	3890	AS	2	STP, Golf Course
	Craigieburn	820	AS	18	STP, Golf Course
	Whittlesea	170	AS	20	Pasture

Treatment Key:- AL=Aerated lagoon; AS=Extended Aeration; (BNR)=Biological Nutrient Removal; CA=Activated sludge; EA=Extended aeration; HROP=High Rate Oxidation Lagoon; HRTF=High Rate Trickling Filter; Im=Imhoff; OP=Oxidation Lagoon; PC=Pasveer Channel; TF=Trickling Filter

EFFLUENT REUSE DATA – QUEENSLAND – 2001-2

(Covers the data from 81 STPs with some recycling among the 135 STPs operated by those Shires that agreed to have their figures published. There are 259 Municipally- operated STPs in Queensland. The 135 STPs represented about 70% of the total wastewater treated in Queensland in 2001-2. - Source: B Davis, Queensland EPA)

COUNCIL	LOCATION	Annual Flow (ML)	% Re-use	PURPOSE
Atherton	Atherton	600	20	Trees
Belyando	Clermont	300	62	Shire, Golf Club, Gun club
	Moranbah	660	55	Golf club, Schools, Hospital, Shire irrigation
Biggenden	Biggenden	53	70	Golf course
Boonah	Boonah	135	35	Golf course, Farm irrigation
	Kalbah	45	44	Farm Irrigation
Bowen	Bowen	1280	30	Parks, Sportsground, TAFE, Nursing Home, STP
	Collinsville	260	90	Golf Course
Brisbane (Brisbane Water)	Fairfield	1060	30	Golf course, Univ. of Qld, Football Ground., STP
	Gibson Island	15000	3	Golf course, STP
	Inala	2150	10	Golf club
	Karana Downs	200	70	Golf Club, STP
	Luggage Point	66000	6	Oil Refinery
	Oxley Creek	20000	1	Golf driving range, STP
	Wacol	1600	2	STP
Bulloo	Thargomindah	20	100	Golf Club
Bundaberg	East Bundaberg	2050	2	Canefields
	Thabeban	235	100	Canefields
Burdekin	Ayr/Brandon	875	90	Canefields
	Home Hill	230	90	Canefields
Burnett	Coral Cove	50	100	Golf Course
	Nielsen Park	430	7	Sports Ground
Caboolture	Bribie Island	1650	100	Groundwater recharge, Shire irrigation, Roadworks,
	Sth Caboolture	2900	2	Irrigation, Roadworks, Turfgrass
	Woodford	125	8	Irrigation, roadworks
Cairns	Marlin Coast	1975	9	Golf Clubs (2)
Calliope	Boyne Island	650	30	Golf course, Ovals
	Calliope	75	100	Golf course
	Yarwun	30	100	STP lawns
Charters Towers	Charters Towers	1030	30	School, College, Sports Ovals, Golf Club
Cooloola	Gympie	1200	16	Golf Club
	Tin Can Bay	230	50	Golf Club
Crow's Nest	Crow's Nest	65	90	Golf Club
	Highfields	20	100	Pasture irrigation
Duaringa	Blackwater	745	90	Golf Club, Local parks & gardens, STP trees
Eidsvold	Eidsvold	50	80	STP
Emerald	Black Gully	140	100	Farm irrigation
	Park Avenue	730	85	Farm irrigation – lucerne, nursery, cemetery, plant
Gatton	Gatton	500	100	Pasture (3), Olives & Stonefruit, Soccer Club
	Helidon	35	100	Farm irrigation – lucerne
Gladstone	Calliope River	2750	3*	Power Station (*100% following year)
Hervey Bay (Wide Bay Water)	Eli Creek	1800	62	Canefields, Turf, Golf Course
	Pulgul Creek	1200	30	Turf farm, Pastures & trees
	Torbanlea	40	100	Sports ovals
Inglewood	Inglewood	67	100	Farm – pastures & natural grassland
Jondaryan	Oakey	270	50	Farm irrigation
Kingaroy	Kingaroy	550	27	Golf Club, Farm pastures, tree lot
Livingstone	Emu Park	200	100	Golf Club, Shire roadside landscaping
	Yeppoon	850	30	Golf, Pony Club, Racecourse, Rugby Club, Tree lot
Logan	Logan WPCC	15600	1	Landscape, turf, STP

EFFLUENT REUSE DATA – QUEENSLAND – 2001-2 (continued)

COUNCIL	LOCATION	Annual Flow (ML)	% Re-use	PURPOSE
Mackay	Baker's Creek	500	100	Canefields, STP
Maroochy	Coolum	1780	13	Golf Courses (2)
	Eumundi	45	7	Roadworks – dust suppression
	Maroochydore	7200	5	Golf course, Canefields. Roadworks
	Nambour	2000	3	Football oval, roadworks
	Suncoast	900	17	Resort, Sports complex, Roadworks
Millmerran	Cecil Plains	20	75	Golf course
	Millmerran	180	30	Golf course
Mundubbera	Mundubbera	30	90	Golf course, Farm irrigation
Murgon	Murgon	270	100	Golf course, Farm irrigation
Murilla	Miles	100	25	Trees
Nanango	Nanango	220	70	Golf Club, Shire use, Farm irrigation
Nebo	Glenden	100	100	Sports fields, Golf Club
Noosa	Coastal	3200	2	Golf club
Redcliffe	Redcliffe	5100	10	Golf Club, STP
Redland	Capalaba	2900	7	Turf farm,
	Mt Cotton	200	11	Golf Club
	Victoria Point	1000	14	Golf Club
Roma	Roma	900	100	Irrigated lucerne, Golf Club
Rosalie	Yarraman	60	100	Paddock irrigation
Sarina	Sarina	340	40	Golf course, Canegrowing
Hinchinbrook	Ingham	1400	80	Indirect reuse – Sugar Mill, Canegrowing
	Lucinda	25	100	STP
Stanthorpe	Stanthorpe	350	25	Golf, Sports oval, Amenity, High School agric.
Thuringowa	Condon	1000	55	Golf course, STP
	Deeragun	220	9	Amenity – verges, STP
	Mt Low	120	75	Farm irrigation, STP
Toowoomba	Wetalla	970	14	Leather industry, Power station, STP
Warwick	Killarney	70	100	Irrigation
	Warwick	800	100	Stud farm irrigation
Winton	Winton	140	10	Parks and ovals

EFFLUENT REUSE DATA – SOUTH AUSTRALIA – 2001-2

(Source: SoE –SA (2003); *Lightbody and Endley 2002)

REGION	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Adelaide Metropolitan Area (SA Water)	Bolivar	45700	CA+DAFF	21	N. Adelaide Plains Vegetables, Grapes
	Christies Beach	10700	CA+IFAS	18	Grapes–Willunga Basin Pipeline Co
	Glenelg	20800	CA+IFAS	10	STP, Recreational, Local Government
Henry Walker Env.	Aldinga	200	OD	100	Grapes
SA Country Schemes (SA Water)	Angaston	100	AP	12	Grapes
	Bird-in-Hand	280	AP	0.5	Pasture and Woodlot
	Gumeracha	50	TF	100	Forestry – building & cabinet grade
	Hahndorf	380	OD	100	Hahndorf Ck.
	Mannum	90	OP	100	Golf Course
	Murray Bridge	970	TF	100	Irrigate Army firing range, wetland
	Myponga	40	OP	100	Irrigated fodder, cattle
	Port Augusta W	230	AL	78	Golf Course
	Victor Harbor	990	TF	8	Golf Course
Septic Tank Effluent Disposal Schemes (Local Government)	Milang	50	STEDS-OP	43	Lucerne
	Mount Barker	660	STEDS-OP	24	Irrigation
	Renmark	220	STEDS-STP	31	Irrigation
	Strathalbyn	100	STEDS-OP	69	Polo grounds, Racecourse
	105 other towns*	5500	STEDS-OP	50	Local amenities, agriculture
Plants with no reuse	*All other plants*	*20900*	*Various*	*0*	
TOTAL FOR SA	**All plants**	**108000**		**15**	

Treatment Key:- AL=Aerated lagoon; AP=Aerated Pond; CA=Activated sludge; DAFF Dissolved Air Floatation & Filtration; EA=Extended aeration; IFAS=Integrated Fixedfilm Activated Sludge; OD=Oxidation ditch; OP=Oxidation pond; STEDS=Septic Tank Effluent Disposal Scheme; TF=Trickling Filter

EFFLUENT REUSE DATA – WESTERN AUSTRALIA – 2001-2

(Sewage Treatment Plants run by mining companies and several small local government plants from which data were unobtainable are excluded)

(Source: WA Water Corporation, some local Shire Councils)

REGION	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Perth Metro	Kwinana	1050	AS	100	Industrial
Agricultural Areas and Goldfields	Esperance	530	AP	49	Golf Course, Town Ovals
	Corrigin	30	OP	90	Town Ovals
	Dumbleyung	13	OP	100	Playingfields
	Kellerberrin	40	OP	90	Town Ovals
	Merredin	150	OP	90	School, Town Ovals
	Mukinbudin	20	OP	90	Town Ovals
	Narembeen	40	OP	90	Town Ovals
	Northam	430	OP+Al	45	Town Ovals, High School, Trotting track (started 1967)
	Wongan Hills	70	OP	90	Town Ovals
	Wyalkatchem	45	OP	90	Town Ovals
Great Southern	Albany 2	2010	AP	91	Woodlot, Grazing
	Boddington	20	OP+Al	90	Grazing
	Katanning	280	AP+Al	36	Town amenities
	Kojonup	60	OP+Al	72	Sports Grounds
	Lake Grace	13	STED+OP	75	Sporting ovals
	Mt Barker	60	OP	90	Cattle yards
	Narrogin	370	AP	42	Town Ovals, School
	Pingelly	30	OP	86	Town Ovals
	Wagin	70	OP	36	Town Ovals
Mid-West	Carnarvon	200	OP	90	Town amenities, Oval, Mine Site
	Exmouth	220	OP	68	Town Ovals
	Geraldton 2	990	AP	29	Golf Course, Hospital Grounds
	Kalbarri	220	AP	85	Golf Course
	Three Springs	40	OP	34	Town Ovals
North West	Broome	950	OP	68	Golf Course, Haynes Oval, Stream flow
	Derby	310	OP	90	Golf Course
	Karratha 1	610	OP	85	Town Ovals
	Karratha 2	290	OP	85	Town Ovals
	Port Hedland	480	OP	79	Revegetation, Mine site, School, Town Ovals
	South Hedland	1230	OP	79	School, Town Ovals, Golf Course
	Wickham	300	OP	37	Town Oval
	Wyndham	120	OP	48	Town Oval
South West	Bridgetown	50	CA	100	Golf Course, Tree Lot
	Dardanup	30	OP	69	Woodlot
	Donnybrook	20	OP	74	Woodlot
	Dunsborough	430	CA	100	Woodlot
	Halls Head	720	CA	5	Mandurah town amenities
	Harvey	240	AP	70	Woodlot
	Manjimup	280	AP+Al	100	Golf Course
	Margaret River	240	CA	100	Tree Farm, Grazing, Gold Course
	Pinjarra	250	OP+Al	95	Industrial
	Waroona	60	OP+Al	94	Mine site

Treatment Key:- +Al= plus Alum dosing; AP=Aerated Pond; CA=Activated sludge; OP=Oxidation pond
(Other options not used include AL=Aerated lagoon; DAFF Dissolved Air Floatation & Filtration; EA=Extended aeration; IFAS=Integrated Fixedfilm Activated Sludge; OD=Oxidation ditch; TF=Trickling Filter, add others if necessary

EFFLUENT REUSE DATA – TASMANIA – 2001-2

(Source: David Dettrick, DPIWE, Tasmania)

MUNICIPALITY	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Break O'Day	Scamander	90	Secondary	100	Golf course
	St Marys	70	Secondary	80	Agricultural
	Stieglitz	40	Secondary	100	Aerodrome
Brighton	Bridgewater	1100	Secondary	100	Agricultural
	Brighton	70	Secondary	100	Agricultural
Central Highlands	Bothwell	60	Secondary	100	Agricultural
Clarence	Rosny	2800	Secondary	50	Agricultural
Dorset	Bridport	180	Secondary	80	Golf course
Glamorgan/Spring Bay	Bicheno	160	Secondary	100	Golf course
	Orford	170	Secondary	80	Agricultural
	Swansea	70	Secondary	100	Agricultural
	Triabunna	80	Secondary	100	Agricultural
Hobart	Selfs Point	4750	Tertiary	10	STP, Sports fields, Cenotaph
Latrobe	Latrobe	340	Secondary	30	Agricultural
Launceston	Lilydale	50	Secondary	100	Agricultural
Meander Valley	Carrick	180	Secondary	100	Agricultural
Northern Midlands	Campbell Town	120	Secondary	100	Agricultural
	Cressy	90	Secondary	100	Agricultural
	Evandale	140	Secondary	100	Agricultural
	Perth	160	Secondary	100	Agricultural
Sorell	Midway Point	300	Secondary	10	Agricultural
	Sorell	300	Secondary	100	Agricultural
	Lewisham	30	Secondary	100	Golf course
Southern Midlands	Bagdad	30	Secondary	100	Agricultural
	Campania	50	Secondary	100	Agricultural
	Kempton	50	Secondary	100	Agricultural
West Tamar	Beauty Point (Ilfraville)	200	Secondary	100	Agricultural – Dairy
	Exeter	40	Secondary	100	Agricultural
	Legana Industrial	200	Secondary	100	Agricultural – Dairy
	Riverside	1020	Secondary	10	Golf course

EFFLUENT REUSE DATA – AUSTRALIAN CAPITAL TERRITORY – 2001-2

(Source: ACTEW)

REGION	LOCATION	Annual Flow (ML)	Treatment Type	Re-Use %	PURPOSE
Canberra	Fyshwick		OP		Duntroon playing fields, Canberra parks
	Lower Molonglo	30000*	CA	6	Vineyards, Golf Course

* includes surplus effluent conveyed from Fyshwick

Treatment Key:- AL=Aerated lagoon; AP=Aerated Pond; CA=Activated sludge; DAFF Dissolved Air Floatation & Filtration; EA=Extended aeration; IFAS=Integrated Fixedfilm Activated Sludge; OD=Oxidation ditch; OP=Oxidation pond; STEDS=Septic Tank Effluent Disposal Scheme; TF=Trickling Filter

EFFLUENT REUSE DATA – NORTHERN TERRITORY – 2001-2

(Source: P. Heaton, NT PowerWater)

REGION	LOCATION	Annual Flow (ML)	Treatment Type	% Re-use	PURPOSE
Darwin	Darwin Golf Club	5300	OP,DAF,MF	4	Golf Course
	Marrara	5300	OP.	5	Sports Ovals (various clubs)
	Humpty Doo	11	OP	100	Natural vegetation
Katherine	Pine Creek	95	OP	9	Sports Oval, Rail corridor
	Katherine	200	OP	22	Cattle feedlot,
Alice Springs	Alice Springs	2800	OP	20	Sports ovals, Showground
	Yalara	300	CA	100	Tree farm
	Kings Canyon	65	OP	100	Tree farm

Treatment Key:- CA=Activated sludge; DAF Dissolved Air Floatation & Filtration; OP=Oxidation pond

APPENDIX 2

PRINCIPAL LEGISLATION IMPACTING ON THE PRODUCTION AND USE OF RECYCLED WATER

FEDERAL LEGISLATION

Corporations Act 2002
Environment Protection and Biodiversity Conservation Act 1999
Trade Practices Act 1974

STATE LEGISLATION

New South Wales

Hunter Water Board (Corporatisation) Act 1991
Independent Pricing and Regulatory Tribunal Act 1996
Local Government Act 1993
Protection of the Environment Administration Act 1991
State Owned Corporations Act 1989
Sydney Catchment Authority Act 1998
Sydney Water Act 1994
Water Management Act 2000
Water Supply Authorities Act 1987

Victoria

Environment Protection Act 1970,
Essential Services Commission Act 2001
Health Act 1958
Local Government Act 1989
Melbourne and Metropolitan Board of Works Act 1958
Melbourne Water Corporation Act 1992
State Owned Enterprises Act 1992
Water Act 1989
Water Industry Act 1994

Queensland

City of Brisbane Act
Environmental Protection Act 1994
Environment Protection Regulation 1998
Food Production (Safety) Act 2000
Health Act 1937
Health Regulation 1996
Integrated Planning Act 1997

Local Government Act 1993
SEQWB (Reform Facilitation) Act 1999
Sewage and Water Supply Act 1949
Standard Sewerage Law
Standard Water Supply Law
Water Act 2000

South Australia

Food Act 1985
Environment Protection Act 1993
Development Act 1993
Local Government Act 1999
Public and Environmental Health Act 1987
Public Corporations Act 1993
Sewerage Act 1929
South Australian Water Corporation Act 1994
Water Conservation Act 1936
Water Resources Act 1997
Waterworks Act 1932

Western Australia

Environmental Protection Act 1986
Financial Administration and Audit Act 1985
WA Health Act 1956
Water Agencies (Powers) Act 1984
Water Corporation Act 1995
Waters & Rivers Commission Act 1995

Tasmania

Environmental Management and Pollution Control Act 1994
Land Use Planning and Approvals Act 1993
Local Governments Amendment Act 1999
Public Health Act 1997
Resource Management and Planning Appeals Act 1993
Sewers and Drains Act 1954

Northern Territory

Government Owned Corporations Act 2001
Power and Water Authority Act 1987
Territory Health Services
Water Supply and Sewerage Services Act
Water Act

Australian Capital Territory

Environmental Protection Act 1997
Territory Owned Corporations Act 1990
Utilities Act 2000

APPENDIX 3

SUMMARIES OF REGULATORY FRAMEWORKS AND GUIDELINES IN INDIVIDUAL JURISDICTIONS

(Source – NRMSC 6 – Item 4.8, Annex A - revised)

State or Territory *Queensland*

Organisation compiling information with person contact details

EPA Greg Jackson
Greg.Jackson@EPA.qld.gov.au
Tel. 07 3225 1301
Fax 07 3227 8341

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Reclaimed water[2] 'centralised' [3] treatment'	STPs with >21 EP require licence. Reuse not regulated directly but most licences specify need for Third Party Agreement between supplier and user.	New draft *Queensland Guidelines for the Safe Use of Recycled Water* published March 2004. In the interim reference has been made to South Australian and National Reclaimed Water Guidelines .	For the new Qld guidelines, water quality parameters largely reflect current National & South Australian Guidelines, except new Class introduced (A+) that requires treatment process to achieve 5 log removal of viruses and protozoans.	New Qld guidelines advocate use of HACCP style risk management as part of Recycled Water Safety Plans, but also covers the standard management controls for recycled water.	Suitability for use depends on fitness for purpose and management controls used. All uses possible except direct potable, swimming. Use for firefighting is currently not supported pending development of National water recycling guidelines
Reclaimed water household (on-site) level[3] treatment	Only permitted in non-sewered areas. Regulated by *Water Act 2000*, *On-site Sewerage Code* and *Plumbing & Drainage Act 2002*. Dept Local Govt & Planning (DLGP) approves onsite treatment systems. Local Govt approves installation.	DLGP has *Onsite Sewerage Facilities: Guidelines for Effluent Quality* as well as *On-site Sewerage Code*. Reference also made to AS/NZS 1546 & AS/NZS 1547.	Secondary treated effluent (BOD=20, TSS=30) may be discharged to land by sub-surface irrigation without disinfection. For surface or spray irrigation, disinfection is required leading to <200 TCs per 100ml.	Only approved systems to be used. Site evaluation required. Performance standards and design criteria as per AS/NZS 1547:2000. Owner must have maintenance contract.	These provisions only apply to new systems, those undergoing upgrading or expansion or where public health or environmental protection has been compromised. Suitable for garden irrigation only

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Grey water[2] 'centralised' treatment level	As per Reclaimed water 'centralised treatment' above	As per Reclaimed water 'centralised treatment' above	As per Reclaimed water 'centralised treatment' above	As per Reclaimed water 'centralised treatment' above	Greywater is considered sewage so all regulatory requirements for sewage treatment apply
Grey water household level	As per Reclaimed water household (above)	As per Reclaimed water household (above). DNRM also has *Guidelines for the Use and Disposal of Greywater in Unsewered Areas*	As per Reclaimed water household (above)	As per Reclaimed water household (above)	As per Reclaimed water household (above)
Stormwater[4] 'centralised' level	No regulation of reuse.	Stormwater is covered in new draft *Queensland Guidelines for the Safe Use of Recycled Water. Queensland Urban Drainage Manual* provides advice on drainage issues.	Same as for reclaimed water, centralised treatment (above).	Same as for reclaimed water, centralised treatment (above).	Suitable for most purposes, subject to treatment depending on quality
Stormwater Household level	No regulation of reuse.	Stormwater is covered in new draft *Queensland Guidelines for the Safe Use of Recycled Water.*	Same as for reclaimed water, centralised treatment (above).	Not specifically addressed	Suitable for most purposes, subject to treatment depending on quality

Notes
1. The uses are intended to cover both uses that are explicitly permitted under guidance and uses that are not covered or prohibited.
2. Reclaimed water refers to reclamation of sewage ie including black-water and grey water, while grey water refers to treatment that specifically excludes blackwater.
3. Centralised versus household categories are included to capture the different control frameworks that apply in some jurisdictions based on small-scale / household (on-site systems) treatment versus large scale centralised treatment facilities;
4. Stormwater does not include 'rain-water' and rain-water tanks from direct collection from roof areas;

State or Territory	*New South Wales*
Organisation compiling information with person contact details	Natural Resources Policy Branch Department of Infrastructure, Planning and Natural Resources Paul Elton 02 9228 692 **pelton@dlwc.nsw.gov.au**

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Reclaimed water[2] 'centralised'[3] treatment'	**Sewage management systems with capacity of over 2500 equivalent persons (EP) or 750 kilolitres per day are regulated by the EPA through environment protection licences.** **Local Councils are responsible for regulating all systems not licensed by the EPA (ie systems under 2500 EP). Local council regulation is through an approval to install and operate for each individual site.**	The *NSW Guidelines for Urban and Residential Use of Reclaimed Water* (NSW Recycled Water Coordination Committee, 1993) These guidelines are predominantly applicable to the development of large dual reticulation schemes, which are centrally managed	Discharge into distribution systems: Faecal coliforms <100/100mL Coliforms <10/100mL (in 95% of samples) Virus < 2/50L Parasites < 1/50L Also limits for turbidity (<2 NTU g. mean and < 5 NTU 95%ile), pH (6.5 to 8.0 allowable, 7.0 to 7.5 desirable). Point of use: Coliforms <2.5/100mL geometric mean (5 samples), and <25/100mL (95% samples). Chlorine residual (<0.5 mg/L)	Provides general information on treatment trains, monitoring, commissioning, and operation. Also provides general guidance on pipework controls, cross connection and backflow prevention, and community information. Refers to EPA's irrigation guidelines for information on nutrient/salt management.	'Suitable' Residential garden irrigation, toilet flushing, car washing and other outdoor such as washing paths, firefighting, passive recreation waterbodies, ornamental water bodies. NOT suitable: Drinking, cooking, bathing, clothes washing, swimming, irrigation of crops for human consumption consumed raw.

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
		The draft *Environmental Guidelines for Industry: The Utilisation of Treated Effluent by Irrigation* (NSW EPA 1995). The guidelines are under review	Anticipate that revised guidelines will source microbial guidance from national reclaimed guidelines. In-soil contaminant limits similar to NSW Biosolids Guidelines limits.	Provide guidance on salinity / nutrient management, site selection and design of irrigation systems, planning and licensing matters.	Applicable to large scale irrigation reuse of municipal, agricultural and industrial effluents
		The *National Water Quality Management Strategy-Guidelines for Sewerage Systems-Use of Reclaimed Water* (2000). Are endorsed by NSW Health, but not for residential reuse schemes.	(not reviewed)	-	-

New South Wales Summary continued …

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Reclaimed water household(on-site) level[3] treatment	Local Councils are responsible for regulating all systems not licensed by the EPA (ie systems under 2500 EP). Local council regulation is through an approval to install and operate for each individual site.	Environment and Health Protection Guidelines – On-site Sewage Management for Single Households (NSW Department of Local Government). Currently under review, also supplemented by a number of technical sheets.	Specifies broad performance objectives, ie protection of surface waters. Does not contain specific guidance on limits, etc for effluent management, see NSW Health Guidance below.	Contains broad advice on management controls. Aimed mainly at local government as regulators of systems. Provides information on regulation, planning considerations, site and system selection, as well as system design, operation and management.	Does not contain specific guidance on effluent uses, see NSW Health Guidance below.
		NSW Health – Advisory note 4 – Effluent Treatment Standard Required for Particular Land Application Systems[5].	Total coliforms < 30/100mL specified for subsurface or low level surface irrigation. Total Coliforms of < 10/100mL for indoor uses toilet flushing and clothes washing Requires discharge at depth > 300 mm for undisinfected effluent. Requires secondary treated effluent disinfected to relevant level for other uses.		
Grey water[2] 'centralised' treatment level	See "Reclaimed Water – Centralised treatment"	-	-	-	-

continued …

New South Wales summary continued

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Grey water household level	See Reclaimed water household (on-site) level treatment	Greywater reuse in sewered single domestic premises (NSW Health, 2000)[6]	Total coliforms < 30/100mL specified for subsurface or low level surface irrigation. Total Coliforms of < 10/100mL for indoor uses toilet flushing and clothes washing Requires discharge at depth > 300 mm for undisinfected effluent. Requires secondary treated effluent disinfected to relevant level for other uses.	Contains broad advice on management controls. Aimed mainly at system users. Provides information on greywater sources and quality legislation and the roles of agencies, site and system selection and design.	Allows irrigation, toilet flushing and laundry use depending on level of treatment and disinfection.
Stormwater[4] 'centralised' level	Local councils have responsibility for regulation of stormwater for all non-scheduled development work and activities. The EPA regulates scheduled activities under environment protection licences.	Managing Urban Stormwater: Soils and Construction, **(NSW Department of Housing, 1998), currently under review.**	Do not contain guidance on specific stormwater uses. Depending on scale of use would refer to relevant reclaimed water guidance for health criteria.	Management controls are predominantly aimed at ensuring discharge of stormwater from construction and industrial sites does not harm the receiving environment.	Do not contain guidance on specific stormwater uses. Presently developed on a case by case basis with reference to relevant reclaimed water guidance.
Stormwater Household level	See "Stormwater 'centralised' level"	-	-	-	-

State or Territory	*South Australia*
Organisation compiling information with person contact details	Environmental Health Service Department of Human Services Dr David Cunliffe 08 8226 7153 david.cunliffe@dhs.sa.gov.au

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Reclaimed water[2] 'centralised'[3] treatment'	All reclaimed water schemes require approval by DHS under the Public and Environmental Health Act. In addition all schemes from sewage treatment plants with a capacity exceeding 100 persons in a catchment area or 1000 persons in a non-catchment require licenses under the Environment Protection Act. DHS approval deals with protection of human health. EPA license deals with protection of the environment.	*South Australian Reclaimed Water Guidelines*	The reclaimed water guidelines provide guidance on use for a range of applications including: • agricultural irrigation • municipal use (parks, public gardens, sports grounds, dust suppression etc) • residential (non-potable) use • environmental use (wetlands) • industrial use • firefighting. ***Guidance is also provided on storage options including ASR.*** Four categories of water quality requirements are set ranging from Class A to Class D. Class A represents the highest quality and in addition	Management is achieved through a balance of treatment and on-site controls. The latter include end use restrictions, irrigation method controls and plumbing controls. All systems require signage and marking of key plumbing installations. Monitoring results have to be provided to DHS/EPA as specified in license and approval conditions. Schemes subject to an EPA license must furnish an annual report to the EPA. Irrigation management plans are required for all schemes. Non compliance with set	Almost all uses of reclaimed water will be considered. The exceptions are potable use and human consumption aquaculture (after consultation with primary industries department). No specific guidance is provided for hydroponic use but this is permitted on a case by case basis.

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
			to traditional microbial indicators requires consideration of viruses, protozoa and helminths with requirements based on the end-use. For unrestricted irrigation of food crops treatment is required to achieve <1 virus and protozoa per 50L and <1 helminth per L. Chemical requirements are derived from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality	conditions has to be reported immediately.	
Reclaimed water household(on-site) level[3] treatment	On site systems require approval under the Public and Environmental Health Act. Standard systems can be approved by Local Councils all others by DHS.	*Standard for the Construction, Installation and Operation of Septic Tank Systems in South Australia* including Supplement A *Aerobic Sand Filters* and Supplement B *Aerobic Wastewater Treatment Systems*	On site use is restricted to spray/drip/subsurface irrigation of landscape areas, trees and shrubs. Food crops cannot be irrigated except for drip/subsurface irrigation of fruit and nut trees. Treatment is intended to achieve <10 E.coli, < 20mg/L BOD, < 30 mg/L SS.	Schemes can be audited and orders issued for remedial action if required under the Public and Environmental Health Act. Off-site impacts can also be dealt with under the Environment Protection (Water Quality) Policy. Approval can require proof of maintenance contract. Centralised management being considered.	
Grey water[2] 'centralised' treatment level	Require approval from DHS under the Public and Environmental Health	*Greywater/sullage systems* DHS information guide For larger systems	Water quality requirements will generally be consistent with those specified in the *South Australian Reclaimed*	Management controls would be consistent with those applied to reclaimed water for human health	Greywater reuse supported, however, proponents often underestimate potential health, environmental and

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
	Act.	requirements will generally be consistent with those specified in the *South Australian Reclaimed Water Guidelines*	*Water Guidelines.*	protection. Large schemes may also require an EPA license.	aesthetic (odour) impacts.
Grey water household level	Permanent systems require approval from DHS under the Public and Environmental Health Act.	*Greywater/sullage systems* DHS information guide	Requirements generally consistent with those required for on-site reuse of domestic sewage.	Management as per on-site reuse of domestic sewage.	Household reuse supported but as above potential impacts underestimated.
Stormwater[4] 'centralised' level	Permit required from Department of Land Water and Biodiversity Conservation. License required under the Environment Protection Act if aquifer storage is involved.	Code of practice in development for Aquifer Storage and Recovery systems	Water quality requirements are derived from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.	Irrigation management plans and annual reports required by EPA if ASR incorporated.	Current approach to stormwater use (excluding ASR) is focussed on water volume issues
Stormwater Household level	Would largely be treated as rainwater collection and use	No specific guidance		Public and Environmental Health Act and Environment Protection (Water Quality) Policy can be used to require remedial action to be taken in the event of unsatisfactory performance and off-site impacts.	

State or Territory	*Victoria*
Organisation compiling information with person contact details	Hamish Reid EPA Victoria Hamish.reid@epa.vic.gov.au Tel: 03 9695 2530

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Reclaimed water (treated sewage) 'centralised' treatment'	Sewage treatment plants > 5,000L/d typically require works approval and licence. Recycling schemes involving environmental discharge require Environment Improvement Plan to demonstrate compliance with relevant guidance	*Guideline for Environmental Management (2002): Use of Reclaimed Water* describes acceptable uses and water grades. Guideline for Wastewater Irrigation (1991) describes irrigation management for protection of soils and water bodies.	Urban use would typically necessitate 'Class A' water (Tertiary treatment and pathogen reduction) based on indicative criteria of <10 *E.coli*/ 100ml, ≤ 2 NTU, < 10 / 5 mg/l BOD / SS, > 1 mg/l chlorine residual, however, indicators customised after verification to achieve < 1 helminth/l, < 1 virus/50l, and < 1 protozoa/50l. Contaminant limits based on Australian and New Zealand Guidelines for Fresh and Marine Water Quality and outcome of land capability assessment. Nutrient reduction case-by-case eg depending on surface water risks.	Controls are included on: Achieving water quality specs; Plumbing controls eg AS 3500; Cross connection inspections; Community education; Signage measures; Irrigation management plan for large scale water users; Overall recycling scheme managed under an Environmental improvement plan.	Guidance accepts: Toilet flushing; Garden watering and open space irrigation; Fire protection systems; Guideline doesn't provide guidance on: Laundry systems; Fire fighting; Indirect or direct potable eg hot water systems; Swimming pools and related recreational uses. Guideline doesn't specifically prohibit any uses, however, the absence of guidance makes various uses unlikely to receive approval.

Victoria summary continued

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
Reclaimed water household(on-site) level[3] treatment	Treatment and recycling of recycled water from sewage treatment systems <5,000L/d (septic tanks) is administered by local councils. Permit process requires environmental discharge, hence 100% in-house recycling is not captured	EPA Certificate of Approval CA35 and Australian Standard AS1547, *Septic Tanks Code of Practice*, EPA publication 891, 2003	Council permits are based on EPA approved treatment plant designs.	Plumbing regulations impose management controls on in-house plumbing. Local councils need to assess irrigation proposals against EPA Certificate of Approval CA35 and Australian Standard AS1547, which describe treatment standards and management practices for above and below ground irrigation.	Focus is on sub-surface or drip irrigation. Guidance does not include in-house use such as toilet flushing or clothes washing.
Grey water[2] 'centralised' treatment level	General framework applied for centralised sewage treatment is used				
Grey water household level	General framework applied for household greywater treatment is used, however, targeted guidance and controls are being developed. Direct use of greywater on gardens without treatment does not require permits.				
Stormwater[4] 'centralised' level	Approvals relate to collection and	Best Practice Environmental	Available guidance is focused on Water Sensitive Urban	Available guidance is focused on Water	N/A

Water source	Regulatory or permit framework	Relevant guidance documents	Water quality focus and specifications	Key management controls	Position on key uses[1]
	extraction of the resource rather than environmental or public health management with recycling	Management Guidelines: Urban Stormwater (CSIRO, 1999) and a range of specific guidance eg for construction sites.	Design rather than environmental and health protection from recycling.	Sensitive Urban Design rather than environmental and health protection from recycling.	
Stormwater Household level	As above for centralised stormwater level.				

Table notes

1. The uses are intended to cover both uses that are explicitly permitted under guidance and uses that are not covered or prohibited.
2. Reclaimed water refers to reclamation of sewage ie including black-water and grey water, while grey water refers to treatment that specifically excludes blackwater.
3. Centralised versus household categories are included to capture the different control frameworks that apply in some jurisdictions based on small-scale / household (on-site systems) treatment versus large scale centralised treatment facilities;
4. Stormwater does not include ‘rain-water’ and rain-water tanks from direct collection from roof areas;

ABBREVIATIONS

ACT	Australian Capital Territory
AHMC	Australian Health Ministers Council
ANZECC	Australian and New Zealand Environment and Conservation Council (now replaced by NRMMC)
ARMCANZ	Agriculture and Natural Resources Council of Australia and New Zealand (now replaced by PIMC and NRMMC)
ASR	Aquifer Storage and Recovery
BAC	Biological Activated Carbon
BCC	Brisbane City Council
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CRCWMPC	Cooperative Research Centre for Waste Management and Pollution Control
DAFF	Dissolved Air Floatation/Filtration
DHCS	Department of Health and Community Services (Northern Territory)
DHS-SA	Department of Human Services, South Australia
EC	electro-conductivity unit
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EnHealth	Environmental Health Committee of AHMC.
EP	Equivalent person
EPA NSW	Environment Protection Authority of New South Wales
EPA SA	Environment Protection Authority, South Australia (formerly Agency)
EPA Victoria	Environment Protection Authority Victoria
EPA WA	Environment Protection Authority of Western Australia EPA WA
EPHSC	Environment Protection and Heritage Standing Committee
ET	Equivalent Tenement (= single dwelling equivalent)
FILTER	Filtration and Irrigated Cropping for Land Treatment and Effluent Release.
G	giga (10^9)
GAC	Granulated Activated Carbon
GCCC	Gold Coast City Council
Ha	hectare
HACCP	Hazard Analysis and Critical Control Point
ICM	Integrated Catchment Management
IDAL	Intermittently decanted extended aeration lagoons
IUWM	Integrated Urban Water Management
kWhr	kilowatt hour (10^3 watt hours)
L	Litre
LPS	Low Pressure Wastewater System
m	million
m^3	cubic metre
m^3/s	cubic metre per second
MBBR	Moving Bed Biofilm Reactor
MEUS	Ministry of Energy, Utilities and Sustainability (NSW)
MF	microfiltration
mg	milligram
MGD	million gallons per day
ML	megalitre (10^6 litres)
mL	millilitre
MPC	Maximum Permissible Concentration
MPMSAA	Master Plumbers and Mechanical Services Association of Australia
MPN	Most Probable Number
MW	megawatt
NDMA	N-nitrosodimethylamine (a possible carcinogen)
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NHT	Natural Heritage Trust
NRMMC	Natural Resources Management Ministerial Council
NRMSC	Natural Resources Management Standing Committee
NSW	New South Wales
NT	Northern Territory

NTU	Nephelometric Turbidity Unit
O&M	operations and maintenance
PIMC	Primary Industries Ministerial Council
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
Q	Queensland
QDNR&M	Department of Natural Resources and Mines (Queensland Government)
QDPI	Department of Primary Industries (Queensland Government)
QDSD	Queensland Department of State Development
QDSD	Queensland Department of State Development
QEPA	Environmental Protection Agency (Queensland Government)
QUT	Queensland University of Technology (Queensland Government)
REMS	Reclaimed Water Management Scheme (Shoalhaven Water)
RO	reverse osmosis
RWTP	Recycled Water Treatment Plant
SA	South Australia
SAR	sodium adsorption ratio
SEQ	South East Queensland
SOPA	Sydney Olympic Park Authority
SS	suspended solids
STEDS	Septic Tank Effluent Disposal Scheme (South Australia)
STP	Sewage Treatment Plant
SWOT	Strengths, Weaknesses, Opportunities, and Threats Analysis
T	Tasmania
TN	total nitrogen
TP	total phosphorus
Tr	trace
UV	Ultraviolet
UWS	University of Western Sydney
V	Victoria
VS	Vacuum Wastewater system
W	watt
WA	Western Australia
WC	water closet (UK) – toilet
WFP	Water Filtration Plant
WPP	Water Purification Plant
YVW	Yarra Valley Water

ACKNOWLEDGMENTS

Grateful acknowledgement is made to the following, who have provided helpful advice and perspectives to the Review:

Eva Abal, Scientific Coordinator, Healthy Waterways, Brisbane, Q
Phil Aldridge, Manager, Caloundra-Maroochy Water Supply Board, Palmwoods, Q
John Anderson, Technical Director, NSW Dept of Commerce, Sydney, NSW
Neil Andrew, Speaker, House of Representatives, Canberra, ACT
Lorna Andrews, Snr. Business Planner, Strategic Directions, Sydney Water, Sydney, NSW
Michael Arbon, Water Recycling, Melbourne Water, East Melbourne, V
Nicholas Ashbolt, Assoc. Professor, Centre for Water and Waste Technology, UNSW, Sydney
Tad Bagdon, Manager, Sustainable Water Systems and Technology, Queensland EPA, Brisbane
Aspi Baria, Engineer, ACTEW Corporation, Canberra, ACT
Snow Barlow, Dean, Agriculture and Food Systems, University of Melbourne, Parkville, V
Keith Barr, Principal Process Operations Engineer, Brisbane Water, Rocklea, Q
Nigel Barrett, Sydney Water, Sydney, NSW
Julie Baud, Treatment Plant Development & Recycling Team, Yarra Valley Water, V
Brian Bayley, CEO, Melbourne Water, East Melbourne, V
Roger Beale, Secretary, Environment Australia, Canberra, ACT
Toby Bekkers, Manager, Paxton Vineyard, McLaren Vale, SA
William Benke, Planning Engineer, ACTEW Corporation, Mitchell, ACT
Michael Boake, Technical Director, Vivendi Water, Pyrmont, NSW
Seth Bolas, Research Economist, WA Office of Water Regulation, Perth, WA
Jim Booth, GM Nat. Res. Policy, NSW Dept. Sustainable Natural Resources, Sydney, NSW
Geoff Borton, Manager (Internat.), Waste Technologies Australia, UNSW, Kensington, NSW
Mick Bourke, Chairman, Victorian EPA, Southbank, V.
Don Bursill, CEO, CRC for Water Quality and Treatment, Bolivar, SA
Ian Burton, Local Govt. Programs Mgr, Ministry of Energy & Utilities, Tamworth, NSW
Peter Byrnes, Barwon Water, Geelong, V
Keith Cadee, GM Bulk Water, WA Water Corporation, Leederville, WA
Philip Callan, National Health and Medical Research Council, Woden, ACT
Ross Campbell, Director, National Competition Council, Melbourne, V
Andrew Chapman, Principal Engineer, Parsons Brinckerhoff Australia, Melbourne, V
Murray Chapman, Coordinator, Irrigation R&D, Land & Water Australia, Baddaginnie, V
Peter Clark, Manager Water & Waste Operations, Toowoomba City Council, Toowoomba, Q
Tom Connor, Director, Engineering Excellence & Technology, KBR, Brisbane, Q
Peter Coombes, University of Newcastle, Newcastle, NSW
Stephen Corbett, Mgr, Environmental Health Branch, Dept. of Health, Gladesville, NSW
Lisa Corbyn, CEO, Department of Environment and Conservation, Sydney, NSW
Simon Coutts, Environmental Officer, Grampians Regional Water Authority, Horsham, V
Gary Cowcher, Catchment Impact manager, Sydney Water, Sydney, NSW
Shaun Cox, CEO, Gold Coast Water, Nerang, Q
Wally Cox, Chairman, WA EPA, Perth, WA
Wendy Craik, National Competition Council member, Canberra, ACT
Colin Creighton, Director, Water for Healthy Country Flagship Project, CSIRO, Canberra, ACT
John Cugley, A/Director, Monitoring and Evaluation Division SA EPA, Adelaide, SA
Peter Cullen, Fellow, CSIRO Land & Water, Canberra, ACT
David Cunliffe, Department of Human Services, Adelaide, SA
Michael D'Occhio, Director, Research, University of Queensland, Gatton, Q
Ross Dalton, National Resources Management Policy, DAFF, Canberra, ACT

Peter Dart, Principal Research Fellow, University of Queensland, St Lucia, Q
Gerry Davies, Manager, Water Policy, Primary Industries & Resources, Adelaide, SA
Sharon Davies, Manager Water Smart Growth, Sydney Water, Sydney, NSW
Brian Davis, Queensland EPA, Brisbane, Q
Brian Devine, A/Director, Environmental Health, Dept. of Health WA, Shenton Park, WA
Charles Dharmasena, Production Officer, Sydney Water, Rouse Hill, NSW
Kirilly Dickson, ActewAGL Ltd, Canberra, ACT
Peter Dillon, Principle Research Engineer, CSIRO Land & Water, Urrbrae, SA
Stuart Doak, Director, Technical services, Gladstone City Council, Gladstone, Q
Peter Dolan, A/Manager, Pollution Avoidance Division, SA EPA, Adelaide, SA
Sam Drummond, Economist, National Competition Council, Melbourne, V
Edwin Engelbrecht, Network Manager, Sydney Water, Rouse Hill, NSW
Leon English, Program Manager, Allocation Branch, WA EPA, Perth, WA
Greg Fahey, Project Manager Infrastructure Partnerships, Dept. State Development, Brisbane, Q
Mary-Anne Franco-Dixon, Department of Primary Industries, Brisbane, Q
Rob Freeman, CEO, Dept Water, Land & Biodiversity Conservation, Adelaide, SA
Ted Gardner, Principal Scientist, Catchment Processes, Dept. Nat.Res.& Mines, Indooroopilly, Q
David Garman, Executive Director, Waste Technologies of Australia, UNSW, Kensington, NSW
Kym Good, CEO, Northern Adelaide Plains Barossa Catchment Water Mgmt Bd., Salisbury, SA
Ian Gould, Queensland EPA, Brisbane, Q
Don Graham, Senior Analyst – Pricing, Sydney Water, Sydney, NSW
Trudy Green, Sydney Water, Sydney, NSW
Paul Greenfield, Senior Deputy Vice-Chancellor, University of Queensland, St Lucia, Q
Allan Gregory, Manager Water Conservation & recycling, Sydney Water, Sydney, NSW
Stephen Hains, City Manager, City of Salisbury, Salisbury SA
Peter Hall, Manager, Project Services, Ipswich Water, Yamanto, Q.
Max Harvey, A/Director, Operations Division, SA EPA, Adelaide
Belinda Hatt, Monash University, Clayton, V
Hazuo Hattori, Engineer, Osaka Prefectural Waterworks, Osaka, Japan
Shingo Hayashi, Engineer, Osaka Prefectural Waterworks, Osaka, Japan
Paul Heaton, Manager Water Facilities, Power & Water Corporation, Darwin, NT
Mark Herbert, WA Water Corporation, Leederville, WA
Mike Hollitt, Project Director, Water Cycle), WA Water Corporation, Leederville, WA
Theo Hooy, Acting Assistant Secretary, Environment Australia, Canberra, ACT
David Hunter, Group Director, Coomes Consulting Group, South Melbourne, V
Rob Joy, Deputy Chairman, EPA Victoria, Southbank, V
Dion Karafilis, WA Water Corporation, Leederville, WA
Jurg Keller, Director, Advanced Wastewater Mgmt Centre, Univ. of Queensland, St Lucia, Q
Jeff Kidd, Opns. Supervisor, Gerringong Gerroa STP, General Water Australia, Gerroa, NSW
David Knights, Engineer, Sydney Water, Sydney, NSW
Trevor Kroemer, Manager Water and Sewer, Roxby Downs Council, Roxby Downs, SA
Adrian Langdon, Water Tr. & Recycl. Br., Min. Energy, Utilities & Sustnblty., Parramatta, NSW
John Langford, CEO, Water Services Association of Australia, Melbourne, V
Ian Law, Consultant, Wellington, NSW
Ray Ledger, Principal Adviser, Wastewater, SA EPA, Adelaide, SA
Michael Lever, Manager, Wide Bay Water Corporation, Hervey Bay, Q
Andrzej Listowski, Mgr. Water & Energy, Sydney Olympic Park Authority, Olympic Pk., NSW
Darryl Lloyd, Program Manager, Water Recycling, Sydney Water, Sydney, NSW
Michael Loh, Engineer Planning, Infrastr. Planning Br., WA Water Corpn., Leederville, WA
Terry Loos, Assistant Manager, Water Planning, Queensland EPA, Brisbane, Q
Peta Maddy, Project Manager, Water Recycling, Melbourne Water, East Melbourne, V
Tom Major, Engineer, Calaqua, Caloundra, Q
Peter Marczan, Mgr. Technical Advisory, Water & Catchment Policy, NSW EPA, Sydney, NSW

Chris Marles, SA Water Corporation, Thebarton, SA
Richard Marks, Kellogg, Brown and Root Pty Ltd., Adelaide, SA
Darla Hatton Macdonald, Policy and Econ. Res. Group, CSIRO Land and Water, Urrbrae, SA
Jennifer McKay, Professor of Business Law, University of South Australia, Mawson Lakes, SA
Don McFarlane, Director, Resource Mgmt Div., WA EPA, Perth, WA
Daryl McGregor, Manager, Albury Water, Albury, NSW
Ian McPhail, Executive Director, Queensland EPA, Brisbane, Q
Brian McRae, Chief Policy Officer, Aust Water Association, Artarmon, NSW
Thea Mech, Policy and Economics Research Group, CSIRO Land and Water, Urrbrae, SA
Garry Meinck, (GM Planning and Devel.), WA Water Corporation, Leederville, WA
Thomas Melin, Institut für Verfahrenstechnik, Aachen, Germany
Wayne Meyer, Business Manager, CSIRO Land and Water, Urrbrae, SA
John Mitchell, CEO, Gippsland Water, Traralgon, V
Peter Michell, GM Business Development, Michell Australia Pty Ltd, Salisbury South SA
Barbara Mitrevski, Urban and Rural Land Corporation, Melbourne, V
Walter Moore, REMS Project Coordinator, Shoalhaven Council, Nowra, NSW
John Mott, Strategic Coordinator, University of Queensland, St Lucia, Q
Barry Noller, Dep.Dir. National Res. Centre for Environmental Toxicology, Coopers Plains, Q
Richard Nott, Director, Water Quality, Dept of Environment and Heritage, Canberra, ACT
Darren Oemcke, Chief Executive, Provisor Pty Ltd, Urrbrae, SA
Jason Olsen, Senior Policy Officer, Department of Primary Industries, Brisbane, Q
Lew Owens, Chairperson, SA Essential Services Commission, Adelaide, SA
Gary Palmer, Manager, Calaqua, Caloundra, Q
Robert Patterson, Lanfax Labs, Armidale, NSW
Colin Pitman, Director, Contract Management, City of Salisbury, Salisbury, SA
Kaye Power, Snr. Policy Adv., Environmental Health, Department of Health, Gladesville, NSW
Ian Rae, Technical Director, Academy of Technological Science and Engineering, Carlton V
Russell Reichstein, Water Engineer, Parsons Brinckerhoff Australia, Melbourne, V
Hamish Reid, Project Manager, Water & Catchments, Victorian EPA, Southbank, V
Barbara, Richardson, Director, Waters & Catchment Policy, NSW EPA, Sydney, NSW
John Ringham, Head, Water Services, SA Water Corporation, Thebarton, SA
Peter Robinson, Principal Consultant, Business Solutions, Earthtech, Melbourne, V
Jamie Roodenrys, STEDS Program Manager, Local Government Association, Adelaide, SA
Ross Sadler, Scientific Adviser, Public Health, Queensland Health, Coopers Plains, Q
Haruyo Sasaki, Executive Dir., Sapporo Int. Communications Plaza Foundation, Sapporo, Japan
Gerrit Schrale, Irrign. Prog. Leader, Dept Water, Land & Biodiversity Conservation, Urrbrae, SA
Richard Schuil, Planning Manager, Sydney Water, Sydney, NSW
David Sedlak, Assoc. Professor, Civil & Envir. Eng., University of California, Berkeley, CA
Glen Shaw, National Research center for Environmental Toxicology, Coopers Plains, Q
Paul Sherman, Environment Technical Services, Queensland EPA, Brisbane, Q
Hillel Shuval, Professor of Environmental Science, Hebrew University of Jerusalem, Israel
Lester Sickerdick, SA Water Corporation, Thebarton, SA
Jenifer Simpson, Keil Mountain, Woombye, Q
David Smith, University of Melbourne, Parkville, Q
Simon Smith, Exec. Director Economics & Environmental Reporting, NSW EPA, Sydney, NSW
Stephen Smith, Deputy Manager, Onkaparinga CWMB, Aberfoyle Park, SA
Cate Soroczan, Senior Researcher, Canada Mortgage and Housing Corporation, Ottawa, Canada
Leigh Sparrow, Prog.Mgr., Horticulture Aust., Sen. Research Fellow, TIAR, Kings Meadow, T
Peter Spencer, WA Water Corporation, Leederville, WA
Geoff Stallman, Queensland EPA, Brisbane, Q
Brian Steffen, Director-General, NSW Ministry of Energy & Utilities, St Leonards, NSW
Darryl Stevens, CSIRO Land and Water, Urrbrae, SA
John Stevens, Strategy Leader, Integrated Servicing, Sydney Water, Sydney, NSW

Peter Sutherland, Executive Director, Dept. Sustainability and Environment, East Melbourne, V
Geoff Syme, CSIRO Land and Water, Floreat Park, WA
John Tamblyn, Chairperson, Essential Services Commission, Victoria, Melbourne, V
Michael Taylor, Secretary, DAFF, Canberra, ACT
Glen Templeman, Manager, Willunga Basin Water Company, McLaren Vale, SA
Andrew Thomas, Managing Director, Michell Australia Pty Ltd, Salisbury South, SA
Marcus Thomas, Waste Water Treatment Manager, Brisbane Water, Luggage Point, Q
Ron Thompson, Water Reuse Operations Team Leader, Sydney Water, Sydney, NSW
Graham Thomsen, Deputy Chairman, Wide Bay Water Corporation, Hervey Bay, Q
Bill Till, Program Manager, Stream & Stormwater Management, WA EPA, Perth, WA
Bill Tompkinson, Planning & Development Manager, Shoalhaven Council, Nowra, NSW
Simon Toze, CSIRO Land and Water, Floreat Park, WA
David Trstenjak, Queensland EPA, Brisbane, Q
Nick Turner, WA Water Corporation, Leederville, WA
Daniel van Oosterwijck, Yarra Valley Water, V
Paul Vogel, CEO, SA EPA, Adelaide, SA
Leanne Wallace, Group GM, Nat.Res. Products, NSW Sust. Natural Resources, Sydney, NSW
Cory Watts, Australian Conservation Foundation, Carlton, V
Asoka Wijeratne, Exec. Mgr., Water & Regulatory Affairs, ACTEW Corpn., Canberra, ACT
Rod Williams, Gosford City Council, Gosford, NSW
Ralph Wooley, Brisbane City Council Water Supply & Sewerage, Brisbane, Q
Clive Wright, Business Developmt. Mgr., Recycled Water & Irrigation, Earthtech, Melbourne, V
Satoshi Yamazaki, Fenner Hall, Australian National University, Canberra ACT
Wendy Yeomans, Hunter Water, Newcastle, NSW
Mike Young, Policy and Economics Research Group, CSIRO Land and Water, Urrbrae, SA
Toru Yoshioka, Sewage Engineer, City of Sapporo, Sapporo, Japan

REFERENCES

ABS (1994). *Environmental issues, People's views and Practices.* Australian Bureau of Statistics, Canberra, June 1994

ACTEW (2003). Annual Report 2003. http://www.actew.com.au/publications/corporate/actewAR/index.html

ActewAGL (2003a) Lower Molonglo Treatment Train http://www.actewagl.com.au/wastewater/network/treatment/processFlow.cfm

ActewAGL (2003b) Watermining. http://www.actewagl.com.au/projects/watermining.cfm

ActewAGL (2003c) CRANOS. http://www.actewagl.com.au/projects/cranos.cfm

Adham, S., Gagliardo, P., Boulos, L. Oppenheimer, J. and Trussell, R. (2001). Feasibility of the membrane bioreactor process for water reclamation *Water Science and Technology* **43**: (10) 203-209

Allison, L (2002). *The value of water: Inquiry into Australia's management of urban water.* Report of the Senate Environment, Communications, Information Technology and Arts References Committee December 2002. http://www.aph.gov.au/senate/committee/ecita_ctte/water/report/

Altemonte Springs (1997). Fact Sheet - Project Apricot 10/97 and others, City of Alamente Springs, Florida

Anderson, J. (2003). *Walking like dinosaurs: Water, reuse and urban jungle footprints*. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Anderson, J., Adin, A., Crook, J., Davis, C., Hultquist, R., Jimenez-Cisneros, B., Kennedy, W., Sheikh, B. and van der Merwe, B. (2001). Climbing the ladder: a step by step approach to international guidelines for water recycling. *Water Science and Technology* **43** (10): 1-8

Andrew, N. (2003). Speaker, House of Representatives, Canberra, ACT, pers. comm..

ARCWIS (2002). *Perth Domestic Water-Use Study Household Appliance Ownership and Community Attitudinal Analysis 1999-2000.* Sydney: CSIRO Urban Water Program.

ARMCANZ/ANZECC (1997). *National Water Quality Management Strategy – No. 11. Australian Guidelines for Sewerage Systems – Effluent Management*. Agriculture and Resource Management Council of Australia and New Zealand, and Australian and New Zealand Environment and Conservation Council, Canberra ACT.

ARMCANZ/ANZECC (2000a). *National Water Quality Management Strategy – No. 14. Australian Guidelines for Sewerage Systems – Reclaimed Water*. Agriculture and Resource Management Council of Australia and New Zealand, and Australian and New Zealand Environment and Conservation Council, Canberra ACT.

ARMCANZ/ANZECC (2000b). *National Water Quality Management Strategy – No. 10. Australian Guidelines for Urban Stormwater Management*. Agriculture and Resource Management Council of Australia and New Zealand, and Australian and New Zealand Environment and Conservation Council, Canberra ACT.

Asano, T (1998). *Wastewater reclamation and reuse*. Water Quality Management Series Volume 10, CRC Press, Boca Raton, FL, USA.

Asano, T. (1999). *Wastewater Reuse for non-potable applications: an introduction. In Proceedings of the International Symposium on Efficient Water Use in Urban Areas.* UNEP International Environmental Technology Centre, Osaka, Japan

Asano, T., Smith, R.G. and Tchobanoglous, G (1985). *Municipal Wastewater Treatment and Reclaimed Water Characteristics*. In: Irrigation with Reclaimed Municipal Wastewater – a Guidance Manual (Pettygrove, G.S. and Asano, T., eds) Lewis Publishers, Chelsea, Michigan

Ashbolt, N. (2003). Centre for Water and Waste Technology, University of NSW, Sydney, NSW, pers. comm.

ATSE (2002). *Perth's water balance – the way forward.* Academy of Technological Sciences and Engineering, WA Division, Perth, WA. November 2002

AWA (2004). AWA *Ten-point Plan – Submission to intergovernmental deliberations on the National Water Initiative*. Australian Water Association, Artarmon, NSW, 2004

Bakr, M. (2003) Sewage salvation. *Al Ahram Weekly*, http://weekly.ahram.org.ed/print/2003/641.sc4.htm

Balkema, A. J., Preisig, H. A., Otterpohl, R. and Lambert, F.J.D. (2002). Indicators for the sustainability assessment of wastewater treatment systems. *Urban Water* **4**(2):153-161.

Baluch, J. (2003). Central Oval Water reclaimation and Recycling Plant. http://www.portaugusta.sa.gov.au/common/rwp.html

Barbaballo, S., Cirelli, G. L. and Indelicato, S. (2001). Wastewater reuse in Italy. *Water Science and Technology* **43**: (10) 43-50

Baria, A. (2003). ACTEW, Canberra, ACT, pers. comm.

Barr, K. (2003). Brisbane Water, Brisbane, Q., pers. comm..

Barton, T (2003). *Wastewater: Further strategies being explored*. Press release by Queensland Minister for State Development, August 12 2003, Brisbane

Barwon Water (2003a). *Water for tomorrow - Water Resources Development Plan.* Barwon Water, Geelong, Victoria, March 2003

Barwon Water (2003b). *Barwon Water's use of Recycled Water*. Barwon Water, Geelong, February 2003, 12 pp

Bekkers, T. (2003). Paxton Vineyard, McLaren Vale, SA, pers. comm..

Bencke, W (2001). *Domestic Wastewater Recycling trial – implementing on site wastewater recycling in urban areas – lessons* learned. ActewAGL, Canberra, ACT. June 2001

Blackwell, J., Biswas, T.K., Jayawardane, N.S. and Townsend, J.T. (2000). *Irrigation – Getting the Edge*. Grains R&D Cororation irrigation update meeting, Mathoura, NSW, 16 August 2000

Bluml, M. et al. (2002). *Identification and preliminary risk assessment of prime development zones in the greater Melbourne area for recycled water use.* Department of Natural Resources and Environment - Centre for Land Protection Research, Bendigo, Victoria

Boake, M. and Ovens, G. (2003). Gerringong Gerroa Sewerage Scheme. *Water* **30** (7): 58-61

Boland, D, (2002). *Development of a Water Supply Pipeline from Kimberleys to Perth – Independent Review of Feasibility Studies*. Report to Water Corporation, WA, GHD, Perth, September 2002, 16 pp. In: Our Water Future, Proceedings, Western Australia's Water Symposium, Parliament House, Perth, 1-7 October 2002

Booth, C.A., Attwater, R., Derry, C. and Simmonds, B. (2003) The Hawkesbury Reuse Scheme. *Water* **30** (5): 42-44, August 2003

Brindal, M. (2000). State Water Plan 2000. Department of Water Resources, Adelaide SA, September 2000

Brown, J and Ramachandran, K. (2001) Planning for a Large Scale Effluent Recycling in Industries from Wollongong STP. Sixth World Congress of Chemical Engineering, Melbourne, September 22-27 2001

Brown and Root (2001). *South East Queensland Recycled Water Project – Cost report summary.* Brown & Root Services Asia Pacific Pty Ltd, Milton, Q.

Bruvold, W. (1988). Public Opinion on water reuse options. *Research Journal of WaterPollution Control Federation,* **60**(1): 45-49.

Buechler, S, Hertog, W. and van Veenhuizen,R. (2002). Wastewater use in urban Agriculture. *Urban Agriculture* **8**:1-4 http://www.ruaf.org/no8/01_editorial.pdf

Burgess, H. T. (ed) (1907), *Cyclopaedia of South Australia* Vol 2, Cyclopædia Publishing Co.,Adelaide.

Bursill, D. (2003). CRC Water Quality and Treatment, Bolivar, SA, pers. comm.

Burton I. (2003). Ministry of Energy, Utilities and Sustainability, Tamworth, NSW, pers. comm

Byrnes, P. (2003). Barwon Water, Geelong, Victoria, pers. comm.

Byrnes, P. (2004). Barwon Water, Geelong, Victoria, pers. comm.

Caiger, L and Tuft, R (1999). Reuse of effluent on playing fields: Clarification of Health issues. Australian Water Association 18th Convention, Adelaide, paper 68_72, Australian Water Association, Sydney.

California DWR (2003). Water Recycling 2030 – Recommendations of California's Recycled Water Task Force. Department of Water Resources, Sacramento, California, June 2003

California SWRCB (2003). http://www.swrcb.ca.gov/recycling/recyfund/

Camkin, J (2002). *Current uses and projected demand.* In: Our Water Future, Proceedings, Western Australia's Water Symposium, Parliament House, Perth, 1-7 October 2002

Campbell, R. (2003). National Competition Council, Melbourne, Vic., pers. comm.

Carr, R (2002), *Growing Pains II – Planning Sydney's future.* Speech by Bob Carr, Premier of NSW , November 8 2002

Cavallini, J.M. and Young, L.E. (2002). Integrated systems for the treatment and recycling of wastewater in Latin America: Reality and potential. *Urban Agriculture* **8**:18-19 http://www.ruaf.org/no8/18_cepis.html

CCC (2003). *Seawater and the California Coastal Act – Draft Seawater Desalination report.* California Coastal Commission, Sacramento, California, August 2003

Chapman, M. (2003). Land and Water Australia, Baddaginnie, Vic., pers. comm.,

Chaudhary, D. S., Guo, W., Vigneswaran, S, Ngo, H.H. and Vigneswaran, B. (2003). *Submerged membrane-adsorption system: an energy efficient process for water reuse.* CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 358, Australian Water Association, Sydney.

Clancy, J.L. (2000). Sydney's 1998 water quality crisis. *Journal of the American Waterworks Association* **92** (3) 55

Clark, P. (2003). Toowoomba City Council, Toowoomba, Q., pers. comm.

CoAG (2003). National water initiative http://www.dpmc.gov.au/docs/national_water_initiative_progress.cfm

Conaughton, G. (2003). Rocket fuel threatens water supply. *Californian North County Times*, 19 April 2003. www.nctimes.net/news/2003/20030419/61636.html

Connell Wagner (2002). *Investigations into Water Reuse Options in the Upper Spencer Gulf Cities of Port Augusta, Port Pirie and Whyalla*. Report for Department of Water Resources, ref. D241.00, Connell Wagner Pty Ltd, Adelaide, July 2002/

Coombes, P.J., Argue, J.R. and Kuczera, G. (2000). Figtree Place : a case study in water sensitive urban development. *Urban Water.* **1**(4). 335 – 343.

Coombes, P. J. and Kuczera, G. (2003). *A sensitivity analysis of an investment model used to determine the economic benefits of rainwater tanks.* Institution of Engineers, Australia, 28th International Hydrology and Water Resources Symposium, Wollongong, NSW, 10-14 November 2003.

Coombes, P., Kuczera, G. and Kalma, J. (2000). Economic benefits arising from use of water sensitive urban development source control measures. 3rd Int. Hydrol. And Water Resources Symposium, Perth, November 2000. (Inst. Engs. Aus). 152-157.

Corbyn, L. (2003). Chief Executive, NSW Department of Environment and Conservation, Sydney, pers. comm.

Costanza, R., d'Arge, R., de Groot, R., Farmer, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O.Neill, R.V., Peruelo, J., Raskin, R.G., Sutton, P. and van den Belt M. (1996). The value of the world's ecosystem services and natural capital. *Nature* **387**: 253-260, 15 May 1997.

Coutts, S. (2003). Grampians Water, Horsham, Victoria, pers. comm.

Cowcher, G. (2003). Sydney Water, Sydney, NSW, pers. comm.

Cowie, C. (2003). *Health guidance for rainwater tanks*. Powerpoint presentation, NSW Department of Health, Sydney, 2 May 2003

Cox, W (2002). Our Water Future – Proceedings of Western Australia's Water Symposium, Parliament House, Perth, 7-9 October 2002

Cox, W. (2003). Environment Protection Authority, WA, Perth, WA, pers. comm..

CRCWMPC (2002). *Annual Report 2002*. Cooperative Research Centre for Waste Management and Pollution Control Ltd., Sydney NSW

CRCWQT (2002). *Annual Report, 2001-2.* Cooperative Research Cnetre for Water Quality and Treatment, Salisbury, SA

CRCWQT (2003). Netherlands bans dual supplies. *Health Stream*, Sept. 2003, Cooperative Research Centre for Water Quality and Treatment, Bolivar, SA

Crook, J. (1998). *Water Reclamation and Reuse Criteria*. Ch 14, In T Asano Ed., *Wastewater Reclamation and Reuse*, Ch 14. Technomic Publishing, Lancaster, PA

CSIRO (2002). Findings of the reclaimed water (water recycling) forum, held at CSIRO Floreat Park, WA. March 2002

Cunliffe, D. (1998) *Guidance on the use of rainwater tanks*. National Environmental Health Forum Monographs – Water Series No. 3. South Australian Health Commission, Adelaide

Cunliffe, D. (2003). South Australian Department of Human Services, Adelaide, SA, pers. comm.

Cunliffe, D. (2004). South Australian Department of Human Services, Adelaide, SA, pers. comm.

Cunliffe, D. and Stevens, M. (2003). *Success Of HACCP In The Drinking Water Industry – Can It Be Adapted To Reuse Schemes?* . CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Davis, B. (2003). Queensland EPA, Brisbane, Q., pers. comm.

de Rooy, E. (2003). Sydney Water, Sydney, NSW, pers. comm

de Rooy, E. and Engelbrecht, E. (2003). Experience with residential water recycling at Rouse Hill. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Dettrick, D. (2002). Environmental guidelines for the use of recycled Water in Tasmania. Department of Primary Industries, Water and Environment, Hobart, Tasmania, December 2002 www.dpiwe.tas.gov.au/inter.nsf/WebPages/CDAT-5JV3TW?open

Dettrick, D. (2003). Department of Primary Industries, Water and Environment, Hobart, Tas., pers. comm..

DHS (2001). *California Health Laws Related to Recycled Water*, State of California Department of Health Services, Sacramento CA, June 2001 edition.

DHS (2003). Drinking Water Action Levels: Current. 5 November 2003. www.dhs.ca.gov/ps/ddwem/chemicals/AL/actionlevels.htm

DHS-SA (1999). *South Australian Reclaimed Water Guidelines – Treated Effluent.* Department of Human Services, Adelaide, SA. April 1999 http://www.environment.sa.gov.au/epa/pdfs/reclaimed.pdf

Department of Health WA (2002). Draft Guidelines for the reuse of greywater in Western Australia. Department of Health, Perth, WA, http://www.health.wa.gov.au/publications/documents/HP8122%20Greywater%20Reuse%20Draft%20Guidelines.pdf

Dillon, P.J. (2000). Water reuse in Australia: Current status, projections and research. In: Water Recycling Australia, P.J. Dillon, Ed, CSIRO and AWA, Canberra ACT

Dillon, P. and Ellis, D. (2004). Australian Water Conservation and Reuse Research Program. Envir04 Conference, Sydney, March 2004. Australian Water Association, Sydney.

Dillon, P. Pavelic, P. Toze, S. Ragusa, S., Wright, M., Peter, P. Martin, R., Gerges, N., and Rinck-Pfeiffer, S. (1999). Storing recycled water in an aquifer: benefits and risks. Aust Water & Wastewater Assoc. J. *Water* **26**(5) 21-29.

DLWC (2000). *NSW Water Conservation Strategy*, NSW Dept of Land and Water Conservation, Sydney, October 2000

DNRE (2002). *New water for Victoria – Victoria's water recycling action plan.* Department of Natural Resources and Environment, East Melbourne, Victoria

Doak, S. (2003). Gladstone City Council, Gladstone, Q., pers. comm.

Drechsel, P, Blumenthal, U.J. and Keraita, B (2002). Balancing Health and Livelihoods – adjusting wastewater irrigation guidelines for resource-poor countries. *Urban Agriculture* **8**: 7-9 http://www.ruaf.org/no8/07_guidelines.pdf

DSE (2003). *Securing our Water Future – Green Paper for Discussion*. Department of Susainability and Environment, East Melbourne, August 2003

DWR (2003). *Water recycling 2030 – Recommendations of California's Recycled Water Task Force.* State of California Department of Water Resources, Sacramento, June 2003

E&WS (1986). *History of Sewerage*. Engineering and Water Supply Department, Adelaide

Edmonds, L. (2003). WA Water Corporation, Perth, WA, pers. comm.

Engelbrecht, E. (2003), Sydney Water, Sydney, NSW, pers. comm.

Environment ACT (2003a). Water ACT – *Think water, act water . Volume 1 -* A *draft Policy for Sustainable Water Resource Management* Environment ACT, Lyneham, ACT, July 2003

Environment ACT (2003b). *Think water, act water. Volume 2 Draft Explanatory Statement,* Environment ACT, Lyneham, ACT, November 2003

EPA Victoria (2001) *Domestic Wastewater Management Series – Reuse options for household wastewater* – Publication 812, Environment Protection Authority, Victoria, Melbourne, November 2001

EPA Victoria (2003). *Guidelines for environmental management – Use of reclaimed water.* Publication 464.2. EPA Victoria, Southbank, Victoria, September 2002. http://epanote2.epa.vic.gov.au/EPA/Publications.nsf/2f1c2625731746aa4a256ce90001cbb5/64c2a15969d75e184a2569a00025de63/$FILE/464.2.pdf

EPA WA (1992). Environmental Protection (Gnangara Mound Crown Land) Policy 1992, *Government Gazette WA*, 1992 P. 6287, 24 December 1992. http://www.epa.wa.gov.au/docs/1074_EPP_GMCL92.pdf

EPA WA (2001). *Kemerton wastewater treatment plant and treated wastewater reuse at Woodlot, Binningup*. Bulletin 1011, Environment Protection Authority, Western Australia, Perth, April 2001

EPA WA (2002). EPA recommendations on a proposal by the Water Corporation of Western Australia to construct and operate a desalination plant at either the Kwinana Power Station or at East Rockingham. Media release, EPA, Perth, 7 October 2002. http://www.epa.wa.gov.au/article.asp?ID=1502&area=News&CID=18&Category=Media+Statements

ESD (1991). Ecologically Sustainable Development Working Groups – Final Report – Agriculture. AGPS, Canberra ACT

Falconer, I.R., Moore, M.R., Chapman, H.F. and Ranmuthugala, G. (2003). Review of Endocrine Disruptors in the context of Australian drinking water. CRC Water Quality and Treatment Occasional Paper No 7. ISBN 1876616229

Feitshans, T. A. (1996). Liability issues in groundwater quality protection. North Carolina Cooperative Extension Service Pub. AG-441-1 (April 1996). www.bae.ncsu.edu/programs/extension/publicat/wqwm/ag441_1.html

Florida Reuse Committee (2003). *Water reuse for Florida – Strategies for effective use of reclaimed water*. State of Florida Department of Environment Protection June 2003. http://www.dep.state.fl.us/water/reuse/docs/valued_resource_Final%20Report.pdf

Florida DEP (1996). *Florida State of Environment – Reuse of Reclaimed Water.* Florida Department of Environmental Protection, Tallahassee, FL

Foster, J (2000) Ecologically sustainable design: Development achievements & opportunities - 'Oaklands Park' 310 Konagaderra Road Oaklands Junction, Victoria. Report, Tract Consultants Pty Ltd, Richmond, Victoria, November 2000

Freeman, R. (2004). South Australian Department of Water, Land and Biodiversity Conservation, Adelaide, SA, pers. comm.

Funamizu, N., Iida, M., Sakakura, Y and Takakuwa, T. (2001). Reuse of heat energy in wastewater: implementation examples in Japan. *Water Science & Technology* **43** (10): 277-285

Gallop, G. (2003). *Securing our future – A state water strategy for Western Australia*. Government of Western Australia, Perth. February 2003

Gardner, T. (2002). Some examples of water recycling in Australian Urban Environments – A step towards environmental sustainability. International Water Association. Water recycling in the Mediterranean Region. Crete. September 2002, 12pp

Gardner, T. (2003). Department of Natural Resources and Mines, Brisbane, Q., pers. comm..

Gardner, T., Millar, G. and Hyde R. (2003). *The Healthy Home® - a step towards sustainable suburbs*. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Gardner, E.A., Morton, D., Sands, J., Matthews, P., Cook, F.J. and Jayawardane, N.S. (2001) The filter system for tertiary treatment of sewage effluent by land application – its performance in a subtropical environment. *Water Science and Technology* **43**: 335-342

Garman D and Borton, G. (2003). CRC Waste Management and Pollution Control, Sydney, pers, comm.

GHD (1977). *Strategies towards the use of reclaimed water in Australia*. .Reclaimed Water Committee, Ministry of Water Resources and Water Supply, Melbourne, August 1977

GHD (1992). *Investigation of Nutrient Pollution in the Murray-Darling River System*. Report to the Murray Darling Basin Commission, Canberra. January 1992. ISBN 1 875209 123

GHD (2002a). *Urban growth areas water recycling strategy report,* Gutteridge, Haskins and Davey, Melbourne, Victoria March 2002

GHD (2002b). *Water recycling strategy for business report*. Gutteridge, Haskins and Davey, Melbourne, Victoria March 2002

Gill, J. (2002). *Managing demand and supply – current practices and new water source development*. In: Cox, W (2002). Our Water Future – Proceedings of Western Australia's Water Symposium, Parliament House, Perth, 7-9 October 2002

Gold Coast Water (2003a) *Water Futures – Pimpama Coomera Water Futures Project.- Summary Report* Gold Coast City Council, July 2003

Gold Coast Water (2003b) *Water Futures – Pimpama Coomera Water Futures Project-<Master Plan Options Report, July 2003* Gold Coast City Council, July 2003

Gould, J., Lee, P., Ryl, J. and Mulligan, B. (2002). Shoalhaven Reclaimed Water Management Scheme – Clever Planning Delivers Bigger Environmental Benefits. 3rd World Water Congress of the IWA, Melbourne 7-12 April 2002, paper e21703.

Greenplumbers (2003). *General info,* and *About the GreenPlumbers®* www.greenplumbers.com.au

Greenway, M. (2003). *The role of wetlands in effluent treatment and reuse schemes*. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Gregory, A. (2000). Strategic directions of water recycling in Sydney. In: Water Recycling Australia, PJ Dillon, (ed), CSIRO and AWA Canberra ACT

Gregory, A. (2003). Sydney Water, pers. comm.

Griffin, T. L. and McCaskill, M. (Eds.) (1986). Atlas of South Australia.. South Australian Jubilee 150 Board. Wakefield Press, Adelaide

Griffiths, P. (2003). Water Recycling Energy Considerations. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

GRS (2003). *Groundwater Replenishment Scheme – Pure solution to Orange County's water needs*. http://www.gwrsystem.com/about/

Hains, S. (2003) *Environmental diversity and economic opportunities – the Salisbury wetland experience*. Planning Institute of Australia Congress, Adelaide, March 31 2003

Hall, P. (2003). Ipswich Water, Yamanto, Q., pers. comm.

Hamlyn-Harris, D. (2001a). *Review of health issues associated with potable reuse of wastewater - Final Report*. Gutteridge, Haskins and Davey Pty Ltd, Brisbane, for the Department of Health and Aged Care, Canberra, March 2001.

Hamlyn-Harris, D. (2001b). *Potable reuse – what are the real public health concerns?* Australian Water Association 19^{th} Convention, Canberra, paper 155, Australian Water Association, Sydney

Hamlyn-Harris, D. (2003). Integrated Urban Water Management and Water Recycling in SE Queensland. Institute of Public Works Engineering Australia, Queensland Division Inc., State Conference, Mackay, 5-10 October 2003 http://www.ipwea.org.au/papers/download/Hamlyn-Harris_David.pdf

Harris, G., Batley, G., Fox, D., Hall, D., Jernakoff, P., Molloy, R., Murray, A., Newell, B., Parslow, J., Skyring, G., and Walker, S. (1996). *Port Phillip Bay Environmental Study Final Report*. CSIRO, Canberra.

Hatt, B, Deletic, A. and Fletcher, T. (2004). Integrated Stormwater Treatment and Re-use Systems – inventory of Australian Practice. Department of Civil Engineering, Monash University, http://www.catchment.crc.org.au/pdfs/prereport_200401.pdf

He Pinjing, Phan, L., Gu Guowei and Hervouet, G. (2001) Reclaimed municipal wastewater – a potential resource in China. *Water Science and Technology* **43**: (10) 51-58

Hellier, K. and Mullenger, J. (2001). *Protecting Melbourne's water supply through a certified HACCP plan*. Australian Water Association 19th Convention, Canberra, paper 85, Australian Water Association, Sydney.

Heron, D. and Lever, M. (2001). *Urban Rural Environmental Partnership*. In: Water Recycling Australia, P.J. Dillon, Ed, CSIRO and AWA, Canberra ACT

Heyworth, J.S., Maynard, E.J. and Cunliffe, D. (1998). Who consumes what: potable water consumption in South Australia. *Water* **25** (1), 9-13

Hickinbotham, M. (1994). *A survey of Water Reclamation and Reuse*. Internal paper, Hickinbotham Group, Hackney, SA, 64pp.

Hills, S. and English, P. (1999) *Water recycling at the Millenium Dome.* Australian Water Association 18th Convention, Adelaide, paper 90_103, Australian Water Association, Sydney.

Holliman, T.R. (1998). *Reclaimed Water distribution and storage*. In T Asano Ed., *Wastewater Reclamation and Reuse*, Ch 9. Technomic Publishing, Lancaster, PA

Hopkins, L., and Barr, K. (2002). *Operating a water reclamation plant to convert sewage effluent to high quality water for industrial use*. 3rd World Water Congress of the IWA, Melbourne 7-12 April 2002, paper e21595.

Huijbregsen, C., Yerrell, K., Bosher, C and Sickerdick, L. (1999) *Bolivar DAFF Plant – Australia's largest reclaimed water treatment plant*. Australian Water Association 18th Convention, Adelaide, paper 65_69, Australian Water Association, Sydney.

Hunter Water (2002). Annual report 2001-2, Hunter Water, Newcastle, NSW.

IPART (2003). http://www.ipart.nsw.gov.au/

Ireland, M. (2003). 20% by 2010: Creating a sustainable future for Melbourne's water resources. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 212, Australian Water Association, Sydney.

Jayawardane, N.S., Biswas, T.K., Blackwell, J. and Cooke, F.J. (2001). Management of salinity and sodicity in a land FILTER system for treating saline wastewater on a saline-sodic soil. *Aust. J. Soil Res*. **39**: 1247-1258

Jönsson, H. (2002). Urine separating sewage systems - environmental effects and resource usage. *Water Science and Technology* **46**(6-7):333–340.

JSWA (2002). Making Great Breakthroughs – All about the sewage works in Japan. Japan Sewage Works Association,, Tokyo. 56pp

Just, G. (2001). *Is your sewage effluent the sweetener in my coffee – one lump or two?* CD ROM, Australian Water Association 19th Convention, Canberra, paper 061, Australian Water Association, Sydney.

KBR (2003). *Balliang Recycled Water Project* – Feasibility study consolidated summary, Kellogg Brown and Root, Melbourne, Victoria, 31 March 2003

Keene, C.F. (2003). Water Desalination – Findings and Recommendations. Department of Water Resources, Sacramento, California, October 2003

Kidd, J. (2003). General Water Australia, Gerringong-Gerroa., pers. comm

Kirchmann, H., and Pettersson, S. (1995). Human urine - chemical composition and fertilizer use efficiency. *Fertilizer Research* **40**(2):149-154.

Kirk, M., Rouch, G. and Veitch, M. (1999). *What happens in an outbreak of waterborne disease? An historical look at the Sunbury Gastroenteritis outbreak*. Australian Water Association 18th Convention, Adelaide, 1999, paper 100, Australian Water Association, Sydney.

Krockenberger, M. (2003). Building our hopes and dreams. *Habitat* **31**: (1), 11-13, February 2003

Kroemer, T. (2003). Roxby Downs Council, Roxby Downs, SA, pers. comm.

Langdon A. (2003). Ministry of Energy, Utilities and Sustainability, Parramatta, NSW, pers. comm.

Langford, J. (2003). Australian Water Services Association, Melbourne, Vic., pers. comm..

Law, I.B. (2003). Advanced Reuse – From Windhoek to Singapore and beyond. *Water* **30**: (5) 31-36

Law, I., Leslie, G and Poon, J (2003). Recent trends in the use of membrane processes to reclaim municipal effluents CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 339, Australian Water Association, Sydney.

Lawrence, B. *et al.* (1998). *Reclaimed Water Scheme – Volume 1, Final Report.* Northern Wastewater Effluent Reuse Advisory Committee. Gold Coast City Council, September 1998. 134pp

Lazarova, V., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntau, H., Salgot, M. and Brissaud, F (2001). Role of water reuse for enhancing water management in Europe and Mediterranean countries. *Water Science and Technology* **43**:(10) 25-33

Ledger, R. (2003). SA EPA, Adelaide, SA, pers. comm.

Leslie, G., Lozier, J. and Law I. (2003). *Treatment technologies to produce Class A water and beyond.* CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Leslie, G (2004). University of NSW, Kensington, NSW. pers. comm.

Lever, M. (2003). Wide Bay Water, Hervey Bay, Q., pers. comm.

Lightbody, P. and Endley P. (2002). *Review of STEDS in South Australia.* Tonkin Consulting, Adelaide

Listowski, A. (2003). Sydney Olympic Park Authority, Homebush, pers. comm.

Lloyd, D. (2003). Sydney Water, Sydney, pers. comm.;

Loh, M., Coghlan, P and Hughes, G. (2003). *Domestic Water Use Study in Perth*. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 324, Australian Water Association, Sydney.

Loh, M. and Coghlan, P. (2003) Domestic Water use Study in Perth, Western Australia, 1998-2001. Water Corporation, WA, Perth, March 203,33pp.

Louisiana Legislature (2003). http://www.legis.state.la.us/leg_docs/03RS/CVT8/OUT/0000KTBK.PDF

LWA (2003). *Project VP14 - Use of reclaimed effluent water in Australian Horticulture*: Land and Water Australia, Canberra ACT

McKay, J. (2003). University of South Australia, Mawson Lakes, SA, pers. comm..

MacKenzie, W.R., Hoxie, N.J., Proctor, M.E., Gradus, M.S., Blair, K.A., Peterson, D.E., Kazmierczak, J.J., Addis, D.G., Fox. K.R., Rose, J.B. and Davis, J.P. (1994). A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply. *New England Journal of Medicine* **331** (3): 161, July 1994

Mallia, H (2003) Membrane technology for water recycling – Melbourne demonstration plant results. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 179, Australian Water Association, Sydney.

Mantovani, P., Asano, T., Chang, A and Okun, D.A. (2001). *Management practices for nonpotable water reuse*. Project 97-IRM-6, Water Environment Research Foundation, Alexandria VA

Marcous, W.M. (2000). Form letter to new Utility Customer, City of Sanford, Florida, September 1 2000

Marcous, W.M. and Porter, P.E. (1997). *Challenges of a Comprehensive Public Access System – The Sanford Experience*. City of Sanford, Sanford FL., 7pp

Marks, J., Cromar, N., Fallowfield, H., Oemcke, D. and Zadoroznyj, M. (2002).Community Experience and Perceptions of Water Use. 3rd World Water Congress of the IWA, Melbourne 7-12 April 2002, paper e20559a

Marks, R. (2004). Kellogg, Brown and Root Pty Ltd, Adelaide, SA, pers. comm..

Marks, R., Wright, C., Kracman, B. and Thomas, R. (1998). *Development of Australia's largest high quality effluent release scheme – Bolivar, SA.* 11th IWSA-ASPAC Conference, Sydney.

Marsalek, J, Schaefer, K, Excall, K, Brannen, L. and Aidun, B. (2002). *Water Reuse and Recycling*. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. CCME Linking Water Science to Policy Workshop Series. Report No. 3, 39pp

Martin, R., Clarke, D., Dennis, K., Graham, J., Dillon, P., Pavelic, P. and Barry, K. (2002). *Bolivar Water Reuse Project. - NHT Project 974517*. Report 2002/02, Department of Water, land and Biodiversity conservation, Adelaide, July 2002

Matheson, W.E. (1972) *Bolivar effluent irrigation project. First progress report of investigations.* Department of Agriculture, South Australia, Soil Conservation Branch Report S10/74

Matheson, W.E. and Lobban, B.L. (1973) *Bolivar effluent irrigation project. Second progress report of investigations.* Department of Agriculture, South Australia, Soil Conservation Branch Report S10/74

Matheson, W.E. and Lobban, B.L. (1974). *Bolivar effluent irrigation project. Third progress report of investigations*. Department of Agriculture, South Australia, Soil Conservation Branch Report S10/74

McClelland, P. (1998). *Sydney Water Inquiry – Fifth Report – Final Report.* Sydney Water Inquiry Secretariat New South Wales. Premier's Department, Sydney NSW http://www.premiers.nsw.gov.au/pubs.htm .

McDonald, B. (2002). Reuse recycling pps. http://www.melbournewater.com.au/applications/library/wsud/presentations/

McEwan, B., (1998). *Indirect potable reuse of Reclaimed Water*. In T Asano Ed., *Wastewater Reclamation and Reuse*, Ch 27. Technomic Publishing, Lancaster, PA

McFarlane, D. (2003). Water & Rivers Commission, Perth, WA, pers. comm.

McGregor, D. (2003a). *The Water Industry in Regional NSW – Current and Future Directions*, CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 310, Australian Water Association, Sydney.

McGregor, D. (2003b*). Water Conservation Strategy*. Albury Water, Albury, 123pp

McGregor, D. (2004). Albury Water, Albury, NSW, pers. comm.

McKay, J and Hurliman, A. (2003). Attitudes to reclaimed water for domestic use: Part 1. Age. *Water* **30** (5):42-45, August 2003

McLean, J. (2003). Aurora integrated water management for a new sustainable suburb. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 076, Australian Water Association, Sydney.

Meakes, R. (2002). *Community Feedback from metropolitan Water Forums.* In: Our Water Future, Proceedings, Western Australia's Water Symposium, Parliament House, Perth, 1-7 October 2002

Melbourne Water (2002a). *Melbourne Water Environment Review*, Melbourne Water Corporation, East Melbourne

Melbourne Water (2002b). http://www.melbournewater.com.au/content/library/wsud/case_studies/inkerman_oasis.pdf

Melbourne Water (2003). *Drought relief, a new water source.* http://www.melbournewater.com.au/content/water_cycle/environmental_sustainability/drought_relief/

Miller, G.G. (2003). *A bill to amend the* Safe Drinking Water Act *to provide for claims relating to drinking water*. 108Th U.S. Congress, 1st session, HR 306, House of Representatives, January 8 2003. www.theorator.com/bills108/hr306.html

Millis, N. (2002). *The Melbourne Experience: Planning Future Water Resources*. In: Our Water Future, Proceedings, Western Australia's Water Symposium, Parliament House, Perth, 1-7 October 2002

Mills, R.A. and Asano, T. (1996) A retrospective assessment of water reclamation projects. Water Science and Technology **33:**(10-11) 59-70

Mills, R.A. and Asano, T. (1998). *Planning and Analysis of Water Reuse Projects.* In T Asano Ed., *Wastewater Reclamation and Reuse*, Ch 2. Technomic Publishing, Lancaster, PA

Mills, W.R. (2000). *Orange County Water District takes a proactive stance on newly regulated compound – N-nitrosomethylamine.* Press Statement, Orange County Water District, Los Angeles, CA, 9 June 2000, www.ocwd.com/_html/_pr/_pr00/pr00_0609.ndma.htm

Mills, W.R. (2002). *Orange County Water District takes a proactive stance on contaminants of concern* – Press release, Orange Country Water District, January 29 2002 www.ocwd.com/_html/_pr/_pr02/pr02_0129_dioxane.htm

Mills, W.R. (2003). *Indirect potable wastewater recycling in California.* Water Recycling Workshop, WA Water Corporation, Perth, June 25-26 2003 www.watercorporation.com.au/waterrecyclingworkshop/Bill%20Mills_Indirect%20Potable.ppt

Mitch W.A., Gerecke A.C. and Sedlak D.L. (2003) A *N*-Nitrosodimethylamine (NDMA) precursor analysis for chlorination of water and wastewater. *Water Research* **37,** 3733-3741.

Mitchell, V.G., Mein, R.G. and McMahon, T.A. (2002). Utilising stormwater and wastewater resources in Urban Areas. *Australian Journal of Water Resources* **6** (1): 31-43

Mitchell, V.G., Shipton, R.J. and Gray, S.R. (2003). Assessing innovative urban water servicing options for a Greenfield development site in Brisbane. *Aust. J. Water Res.* **7** (2):139-154

Mitrevsk, B. (2003). Urban and Regional Land Corporation, Melbourne, Victoria, pers. comm.

Mobbs, M (1998). *Sustainable House,* 1998, Choicebooks, Australian Consumers Association. Marrickville NSW

Moore, W (2003). Shoalhaven Water, Nowra, NSW, pers. comm.

Myers, B.J., Bond, W.J., Benyon, R.G., Falkiner, R.A., Polglase, P.J., Smith, C.J., Snow, V.O. and Theiveyanathan, S. (1999). Sustainable Effluent-Irrigated Plantations: An Australian Guideline. CSIRO Forestry and Forest Products, Canberra, ACT., 293pp

Nancarrow, B.E., Kaercher, J. D., Po, M. and Syme, G.J. (2003). *Social values and impact study – South West Yarragadee Blackwood Groundwater Study. The results of the South West and Perth Community Surveys*. Australian Centre for Water in Society, CSIRO Land and Water, Perth, July 2003, 84pp

NCC (1998). Compendium of National Competition Policy Agreements, Second edition. National Competition Council, Melbourne, Victoria. June 1998

NCC (2001) *2001 NCP Assessment – Ch. 8 Water*. National Competition Council, Melbourne

Newell, B., Molloy, R. and Fox, D. (1999). *Environmental Impact Assessment and Review of Effluent Disposal Options for Eastern Treatment Plant. Final Report June 1999*. CSIRO Environmental Projects Office, Canberra. 67pp

NHMRC. (1996). *Australian Drinking Water Guidelines.* National Water Quality Management Strategy. National Health and Medical Research Council and Agricultural and Natural Resources Council of Australia and New Zealand, Canberra..

Nicholson, B and Ying, G-G. (2003). *Attenuation of disinfection by-products (DBPS) during aquifer storage and recovery (ASR).* In: Dillon, P. Toze, S., Pavelic, P., Skjemstad, J., Davis, G., Miller, R., Correll, R., Kookana, R., Ying G.-G., Herczeg, A., Filderbrandt S., Banning, N., Gordon, C., Wall, K., Nicholson, B., Vanderzalm, J., Le Gal La Salle, C., Gibert, M., Ingrand, V., Guinamant, J-L., Stuyfzand, P., Prommer, H., Greskowiak, J., Swift, R., Hayes, M., O'Hara, G., Mee, B., Johnson, I. (2003). Water Quality Improvements During Aquifer Storage and Recovery, Vol 1. Water Quality Improvement Processes, Ch . 5. AWWARF Project 2618, Final Report (in press) 347pp.

NIWA (2004). *Advanced Pond Systems.* New Zealand Institute for Water at Atmospheric Research, Wellington, NZ.. http://www.niwa.co.nz/rc/pollution/aps

NLWRA (2001). *Australian Water Resources Assessment 2000*. National Land and Water Resources Audit, Canberra

NLWRA (2002). *Australia's natural resources 1997-2002 and beyond*. National Land and Water Resources Audit, Canberra ACT

Nott, R. (2003). Dept of Environment and Heritage, Canberra, ACT, pers. comm.

NRC (1998). *Issues in potable reuse: The viability of augmenting drinking water supplies with reclaimed water.* National Research Council, U.S.A., National Academy Press, Washington, D.C.

NSW Recycled Water Coordination Committee (1993). NSW Guidelines for urban and residential use of reclaimed water.

NWQMS, (2000). *Guidelines for Sewerage Systems – Use of Reclaimed Water.* National Water Quality Management Strategy, ARMCANZ, ANZECC, NHMRC, Canberra, November 2000

Odendaal, P.E., van der Westhizen, J.L.J. and Grobler, G.J. (1998). *Wastewater Reuse in South Africa.* In T Asano Ed., *Wastewater Reclamation and Reuse*, Ch 25. Technomic Publishing, Lancaster, PA

Ong Choon Nam *et al.* (2002). Singapore Water Reclamation Study – Expert Panel Review and Findings June 2002, http://www.pub.gov.sg/NEWater_files/download/review.PDF

Ogoshi, M, Suzuki, Y and Asano, T (2001). Water reuse in Japan. *Water Science and Technology*, **43** (10), 17-23

Owens, L. (2003). Essential Services Commission, Adelaide, SA, pers. comm.

Palmer, G. (2003). Calaqua, Caloundra, Q., pers. comm.

Palmer, N., Lightbody, P., Fallowfield, H and Harvey, B. (1999). *Australia's most successful alternative to sewerage:South Australia's Septic Tank Effluent Disposal Schemes.* Australian Water Association 18th Convention, Adelaide, Australian Water Association, Sydney.

Perkins, P., Richmond. K., Davis. J., Dymke., J. and Wijeratne, A. (2003). ACTEW and the Public-Private Partnership model – Two years on. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 251, Australian Water Association, Sydney.

Pitman, C. (2003). Stormwater harvesting and utilisation. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Planning NSW (2003). BASIX - The Sustainability Index, http://www.planning.nsw.gov.au/settingthedirection/basix.html

PM&C (2003). National Water Initiative – progress of the intergovernmental agreement on the National Water Initiative and the funding of the Murray Darling Basin. http://www.dpmc.gov.au/docs/national_water_initiative_progress.cfm

Power, K. (2003). NSW Health, Sydney NSW, pers. comm.

Price, M (2002), Who needs sustainability? in *Sustainable Groundwater Development*. Hiscock, K.M., Rivett, M.O. and Davison, R.M. (eds.) Geological Survey, London, Special Publications 193: 75-81.

Proctor, R, Ash, R. and Lehmann, R. (1999). *Advanced Sewage Reuse Scheme for Caboolture*. Australian Water Association 18th Convention, Canberra, Australian Water Association, Sydney.

Productivity Commission (1992). *Water Resources and Waste Water Disposal.* Report no 26, 17 July 1992. http://www.pc.gov.au/ic/inquiry/26water/finalreport/26water.pdf

Productivity Commission (2003). *Water rights arrangements in Australia and Overseas.* Commission Research Paper, Productivity Commission, Melbourne, October 2003

Queensland EPA (2002). *Springfield Water Recycling Demonstration Project*, Queensland Environmental Protection Agency, Brisbane,4 pp

Queensland EPA (2003). Advanced Water Recycling Demonstration Plant. Queensland Environmental protection Agency, Brisbane. http://www/epa.qld.gov.au/cgi-bin/w3-msq/environment/environment/suswater/msq1welcome.html

Radcliffe, J. (2003). An overview of water recycling in Australia – Results from the recent ATSE study. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Radcliffe, J. (2004). *Water Recycling in Australia – Arising Policy Issues.* Enviro04 Conference, Sydney, March 2004, Australian Water Association, Sydney.

Rathjen, D., Cullen, P., Ashbolt, N., Cunliffe, D., Langford, J., Listowski, A., McKay, J., Priestley, A. and Radcliffe, J. (2003). *Recycling water for our cities* Report to Prime Minister's Science, Engineering and Innovation Council, 28 November 2003

Reid, H. (2003). EPA Victoria, Melbourne, pers. comm.

Richardson, B. (2003). EPA NSW, Sydney, pers. comm

Richardson, C. S. (1985). Legal aspects of irrigation with reclaimed water in California. In Prettygrove, G. S. and Asano, T, (Eds) Irrigation with reclaimed municipal wastewater, a guidance manual. Lewis Publishers, Chelsea, MI USA

Ringham, J. (2003). SA Water, Adelaide, SA, pers. comm.

Roseth, N. (2003). Community views on alternative water supplies. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Rowe, D. and Magid, I. (1995) Handbook of Wastewater Reclamation and Reuse. Lewis Publishers, CRC Press, Boca Raton.

Safewaterreuse (2003). Cross Connection Incidents. Safe Water Reuse Foundation, San Diego CA., http://www.safewaterreuse.org/incidents.html

SA Water (2003). Penneshaw Desalination Plant. http://www.sawater.com.au/our_water_system/filtration/adelaide_penneshaw.html

Schuil, R. (2004). Sydney Water, Sydney, pers. comm.

Seaton. R., Jeffrey, P. Bosher C, and Hills, S (1999). Local Water Reuse. Designing and Managing the interface with the customer: Australian/UK Comparisons. Australian Water Association 18th Convention, Adelaide, Paper 147_164, Australian Water Association, Sydney.

Sedlak, D. (2004). University of California, Berley, CA., pers. comm..

Shanableh, A and Rahman, A. (2001). *Wastewater - an essential water source for the millennium: risk-based assessment.* Australian Water Association 19th Convention, Canberra, paper 073, Australian Water Association, Sydney

Sheikh, B. (2003). Indirect potable reuse through groundwater recharge and surface water augmentation: The gold standard of water recycling for California, p. CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Shinoda, T. (1999). *Integrated approaches for efficient water use in Fukuoka*. In: Proceedings of an international Symposium on efficient water use in urban areas – innovative ways of finding water for cities. UNEP International Environment Centre, Kobe, 8-10 June 1999.

Shuval, H.I. (2003). Hebrew University of Jerusalem, pers. comm.

Sickerdick, L and Desmier, R. (2000). Uses of Reclaimed Water from SA Water's Wastewater Treatment Plants. In: Water Recycling Australia, P.J. Dillon, Ed, CSIRO and AWA, Canberra ACT

Simpson, J (2002). *Overcoming the Barriers to change in the Water Industry – the importance of Water Education* Utilicon, Melbourne 2002

SKM (2002). Victorian water recycling strategy – Issues & options report, final. Sinclair Knight Mertz, Armadale, Victoria August 2002

Smith, Simon. (2003). NSW EPA, Sydney, pers. comm.

Smith, Stephen, (2003). Onkaparinga Catchment Water Management Board, Aberfoyle Park, SA, pers. comm.).

Snow, J. (1855). *On the mode of Communication of Cholera*. Churchill: New Burlington Street London , England http://www.ph.ucla.edu/epi/snow/snowbook_a1.html

SoE (1996). Australia: State of the Environment. CSIRO, Collingwood, Victoria

SoE-SA (2003). State of the environment report for South Australia 2003 – Supplementary report. SA Environment Protection Agency, Adelaide.

Sorber, C. (1982) Public Health Aspects of Agricultural Reuse Applications of Wastewater. Municipal wastewater Reuse News, AWWA Research Foundation, American Water Works Association, Denver, Colorado, 57, pp.5-10.

Spinks, AT., Dunstan, R.H., Coombes, P. and Kucsera, G. (2003). *Thermal destruction analyses of water related patrhogens at domestic hot water system temperatures.* 28th International Hydrology and Water Resources Symposium, Institution of Engineers, Australia, Wollongong, 10-14 November 2003

SSB (2003). Sewerage Service in Sapporo. City of Sapporo - Sapporo Sewerage Bureau, Sapporo. 8pp.

State of California (2001). Statutes (http://www.leginfo.ca.gov/) and Regulations (http://ccr.oal.ca.gov/)

State of California (2003a). California Codes – Water code Section 13050, subdivision (n).(http://www.leginfo.ca.gov/)

State of California (2003b). California Codes – Water code Section 13550, subdivision (a).(http://www.leginfo.ca.gov/)

Stevens, D et al. (2002) Groundwater on the Northern Adelaide Plains: prioritising research and related communication requirements. Conference record, Waite campus, November 28 2002

Stone, B. (2002). Report – *Prevalence of infections in cuts and abrasions while playing football or training on ovals where treated wastewater is spray irrigated*. Internal Memorandum to Acting Director Environmental Health, Department of Health, WA, 31 October 2002, ref 6337/02

Sydney Water. (1999). *Community Views on Re-cycled Water*. Sydney Water Research Report.

Sydney Water (2002) Towards sustainability report 2002 summary. Sydney Water, Sydney, NSW.

Sydney Water (2003a). *Annual Report 2002-3.* Sydney Water Corporation, Sydney,

Sydney Water (2003b). *Georges River Program, State 2 – Environmental Impact Statement Summary* Sydney Water Corporation, Sydney, April 2003.

Sydney Water (2003c). http://www.sydneywater.com.au/everydropcounts/garden/rainwater_tanks.cfm

Syme, G.J. (2002). Balancing Community Values, needs and water-use. In: Our Water Future, Proceedings, Western Australia's Water Symposium, Parliament House, Perth, 1-7 October 2002

Takeishi, H. (1999). Making effective use of sewerage resources in Yokohama. Australian Water Association 18th Convention, Adelaide, paper 64_68. Australian Water Association, Sydney.

Takizawa, S (2002). *Water reuse for Agriculture and Aquaculture in Hanoi, Vietnam.* In: International Water Management Institute – E-Conference "Agricultural use of untreated urban wastewater in low income countries. 24 June – 5 July 2002. http://www.ruaf.org/conference/wastewater/english/papers/proper_man/takizawa.doc

Taylor, M. and Dalton, R. (2003). Water Resources – Managing the future. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 351, Australian Water Association, Sydney.

Templeman, G. (2003). Willunga Basin Water Co., McLaren Vale, SA, pers. comm..

Thwaites, J. (2004). *Go ahead for Eastern Irrigation Scheme*. Press release, Minister for Water, Melbourne, 8 January 2004

Thomas, K., Fallowfield, H. Cromar, N. and Bosher, C. (2000) *Residential water recycling: quantity and quality aspects*. In: Water Recycling Australia, P.J. Dillon (ed) CSIRO Canberra. Pp17-21

Tokyo Metropolitan Government (2001a). Bureau of City Planning, Tokyo Metropolitan Government, http://www.toshikei.metro.tokyo.jp/plan/pe-017.htm

Tokyo Metropolitan Government (2001b). Bureau of City Planning, Tokyo Metropolitan Government, http://www.toshikei.metro.tokyo.jp/plan/pdf/pdf-120-g.pdf#zoom=100

Tokyo Metropolitan Government (2002). Waterworks Bureau, Tokyo Metropolitan Government. http://www.waterworks.metro.tokyo.jp/eng/supply/supply_12.htm

Toze, S (2003). Natural Disinfection Processes For Reclaimed Water – Soil, Sun, Ponds And Aquifers CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

Toze, S., Hanna, J., Smith, A and Hick W. (2002). Halls Head indirect treated wastewater – a report to the Water Corporation Western Australia. CSIRO Land and Water, Perth, October 2002, 106pp

Turner, N. (2003). *Water recycling around the World and at Home. Sustainability and Water* – Water Recycling Workshop, WA Water Corporation, Perth, June 25-26 2003, http://www.watercorporation.com.au/waterrecyclingworkshop/NICKTURNER_JUNEWORKSH.pdf

Turner, N., Davies, G. and Ryan, C. (2003).Reclaimed Water - Towards a sustainable city for Perth. CD ROM, Australian Water Association 20th Convention, Perth, April 2003, paper 184, Australian Water Association, Sydney.

UNEP-IETC (2000). *International source book on environmentally sound technologies for wastewater and stormwater management.* United Nations Environment Program – International Environmental Technology Centre, Osaka Japan. http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-15/main_index.asp

Urban and Regional Land Corporation (2002), *Annual report 2001*. Urban and Regional Land Corporation, Melbourne.

USA Today (2003). http://www.usatoday.com/news/offbeat/2003-08-01-water_x.htm

US EPA (1992). Guidelines for water reuse. EPA 625/R-92/004, United States Environment Protection Agency, Washington, D.C.

US EPA (2002). "Water recycling and reuse: The environmental benefits. http://www.epa.gov/region9/water/recycling/

Van der Wel, B. (2000). Increasing the viability of urban runoff and sewage effluent as supplementary sources of water in country towns of South Australia. *Australian Journal of Water Resources* **4** (2) 89-97. The Institution of Engineers, Australia.

WA Water Corporation (2000). *Perth metropolitan wastewater system* - Wastewater Happens bulletin no 8, WA Water Corporation, Perth, July 2000.

Wajon, J., Kenaway, S. and Maus, A. (1999). Evaluation of the reuse of wastewater in Perth for the irrigation of parks, gardens and golf courses. Australian Water Association 18th Convention, Adelaide, paper 175_196, Australian Water Association, Sydney.

Wall, G.C., Anderson, B., Evans, A.J., and Donlon, P.C. (2001) Tatura Wastewater Treatment Plant upgrade . A coordinated community approach. Australian Water Association 19th Convention, Canberra, paper 094, Australian Water Association, Sydney.

Water Directorate (2000). Survey of NSW Local Government effluent and biosolids reuse 2000, prepared for NSW Local Government Water Industry Directorate. NSW Department of Public Works and Services, Sydney, NSW

Wedge, J. (2003). A redundant approach to drought-proof water supplies: California's case study *Water Conditioning & Purification*, December 2003

Wells, D. (2001). *Queensland Water Recycling Strategy*. Environmental Protection Agency, Brisbane, October 2001

Western Water (2002). SA Tour shows value of recycled water for farming ventures and environment. *Recycled Water News*, September 2000, Western Water, Gisborne, Victoria.

WHO (1973) *Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards. Technical Report Series Number 517, World Health Organisation*, Geneva.

WHO (1989). *Health Guidelines for use of Wastewater in Agriculture and Aquaculture*. Report of a WHO Scientific Group, Geneva, Switzerland.

Wilf, M. (1998). *Reverse Osmosis Membranes for wastewater reclamation*. In T Asano Ed., *Wastewater Reclamation and Reuse*, Ch 7. Technomic Publishing, Lancaster, PA

Williams, R. (1996). Reclaimed water reuse in residential and commercial situations. Report to the Churchill Fellowship Trust, Canberra, 156pp.

Woolley, R. (2003). Brisbane City Council, Brisbane, Q., pers. comm.

Workman, G., Herbert, R. and Tink, G. (2003). *Overview Of Plumbing Legislation Reform Needed For Urban Water Recycling.* CD-ROM, Water Recycling Australia, 2nd National Conference 1-3 September, 2003 Brisbane. Australian Water Association, Sydney.

WRC (1998). Manual for Managing Urban Stormwater Quality in WA. Waters and Rivers Commission, Perth.

WRC (2003). Urban stormwater management in WA – Principles and Objectives. Water and Rivers Commission, Perth, 6pp

Wright, C. (2003). Earth Tech, Melbourne, Victoria, pers. comm.

WSAA (2001). *WSAAfacts.* Water Services Association of Australia, Melbourne

WSUD (2003) Water Sensitive Urban Design in the Sydney Region. CD-ROM, Upper Parramatta River Catchment Trust, Sydney Coastal Councils Group, Western Sydney Regional Organisation of Councils, Sydney.

Yeomans, W. (2004) Hunter Water, Newcastle, NSW, pers. comm

YVW (2003). *Reuse status report.* Yarra Valley Water, Mitcham, Victoria. March 2003

Zulfic, H. (2002) Northern Adelaide Plains prescribed wells area groundwater monitoring status report 2002. Department of Water, Land and Biodiversity Conservation, Adelaide, SA, Report 2002/14

INDEX