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**FACULTY OF ENGINEERING, COMPUTER & MATHEMATICAL SCIENCES**
**School of Civil and Environmental Engineering**

# The Challenge of Implementing Water Harvesting and Reuse in South Australian Towns


Photo. Rabone (1993)
Photo. Rabone (2000)

**School Oval at Coober Pedy, South Australia**

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Thesis submitted for the degree of
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# Dedication Page

*This work is dedicated to*

- *wise management of the use of all*

  *South Australia's water resources,*

- *my family,*

  *for love, patience and support,*

- *my friends and colleagues,*

  *who refused to let me give up.*

# Abstract to Thesis

Water is precious, particularly in South Australia, the driest State in Australia, with over 80% of its land area receiving less than 250mm of rainfall per year. Security of water supply has always played a critical role in the economic and social development of South Australia, and will continue to do so while dependency on water from the River Murray is so high and there is competition over this from states and for different uses – municipal, irrigation, industry, and the environment. The drive towards sustainable development has evolved to attenuate overconsumption of the world's natural resources of which water is a key element.

Provision of reliable water supplies to regional South Australia has always presented challenges, given the vast distances involved and the limited number of natural water sources. Despite these, a majority of South Australians enjoy the benefit of a reliable and safe water supply, adequate waste disposal system, good community health and high standard of living. A challenge remains to determine the sustainability of current major water pipe transfer systems from remote resources to small communities. There may be scope for managing existing water supplies more effectively and further developing local water harvesting and reuse solutions to minimise the need for more significant infrastructure investment.

This study investigates the challenges and opportunities for extending development of non-potable (secondary) water supply schemes in South Australian towns. These schemes will conserve the State's freshwater resources. The primary focus of this study is harnessing stormwater runoff and treated effluent generated by normal township development to supplement higher quality public water for uses such as irrigation of public areas and sporting fields in country areas. Water harvesting and reuse is not likely to occur due to some technological breakthrough but through application of known technology and the adoption of water conscious ethics by society. However, it is a sensible reality for the South Australian climate, particularly when coupled with appropriate conservation and suitable landscaping practices. Thus, the major theme of this study is information sharing since if people are familiar with and understand the concepts then more communities may be encouraged to develop their resources.

Water reuse has proven to be a beneficial strategy for addressing stormwater runoff and wastewater disposal problems and alleviating localised water supply problems for several South Australian towns and communities. The existing projects demonstrate both the strong community-based and innovative approach to water resources management in this state. They are inherently simple in form, and can often be assembled with readily available materials by people with a basic understanding of plumbing and construction skills (locally available). The potential for localised water harvesting and reuse in South Australian towns is generally limited to single purpose communal non-potable systems. Further, it is likely to only be sustainable in rural communities willing to make a commitment to its long term, proper operation and maintenance, or they could endanger public health.

# Statement of Originality

This work does not contain material which has been accepted for the award of any other Degree or Diploma in a University or other tertiary institution and to the best of my knowledge and belief, does not contain material previously published or written by any other person, except where due reference has been made in the text.

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*Fiona Ann Rabone*

Date: 18/11/2006

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> *"On with it, then, finish the job! Be as eager to finish it as you were to plan it, and do it with what you now have."*
>
> 2 Corinthians 8:11

Of all the things I have done, none have used up so much kindness, grace and patience from my family and friends. The people whose names follow all gave generously of their time, energy and intellect and as a result of their combined efforts make me appear smarter than I am. Without their knowledge and input, this thesis could not have been written.

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I trust that the contents of this document will form a valuable part of the body of knowledge existing on water reuse in South Australian towns to justify the level of support I have received.

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# Abbreviations & Symbols

| | |
|---|---|
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| ARMCANZ | Agricultural Resource Management Council of Australia and New Zealand |
| ASR | Aquifer Storage and Recovery |
| BOOT | Build, own, operate and transfer |
| COA | Commonwealth of Australia |
| COAG | Council of Australian Governments |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CSO | Community Service Obligations |
| CWMB | Catchment Water Management Board |
| DENR | Department of Environment and Natural Resources, SA |
| EC | Electrical conductivity: 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25 degrees Celsius |
| EPA | Environment Protection Agency |
| ESD | Ecologically Sustainable Development |
| EWS | Engineering and Water Supply Department (now SA Water) |
| GL | Gigalitres: 1,000 million litres or 1 million cubic metres |
| ha | hectare (equivalent to 2.471 acres) |
| kL | kilolitres: 1,000 litres or 1 cubic metre |
| km | kilometre (equivalent to 0.6214 miles) |
| MFP | Multi Function Polis |
| ML | Megalitres: 1 million litres or 1,000 cubic metres |
| ML/a | Megalitres per annum |
| NHMRC | National Health and Medical Research Council |
| NPV | Net present value |
| NWI | National Water Initiative |
| OECD | Organisation for Economic Co-operation and Development |
| PPP | Public-private partnerships |
| SAHC | South Australian Health Commission |
| STEDS | Septic Tank Effluent Disposal Scheme |
| SS | Suspended solids |
| TDS | Total dissolved solids |
| TKN | Total Kjeldhal Nitrogen |
| WSUDD | Water sensitive urban design and development |
| WTEDA | Water Treatment and Economic Development Agreement |
| WTP | Water treatment plant |
| WWTP | Wastewater treatment plant |
| WHO | World Health Organisation |
| WSAA | Water Services Association of Australia |

# PART I
# OUR WATER RESOURCES

**Aerial View of Coober Pedy, South Australia (Rabone 2003)**

# Chapter 1
# Introduction

*"Concerns for man and his fate must always form the chief interest of all technical endeavours. Never forget this in the midst of your diagrams and equations."*

ALBERT EINSTEIN

## 1.1 OVERVIEW

Water is a fundamental element of life on earth. Its conservation is of great environmental, economic, social and ethical importance. Australia needs to manage its freshwater resources wisely; reuse of treated effluent and urban stormwater runoff can play a role in achieving this. It has the potential to relieve pressure on the environment and make economic development more sustainable. Currently, less than 10% of the water used by urban and industrial consumers in Australia is recycled (Melbourne Water 2003). Increasing our sustainability involves changing the community's perception and cultural understanding, as well as meeting scientific and implementation challenges. The financial, hydrological, and sociological difficulties faced when attempting to implement water reuse or harvesting schemes are challenging to overcome. Water is a precious commodity, particularly in South Australia; the driest State in Australia. Over 80% of our land area receives less than 250mm of rainfall per year, compared with the national average of 450mm per year. Water from the River Murray plays a critical role in the life and economy of South Australia.

**Figure 1 Location of South Australia (TravelOnline.com)**

Due to the implementation of some successful non-potable water reuse projects in South Australia, opportunities are being pursued to increase the use of recycled, low quality water in both urban and country areas. As a result of the application of water restrictions in 2003, the first for more than forty years, accessing the potential benefits of local water harvesting and reuse has become more important. Many people see it as an investment in the future of South Australia and essential to our community's development.

## 1.2 OBJECTIVES OF THIS STUDY

Increasing the environmental awareness of local governments, businesses and the general community regarding water usage is vital. Gaining an increased understanding offers South Australia a unique opportunity to develop and manage non-potable water harvesting and reuse schemes for public parks, gardens and possibly in the commercial sector. The various challenges that must be overcome in order to achieve this goal are presented in order to assist communities in developing solutions. The key objectives of this research are:

### Objective 1: Assess viability of small-scale, non-potable water supplies

The primary aim of this thesis is to investigate the feasibility of developing a local, non-potable water supply for towns in South Australia, based on a review of the experiences of selected operational schemes. Relevant data was gathered to determine the challenges that prevent sustainable water usage being achieved. A significant intention was to promote awareness of the social, environmental and economic benefits of developing and sustaining localised water resources. The goal is to encourage communities to undertake an audit of local water resources as a starting point in identifying the availability and suitability of water supplies which could be accessed locally.

### Objective 2: Role in urban water supply performance

The secondary aim of this research is to objectively analyse the prospects of meeting part of South Australia's urban water demand with locally harvested and recycled water. Such practices may support the State in reducing its dependence on the River Murray, reduce pollution of surface waters associated with waste discharges from urban centres (ie. rivers and the ocean), and support population and economic growth. The intention of this review is to contribute to the effort of developing policies and practices that optimise existing and new infrastructure and provide best total value to the people of South Australia.

### Objective 3: Identify areas for further research and development

There are many challenges in implementing water harvesting and reuse schemes in regional and metropolitan South Australia. The identification of factors that prevent South Australia achieving positive outcomes in water reuse and harvesting projects is undertaken. This objective is tightly linked with the others and is considered concurrently throughout the study.

## 1.3 SCOPE OF RESEARCH

This study reviews the practicality of, and limitations associated with, the development of local community water harvesting and reuse projects in South Australia. It also looks at how these schemes can be delivered in a way that safeguards public health, minimises detrimental impacts on the environment and improves the standard of living or amenity in the community. The principal water resources considered are:

- harvested stormwater runoff from urban areas; and
- reused treated wastewater effluent (sewage).

The study excludes water harvesting and reuse at the individual domestic householder level. However, many of the principles discussed are applicable to all scales of planning and development, from the single family residence to the design and layout of subdivisions and entire communities.

## 1.4 TOPICS OF REVIEW

The following topics were investigated for the purpose of developing this research:

- The technical, commercial and social issues that need to be addressed by communities in order to sustainably develop their local water resources through water harvesting and reuse;
- The relationship between regional rainfall and evaporation rates, water consumption, wastewater reuse, local hydrology, proximity to major supply pipelines and town planning in determining the hydrological feasibility of water harvesting and reuse schemes;
- The use of various existing township infrastructures such as roads, kerbs and stormwater drains to assist in the economical implementation of water reuse schemes in small urban centres;
- The significance of support from township communities and businesses in the successful establishment, operation and maintenance of water harvesting and reuse projects;
- The importance of data collection in enabling a complete and comprehensive design of a water harvesting and reuse scheme as well as ongoing system monitoring to ensure the scheme meets expectations and operating efficiencies; and
- The role of building capacity for individual's and organisation's '*water wisdom*'; advancing long-term adjustment in our society's values and water use culture. I aim to encourage water-saving policies and practices.

A major theme of the research is the importance of information sharing, as if everyone is familiar with and understands the facts regarding water harvesting and reuse they will encourage and support the development of these resources. Not all water needs to be drinking quality, and existing social infrastructure may be able to be more beneficially used.

## 1.5 STUDY OUTCOMES

The outcomes of the research are as follows:

- Identification of a process that can be used by communities to identify the challenges that will be faced and assess the potential for implementing a safe water harvesting and reuse scheme, based on their collective regional knowledge and experiences;
- Development of guiding principles to help community groups make informed decisions about sustaining and developing their local non-potable water resources; and
- Establishment of key recommendations for developing more effective, efficient and sustainable water services in urban centres in South Australia, with special emphasis on the potential of small-scale water harvesting and reuse in towns.

## 1.6 STRUCTURE OF THESIS

This thesis has been organised into three parts as shown in Figure 2. The structure adopted has resulted in some information from selected South Australian case studies being presented more than once. Experiences drawn from the case studies are incorporated into the feasibility assessment framework discussed in Part I as well as in the detailed write up of selected case studies in Part II which could be published independently as a community reference.

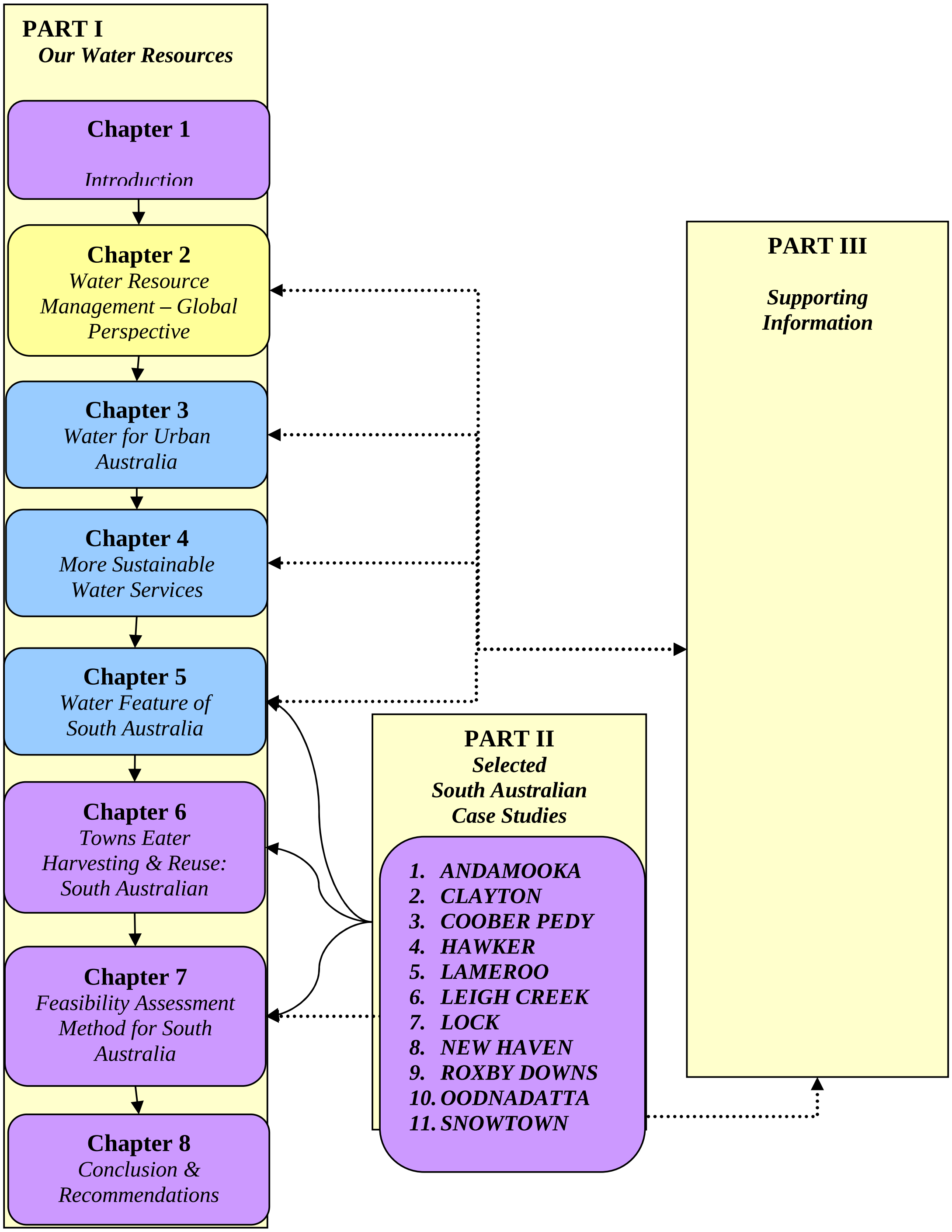


**Figure 2 Structure of Thesis**

### 1.6.1 Part I – Water Harvesting & Reuse Potential

Part I of the thesis, forming the main body of research, consists of eight chapters.

- Chapter 1 provides an introduction to the research into the potential for water harvesting and reuse in country towns in South Australia.

- Chapter 2 contextualises water globally and summarises issues related to the equitable allocation and sustainable use of the world's limited natural freshwater resources; broadly comments on philosophical elements of water use and raises questions involving the resolution of complex ethical matters.

- Chapter 3 describes the water industry in Australia and reflects on whether urban centres in Australia are using water in ways and quantities, that are sustainable. This chapter explores the influence that the prevailing climate of a region has on the water demand pattern. Special emphasis is given to the impact of ongoing national reform within the water industry, which is anticipated to move us closer to sustainability.

- Chapter 4 sets the scene for achieving more sustainable water infrastructure and services in Australia's growing urban centres, while maintaining a high level of service provision. Key issues discussed include; demand management (ie. water efficiency and conservation), supply augmentation (including natural and recycled), water sensitive urban design and development (including policies and practices), and the promise of technology. It raises question regarding when the transformation of existing systems and infrastructure, (often with an asset life between 50 and 100 years) to more modern technology should occur, making way for more sustainable practices.

- Chapter 5 reviews the interwoven social and political history in South Australia regarding the development of water, wastewater and stormwater services. It presents a summary of the development level of South Australia's water resources and what this means for water harvesting and reuse in the future. The impact of national policy on water use trends and patterns is examined.

- Chapter 6 presents findings from reviewing the challenges and opportunities faced by a number of South Australian communities that have developed local water harvesting and reuse projects. Considerable success has already been achieved with the development and use of urban stormwater and treated wastewater in rural communities.

- Chapter 7 examines practices that can assist in achieving successful water reuse and harvesting schemes, including extensive feasibility studies and clear communication with members of the general community. This chapter sets out an approach for assessing the challenges and feasibility of developing a local, non-potable water supply in order to make decision making easier. It also identifies that although technical feasibility and planning are vital, community relations are another key in achieving optimal outcomes.
- Chapter 8 presents the conclusions and recommendations arising from the investigation into the challenges and potential for local water harvesting and reuse projects in regional South Australia.

At the conclusion of Part I there is a bibliography which summarises the literature reviewed during the course of this research.

### 1.6.2 Part II Selected South Australian Case Studies

A major obstacle to the research and development of small, localised water harvesting and reuse schemes has been the difficulty in obtaining operational data and information about existing projects, some of which have been operating for over 20 years. Part II seeks to address this issue and provides a comprehensive account of the South Australian case studies reviewed. This information was assembled with the assistance of local people operating schemes in the towns, from field visits and from published literature (where this exists). This review provides insight into the feasibility of developing water harvesting and reuse for country towns in South Australia. Fundamental issues which arose from these studies are described in Chapter 6 and form the basis of the feasibility assessment and planning process presented in Chapter 7. The information presented in Part II is a subset of the research work that could be published independently as a community reference.

### 1.6.3 Part III- Supporting Information

Part III provides additional detail in the form of appendices to support principles discussed in Part I. Several appendices set out data, statistics, and analyses in a tabulated form for a number of towns (across all prevailing climate conditions in South Australia). The information presented includes average monthly rainfall, evaporation, runoff and irrigation requirements as well as historical water consumption data and population information for these towns. This information may be used to assist in assessing the feasibility of local water harvesting and reuse projects for non-potable uses.

# Chapter 2

# Water Resource Management – Global Perspective

> *"There is enough water in the world, but only if we change the way we manage it. The responsibility to act is ours for the benefit of present and future generations"*
>
> MINISTERIAL DECLARATION
> INTERNATIONAL CONFERENCE ON FRESHWATER (2001)

## 2.1 THE QUEST FOR WATER

Humans have always consumed freshwater and for many millennia human impact on water resources was insignificant and local in character. This resulted in the illusion that water resources were an inexhaustible, free-of-charge gift from the natural environment (Shiklomanov 1999) others believing it to be a gift from God. For example, Genesis 26 of the Bible depicts the relationship between water and ultimate security in the Promised Land (Starr 1993). Similarly, the Koran explicitly states that water is the most precious and valuable resource of the physical environment (Starr 1993). These ancient texts tend to indicate that those who governed millennia ago understood their spiritual connection to the water. Sadly, over time the sense of awe and responsibility has been lost.

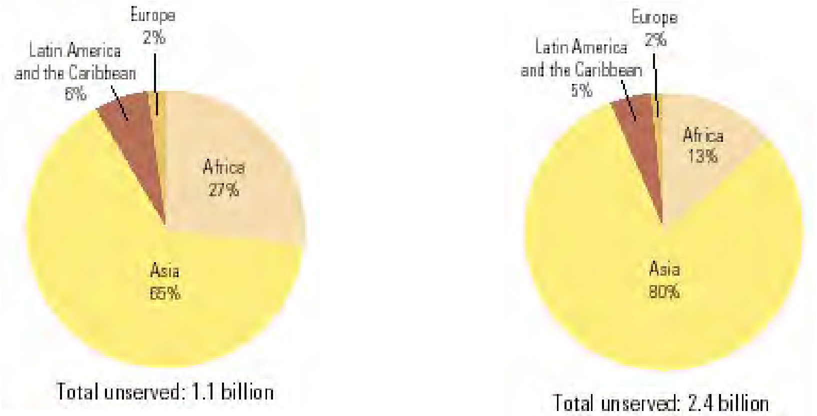
Water is the most widely distributed resource on our planet and is available in different forms and amounts everywhere on Earth. The total amount of water on our planet hasn't changed since the beginning of time, but it is highly susceptible to degradation if not used in a sustainable manner (Fleming 1999). Being both a social and economic good, water must be equitably and sustainably allocated, firstly to basic human needs, secondly to functioning of ecosystems and then to different economic uses.

Water is expected to be the most sought after natural resource in the 21st century, as continued growth of populations and economies is dependent on the quantity and quality of freshwater resources (Wolf 2003). Water is a key element to global sustainability, and is crucial to its social, economic and environmental dimensions (GTZ 2001; WHO 2003). Sustainable water resource management requires integrating appropriate water sensitive principles into the water supply, sanitation, irrigation and drainage sectors. This will involve different forms of service provision to awaken society's water consciousness.

Understanding this global perpective provides an important context for the need to recognise, and learn to overcome, the challenges of implementing water harvesting and reuse in our own region.

## 2.2 WATER: A HUMAN RIGHT

From the beginning of the development of social infrastructure, it has been recognised that water, poverty and health are closely linked (Pigram 1986; GTZ 2001). The connection between polluted water and disease was proved by the state of London's sewers in the 1800s. At the beginning of the 21$^{st}$ century, of the world's population of approximately 6 billion, at least 1.1 billion people live in poverty without access to safe drinking water (AWA 2000; WHO 2003), and almost 2.4 billion have no access to proper sanitation (GTZ 2001). Figure 3 shows the distribution of populations without access to safe water supply and sanitation services. It should be noted that while Asia has the highest number of people unserved by either water supply or sanitation, proportionally this group is actually bigger in Africa due to the difference in population size between the two continents (UNESCO 2004).



**Drinking Water** **Sanitation**

*UNESCO (2004)*

**Figure 3 Distribution of Unserved Populations (UNESCO 2004)**

Safe and sufficient water and sanitation are basic human needs (Pigham 1986; GTZ 2001; WHO 2003). Providing reliable and safe water supplies, adequate waste disposal systems and a comprehensive education program can significantly improve the health of communities.

### *2.2.1 Human Rights*

Many argue that human rights documents would have explicitly included a right to water if it had been foreseen that reliable provision of a resource as fundamental as clean water would be so problematic (AWA 2000; Starr 2003). The right to the highest attainable standard of health was enshrined in the World Health Organisation's (WHO) constitution over 50 years ago, and recognised in article 12.1 of the International Covenant on Economic, Social and Cultural Rights (WHO 2003). This right extends to the underlying determinants of health; central among these are safe water and adequate sanitation. This link was recognised explicitly in an enquiry into the provision of water and sanitation services to Australia's indigenous communities (HREOC 2001):

> *"…satisfactory health is a precondition of the full enjoyment of almost all human rights and fundamental freedoms, water is crucial in a chain of factors affecting the fulfilment of other human rights, and the right to water is implied throughout many of the more wide ranging provision of the various instruments."*

Water rights, in theory, extend to all human beings (Starr 1993). Recognising water as a basic human need and a human right entitles everyone to sufficient, safe, physically accessible and affordable water and it must be enjoyed without discrimination and equally by men and women (WHO 2003). In the case of water, this minimal level includes ensuring people's access to enough water to prevent dehydration (WHO 2003).

### 2.2.2 *Sufficient Water*

The minimum amount of water required to sustain life ranges from about 2 litres per capita per day (Lpcd) in temperate climates to about 4.5 Lpcd for people in hot climates who carry out manual work (Howard & Bartram 2003 in WHO 2003). In addition, people need at least 2 litres of safe water per day for food preparation. Hazeltine and Bull (2003) also consider five litres of clean water as the minimum amount needed per person per day to sustain human life. Table 1 sets out the definition of different levels of access to water and the associated likely volume of water to be used adopted by the World Health Organisation.

**Table 1 Service Level & Quantity of Water Used (WHO 2003)**

| Service Level | Distance/Time | Likely Volume | Intervention Priority |
|---|---|---|---|
| **No access** | More than 1 kilometre/ more than 30 minutes round trip | Very Low (often less than 5 litres per capita per day) | **Very High**<br>Provision of basic level of service |
| **Basic Access** | Within 1 kilometre/ within 30 minutes round trip | Average unlikely to exceed approx. 20 litres per capita per day | **High**<br>Hygiene education<br>Provision of intermediate level of service |
| **Intermediate Access** | Water provided on-plot through at least one tap (yard level) | Average approx. 50 litres per capita per day | **Low**<br>Hygiene promotion still yields health gains<br>Encourage optimal access |
| **Optimal Access** | Supply of water through multiple taps within the house | Average of 100-200 litres per capita per day | **Very Low**<br>Hygiene promotion still yields health gains |

*Source: Howard & Bartram (2003) in WHO (2003)*

The recognised service levels span '*no access*' being less than 5 Lpcd to '*optimal access*' being 100-200 Lpcd. The global target for currently unserved populations (ie without access to sufficient water) is the provision of at least '*basic access*' being 20 Lpcd (WHO 2003). In Australia, most centres of population are connected to a reticulated water supply and therefore have '*optimal*' access. But there are areas where remote communities and individual households are responsible for providing their own water supplies. In these areas, provision of an assured supply of safe water is problematic due to isolation and the small size of the communities and lack of good quality water sources (Heyworth *et al*. 1998).

### 2.2.3 Safe Water

Lack of safe water is a cause of serious diseases such as diarrhoea, which kill over 2 million people every year, the vast majority being children in developing countries (WHO 2003). Increasing access to safe water provides water for drinking, food preparation and hygiene and encourages improved living conditions. Drinking water must be free of organisms that are capable of causing disease, such as those listed in Table 2 below, and from minerals and organic substances that could produce adverse physiological effects (AWWA 1990).

**Table 2 Waterborne Diseases**

| Waterborne disease [a] | Causative organism [b] | Source of organism in water | Symptom |
|---|---|---|---|
| Gastroenteritis | Multiple potentially causative organisms | Animal or human faeces | Acute diarrhoea and vomiting |
| Typhoid | *Salmonella typhosa* (bacteria) | Human faeces | Inflamed intestine, enlarged spleen, high temperature; can be fatal |
| Dysentery | *Shigella* (bacterial) | Human faeces | Diarrhoea; rarely fatal |
| Cholera | *Vibrio chloerae* (bacterial) | Human faeces | Vomiting, severe diarrhoea, rapid dehydration, mineral loss; often fatal |
| Infectious hepatitis | Virus | Human faeces, shellfish grown in polluted waters | Yellowed skin, enlarged liver, abdominal pain; lasts up to 4 months, seldom fatal |
| Amoebic dysentery | *Entamoeba histolytica* (protozoa) | Human faeces | Mild diarrhoea, chronic dysentery |
| *Cryptosporidiosis* | *C.parvum* (protozoa) | Animal or human faeces | Diarrhoea, abdominal discomfort, possibly fatal |
| *Giardiosis* | *Giardia lamblia* (protozoa) | Animal or human faeces | Diarrhoea, cramps, nausea and general weakness; lasts 1 week to 30 weeks, not fatal |

[a] All of the diseases listed can also be transmitted by means other than water.
[b] Not all of the organisms listed cause the associated waterborne disease.

*Source: American Water Works Association 1990 in Productivity Commission (2000)*

Water safety is an important aspect of protecting public health (GWP 2003). Many of the investments that the water industry makes are attempts at preventative health expenditure. However, the health of a community supplied with safe water does not necessarily improve if public health and wastewater disposal issues are neglected (Hazeltine & Bull 2003). Protection of public health is achieved by treatment processes that reduce concentrations of pathogenic bacteria, parasites and enteric viruses in the water (US EPA 1992; CCC 2003; Millis 2003). It is widely recognised by health and water authorities that providing safe water to small and rural communities is an ongoing challenge. Access to safe water in some small, remote and isolated communities is still a political concern in Australia.

### *2.2.4 Physically Accessible Water*

Many people in the world currently without access to safe potable water (refer Figure 3 above) will not realise the goal of water access at home in the short- or even medium-term. In many places water has to be collected from distant sources and it is generally women and children who perform this duty. Research has shown that, on average, households in rural Africa spend 26% of their time fetching water (DFID 2001 in WHO 2003). This work prevents women from spending time on more productive work in the home or elsewhere, or children may miss school. In addition, carrying heavy loads can sometimes cause spinal injuries. Circumstances such as these create great respect for water; people are water conscious and optimise its use.

Improved access gives the poor, especially women, control over basic aspects of their life (WSP 2003). Household consumption rises with convenience of physical access to water, ie. the number of taps connected to a central reticulated supply. This increase is often accompanied with a decline in social water consciousness; a combination of introducing people to new uses and infrastructure that supports use of abundant amounts of water at little or no charge. Example 1 below describes the decline in social water consciousness which occurred in countries in the Arabian Gulf. When deciding on the appropriate level of service of a water supply for a community in a developing country, Hazeltine & Bull (2003) suggest adopting the per capita daily water demand values set out Table 3. In addition, Hazeltine & Bull (2003) also support prohibiting the use of drinking water for garden watering in developing countries as it leads to an enormous water demand for non-essential purposes.

**Table 3 Influence of Physical Accessibility on Water Demand**

| **Level of Service** | **Per Capita Water Demand** |
|---|---|
| Supply with public hand pumps | 15 - 25 l/person per day |
| Supply with public standpipes | 20 - 30 l/person per day |
| Supply with yard connections | 40 - 80 l/person per day |
| Supply with multiple tap house connection | 80 -120 l/person per day |

*Source: Hazeltine & Bull (2003)*

**Example 1**

**Physically accessible water & water consciousness: Arabian Gulf**

*Akkad (1990) described the transformation of the Arabian Gulf societies from simple, traditional communities characterised by a subsistence economy and modest water development technology to a modern society with advanced technologies and affluent economy. Traditionally the rural areas outside the city initially develop their water supply and sewage disposal facilities on a private, house-by-house basis. People had great respect for water and their water needs were simple and matched their water development technologies. They were water conscious and tried to optimise its use.*

*This great societal value declined following the development of water systems. As an area became more developed and the population density increased community water systems emerged. Consequently, the previous interest in saving water diminished and has been replaced by an extravagant use of water as it became a readily available commodity. The average water demand in Saudi Arabian cities is estimated to be 322 litres per capita per day in 1990 and 358 litres per capita per day in the year 2000. The residential water consumption increases 40% if landscaping is maintained.*

*Source: Akkad 1990*

Many countries including Australia have experienced a similar decline in social water consciousness following the implementation of large-scale, centralised water supply systems which support an enormous water demand for non-essential purposes. However, education and pricing policies can act to moderate household consumption levels by encouraging changes in water use practices.

### 2.2.5 *Affordable Water*

The right to water specifically rules out exclusion from a needed service according to ability to pay, ie. water must be affordable for everyone (WHO 2003). It is a sad irony that it is often the poor who receive the least reliable quantity and quality of water supply must pay most per litre for their water – for example, from water vendors in the street (Katko 1991; WSP 2002). According to one recent estimate, the poor in developing countries pay on average 12 times more per litre of water than their counterparts who have a municipal supply (WHO 2003).

Equity demands that poorer households should not be disproportionately burdened with water expenses when compared with richer households (WHO 2003). Ensuring affordability of water requires that the service which is provided matches what people can pay. This may include the use of a range of appropriate low-cost techniques or technologies (with the potential for progressive upgrading) and appropriate pricing policies such as free or low-cost water and income supplements (GTZ 2001; WSP 2002; Hazeltine & Bull 2003).

#### 2.2.5.1 Willingness to Pay

The amount of money spent on resold and vended water demonstrates that consumers are able and willing to pay for reliable water service (Katko 1991; Garrett 1991; WHO 2003). Many countries accept the principle established at international conferences in Dublin and Rio in the 1990s, that the poor are willing to pay for good quality services and should be charged for them (WSP 2002). A user's willingness to pay for water supply may exceed actual water charges as well as full cost recovery, or alternatively, it may be far below full cost recovery (NFI 1991).

There is no need for the optimal charge to reflect the willingness to pay, except that the charge can not exceed the willingness to pay. Many countries with long histories of water supply subsidisation, including Australia, have faced significant political and social challenges in implementing such a pricing policy. Table 4 shows the unit cost of potable (drinking) water for various countries.

**Table 4 Cost of Potable (Drinking) Water in Selected Countries**

| Rank | Country | A$/kL |
|---|---|---|
| 1 | Germany | $2.93 |
| 2 | Denmark | $2.83 |
| 3 | United Kingdom | $2.02 |
| 4 | The Netherlands | $1.87 |
| 5 | France | $1.78 |
| 6 | Belgium | $1.68 |
| 7 | Italy | $1.19 |
| 8 | Spain | $1.17 |
| 9 | Finland | $1.06 |
| 10 | Sweden | $1.01 |
| 11 | Australia | $0.90 |
| 12 | United States | $0.89 |
| 13 | South Africa | $0.70 |
| 14 | Canada | $0.62 |

*Source: Irrigation Association of Australia (IAA) Website (2003). Original source E-Times, the electronic newsletter of the US Irrigation Association*

Water is affordable in Australia, particularly when compared to the price charged in other developed countries such as Germany, Denmark, and the United Kingdom. A fundamental consideration to system sustainability is the balance between affordability, cost recovery for the service and efficient use of resources. Achieving these objectives requires use of appropriate technologies, appropriate pricing structure and well as a willingness to charge for water use.

#### 2.2.5.2 Willingness to Charge

Cost recovery means the extent to which actual charges collected cover capital and recurrent costs of production, delivery and discharge of water. The concept covers anything from providing water completely free (zero cost recovery), to partial, full or more than full cost recovery and can be compatible with many different charging regimes (NFI 1991). Example 2 below describes a case where cost recovery for rural water supply in a low income country has been achieved.

**Example 2 Cost Recovery for Rural Water Supply: China**

*Rural water supply is a high priority for the central Government, which has received World Bank assistance of US$628 million for four successive rural water and sanitation projects in the last 17 years aimed at serving 23 million people in 18 provinces. While the central Government provided a 'basic' level of service, typically through hand pumps, rainwater collection systems and tube wells, the Bank assisted projects offered a higher level of service through piped water supply to individual households. It logically followed that the users had to pay more for these improved services.*

*In the context of the China projects the World Bank typically financed about half of the capital cost of piped water supply systems installed. The Bank made credit/loan to the central Government for a period of 35/20 years was 'on lent' to the provincial government after adding an additional 3-4% and reduced repayment period of 15 years. If the latter falls behind the central Government automatically deducts the debt service amount from routine transfers to the province. For the remaining upfront costs, the provincial and county governments jointly finance 25% and the users contribute 25%, usually in the form of a cash and labour combination.*

*Poverty was a major criterion used to select provinces and countries for these projects. Within the selected countries, denser areas were chosen to make the cost of supplying piped water economically viable. Since users also service the Bank debt through payment of the water tariff, they effectively finance 75% of the overall investment cost as well as 100% of operation and maintenance costs.*

*For more remote and less densely populated areas of the project provinces, however, the approach was to provide 'basic' level of service (similar to central Government). Debt servicing is not passed on to the consumers of these lower service level schemes. However, they still have to contribute the full cost of labour (typically 30-40% of the investment cost) and operate and maintain the schemes on their own.*

*Cost sharing by users has promoted financial sustainability to water supply systems. The costs appear to be affordable for these projects at around 3.5% to 4.0% of the average annual income. While most consumers can probably afford to pay the present level of water tariffs, the possibility of increases in future years could lead to problems in terms of affordability. This should be minimised as the Price Bureau regulate pricing to protect the interests of both consumer and provider.*

*Source: Water and Sanitation Program (2002)*

The Chinese Government has implemented partial user-financing (between 40% and 75%) of the overall capital cost as well as 100% of the ongoing operation and maintenance costs to inculcate the sense of "ownership" and responsibility for ongoing maintenance of the water supply and sanitation facilities. The key to the success of this example is that an increase in the level of service accompanied the additional costs as well as the government's willingness to price water services at a financially sustainable level. These conditions are not met in many other countries, including Australia, where subsidies are common in public utility services, especially between metropolitan and rural water supply systems (WSP 2002; Gomez-Ibanez 2003).

### *2.2.6 Government Obligations*

Regardless of a country's available resource, its government has an obligation to ensure that the minimum essential level of a right is realised. *The Right to Water* (WHO 2003) ascribes the following three duties to government.

#### 2.2.6.1 Duty of Respect: Not Going Backwards

The right to water may be realised, partially or fully, as a result of a person's own actions, government assistance or a combination of both. For example, where the means exists to obtain drinking water, such as government maintaining a water supply infrastructure system or providing social assistance to purchase water services, the removal of such mechanisms should not be permitted (with the exception of severe economic conditions or where an adequate alternative is available). A person must never be placed in a situation of having no water (WHO 2003).

#### 2.2.6.2 Duty to Protect: Regulation of Third Parties

Individuals and corporations have the potential to interfere with a person's or community's water supply. The duty to protect requires that governments diligently take all necessary steps to ensure that the sufficiency, safety, affordability and accessibility of water are protected from interference. For example, pollution from factories, farming or sewage can greatly damage the quality of water used by others for drinking. This will usually require a strong regulatory regime that should include independent monitoring, genuine public participation and imposition of penalties for non-compliance (WHO 2003).

#### 2.2.6.3 Duty to Fulfill: Going forward

This requires that governments take active steps to ensure that everyone enjoys the right in the shortest possible time. Steps may include the use of a range of appropriate low-cost technologies, education concerning hygienic use of water, protection of water sources and methods to minimise wastage (WHO 2003).

### *2.2.7 Other Stakeholders*

Governments have the primary responsibility for ensuring that the right to water is achieved, but the involvement of other stakeholders plays an important role. To guarantee that water is a human right, governments and local communities need to work together in its fulfilment. For example, individuals contribute financially, by way of payment of an affordable fee for connection to safe water and method of disposal of wastewater and in other ways (in kind) to ensure the realisation of their water rights (WHO 2003). Financial institutions play an important role through their financing and influence on the use of domestic resources by national authorities. Their influence may also contribute towards ensuring programs are non-discriminatory, viable and sustainable (WHO 2003).

## 2.3 NATURAL OCCURRENCE OF WATER

Water is the most widespread resource to be found in the natural environment and many human activities affect its distribution, quantity, and quality. The natural water cycle is a complex system; from the climate system that drives it and the materials that water flows across and through, to its modification by human activities. Nature has recycled and reused water for millions of years through the natural water cycle. The first step towards efficient and sustainable use of water is an understanding of the distribution of water, the natural water cycle and the mechanisms for transfer, storage and treatment to provide water to communities.

### *2.3.1 Water Distribution*

Water is available everywhere in different forms and amounts. Scientists believe that the total amount of water on Earth has remained almost exactly the same since the beginning of time (Burgess 1991; Starr 1993). However, while the total quantity of water on Earth never changes, the demands placed on it and associated pollution is increasing (Fleming 1999; Schoenfeldt 2000; GTZ 2001). For example, twenty-five nations are experiencing chronic water shortages and contaminated waters cause almost 80% of the illness in developing countries (Starr 1993). However, a key issue is that most of the Earth's water is non-potable (refer Figure 4).

Of the Earth’s water, 97.5% is salt water found primarily in the oceans that cover 75% of the earth's surface. Seawater, ice caps and brackish groundwater are large resources not currently utilised to the fullest, mainly because of limited technology and/or its cost effectiveness. The remaining 2.5% is freshwater, almost all of which is stored in the ice caps of Antarctica and Greenland, and as groundwater. Only 0.26% of the total amount of freshwater is renewable (active) and is concentrated in lakes, reservoirs and river systems where it is vital for water ecosystems as well as being easily accessible for use by society.

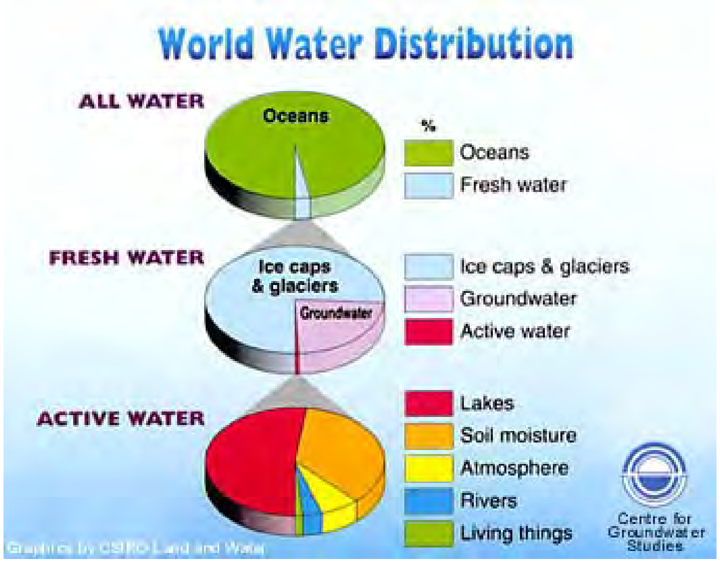


**Figure 4 World Water Distribution (Graphic by CSIRO)**

### 2.3.2 Distribution of Active Water

The management of water resources is further complicated by the fact that the active portion of the world's freshwater is not distributed equally across the continents as shown in Table 5. The distribution of water is influenced predominantly by climatic and geomorphological conditions.

**Table 5 Distribution of Rainfall & River Discharge for Continents**

| Country | Average Annual Rainfall | Average River Discharge |
|---|---|---|
| South America | 1,600 mm | 700 mm |
| North America | 800 mm | 320 mm |
| Europe | 800 mm | 250 mm |
| Africa | 750 mm | 120 mm |
| Asia | 640 mm | 250 mm |
| Australia | 450 mm | 40 mm |

*After Schoenfeldt (2000)*

Australia's average annual rainfall and river discharge are both significantly lower than that of other continents. On a global scale, Australia (together with Southern Africa) experiences higher runoff variability than any other continental area (McMahon & Mein 1986; MDBC 1997). Australia's climate, compounded by the variability of its rainfall, means that entire river systems are subject to considerable variation (fluctuation) in flow from one year to another. Despite these facts, many researchers (Clark 1987; GSA 1999; Schoenfeldt 2000) argue that Australia has enough water for present and future needs provided careful, flexible and innovative development of social infrastructure leads to sensible use of available water resources (ie. natural and recycled). The challenge will be to determine if Australia also has enough water to adequately allow for the natural environment to survive (ie. maintenance of a sustainable ecosystem).

### 2.3.3 Natural Water Cycle

It is important to understand the natural water cycle and the mechanisms for transfer, storage and treatment of water when studying questions of efficient and sustainable use of water. All water is part of the "natural water cycle", which is vital for sustaining the environment and human life. The natural water cycle describes the permanent movement and transformation of water. It connects living things with all elements of the environment in a manner that any changes result in a chain of consequences which spread throughout the ecological system (Jermar 1987). Figure 5 is a simplified illustration of the natural water cycle and the processes by which water continuously circulates from the oceans to the air, over the surface of the land and underground, and back to the oceans. This process consists of evaporation, precipitation (rain), interception by vegetation & evapotranspiration, surface storage, infiltration & percolation and surface runoff (streams, overland flow) and groundwater flow.

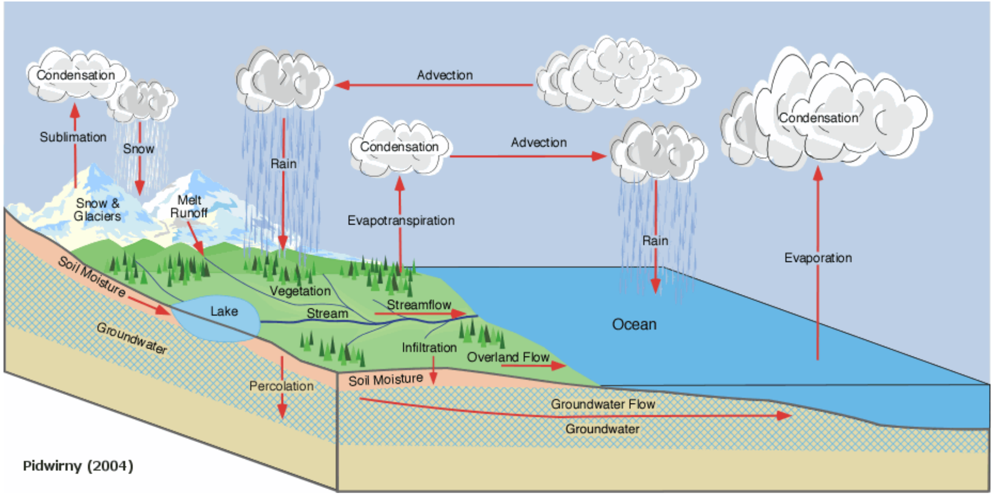


**Figure 5 Natural Water Cycle (Pidwirny 2004)**

Energy from the sun causes water to evaporate from the world's open water surfaces (such as the ocean, rivers, lakes and wetlands). Water in the form of precipitation falls back to the surface, either as rainfall or snowfall after being intercepted by vegetation and other obstructions such as buildings, and then begins to infiltrate the soil. The amount of infiltration depends on the characteristics of the soil and catchment. Water that does not infiltrate the soil may pond on the surface or collect to form streams which discharge into wetlands, lakes or the ocean (WA WRC 1986). Ponded water is then recirculated back to the atmosphere as evaporation and the cycle begins again. This simplified order of events does actually take place, although the cycle is very complicated and frequently has many mini loops and u-turns in it. For example, water may by-pass part of the system by falling as rain directly into the sea, a river or lake. Through this natural water cycle, the Earth has recycled and reused water for millions of years.

Wide variations exist in the rate at which the water moves through the cycle (Brassington 1983), both in spatial and temporal distribution (Pigram 1986) and this affects availability of renewable (active) water for sustainable use. For instance, the period for complete recharge of oceans takes about 2500 years, for groundwater some 1500 years, while water storage in lakes is fully replenished in 17 years and in rivers about 16 days (Shiklomanov 1999). Importantly, in the process of turnover, river runoff is not only recharged quantitatively, its quality is also restored. Water will only return to its natural purity when humans stop contaminating rivers (Pidwirny 2004). The speed at which water moves through the water cycle controls how quickly these human-induced effects come about.

Water required for humans, stock and pasture has traditionally been withdrawn from the natural water cycle system from three renewable (active) freshwater sources; rainwater, surface water and groundwater. Generally, the closest, most accessible or highest quality sources of water are developed first. However, the natural water cycle is disrupted when human land usage intensifies.

### 2.3.4 Water Harvesting

For thousands of years, people lived in relatively small communities where change occurred slowly. Water supply needs for communities were met from local sources using simple techniques. Throughout history, engineering works of all sizes have been constructed to distribute water from places of abundance to places of need in response to the natural variability of water occurrence, ie. water not being present at some locations and times where and when it is needed. These include river regulations, storage reservoirs (dams and aquifers), and transfers by large pipelines or canals. To meet increasing demands from agricultural, social and industrial sectors, more extensive water infrastructure is usually developed. Table 6 below lists typical man-made water infrastructure and its effect on the movement of water through the natural water cycle.

**Table 6 Effects of Water Supply Development on the Natural Water Cycle**

| Water Infrastructure | Effect on Natural Water Cycle |
|---|---|
| **Dam and Reservoir** | Delays and restricts surface water flow. Modifies riverine environment downstream. |
| **Bore** | Modifies the amount of recharge needed to keep the underground reserves balanced. |
| **Water Main** | Redirects the transfer of water. |
| **Sewerage System** | Redirects the transfer of water (sewage). |
| **Drainage** | Transports excess water away from areas to be protected from inundation. |
| **Wastewater Treatment** | Treats sewage and redirects the transfer of water. |
| **Effluent Outfalls** | Modifies the flow pattern of water and wastewater to the environment. |
| **Reuse** | Modifies the return of water and wastewater to the environment. |

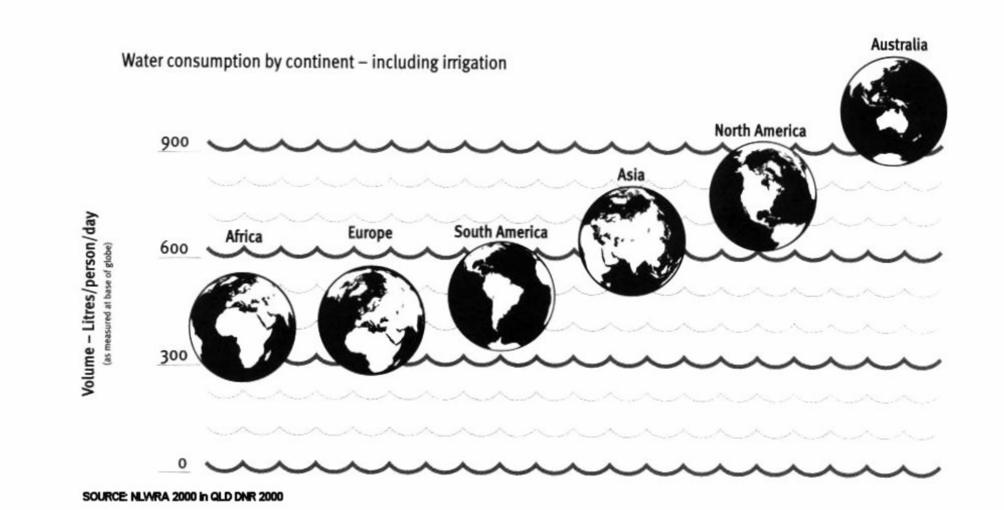
Water supply development and management traditionally focused on harvesting renewable (active) water resources from individual aspects of the water cycle. Much of the water harvested for human activity is eventually returned to the natural system after one use and in some cases such as stormwater systems without being used. However, it may be contaminated making its harvesting and reuse further down the natural water cycle pathway difficult or impossible (Fleming 1999). For example, sewage effluent and stormwater have historically been discharged to the sea or some major water body (AATCE 1998; DEHAA 1999), having an adverse effect on the health and amenity of receiving waters. This separate approach to water supply development has resulted in a number of quite separate fields of water science. Better understanding has resulted in an emphasis on integrated water resource management to achieve sustainable water resource development and use.

## 2.4 WATER ALLOCATION & USE

Water is a finite resource to be equitably and sustainably allocated, firstly to basic human needs, secondly to functioning of aquatic ecosystems, and then to different economic uses (GTZ 2001; WSP 2002; WHO 2003). The primary objective of water supply infrastructure is to ensure the necessary quantity and quality of water is available where it is needed to support the user demands. That is, the provision of water for people (urban demand), food (agriculture), nature (environment), and other uses (industry). Apart from sustaining life of communities, water is fundamental to almost every economic activity. Therefore, understanding how water is used in each country is essential to effectively plan for present and future needs of water users of that community.

### *2.4.1 Water Use by Continent*

Human use of the world's limited natural freshwater resources (being 0.26% of all water) has escalated over the centuries, due to both population increases and per capita water use increases (NCIE 1993 and CSIRO 2003). At present, some 70% of the world's water use is used for irrigation (WHO 2003), 20% is used by industry, and 10% goes to people and houses (NCIE 1993; Brown 2002; World Bank 2003). The pattern of water use varies greatly from country to country, depending on levels of economic development, climate and population size. Africans, for example, devote 88% of their water use to agriculture (mostly irrigation), while highly industrialised European country's allocate more than 50% of their water to industry and energy (hydroelectric) production (NCIE 1993). In arid countries and regions, such as Australia, the Middle East and south western United States, where rainfall is low, evaporation is high and crops must be irrigated most of the year (Akkad 1990) agricultural water use is often high (WHO 2003). Figure 6 shows the average per capita water use (including irrigation) by continent, with Australia having the highest water use per capita compared to the other continents.



SOURCE: NLWRA 2000 in QLD DNR 2000

**Figure 6 Per Capita Use (inc. irrigation) by Continent (QLD DNR 2000)**

The high level of per capita water use in Australia is a reflection of several factors including, the predominantly arid climate extending over most of the country, the pattern of water use between economic sectors (ie. more than 70% of water use for agricultural irrigation), the level of optimal water and sanitation coverage approaching 100% of the population, the inexpensive price of water for drinking and agricultural purposes, and a relatively small population (for area of land) exhibiting controlled growth. Australia has invested in large-scale water supply infrastructure for agricultural production which produces food for local consumption and for export and trade. Nevertheless, Figure 6 implies that there is potential for increasing water use efficiency to ensure sustainable limits are achieved in a water scarce country like Australia as Australia is a comparably extravagant user of water resources.

### *2.4.2 Water for People (Urban Demand)*

Demand for water from urban populations often competes with those of other major water users such as irrigators, industries and natural ecosystems. Recognising water as a basic human need, and a human right, entitles everyone to sufficient, safe, physically accessible and affordable water (as discussed in section 2.2). The global target for populations currently unserved (ie. without access to sufficient water) is provision of ‘basic access’ being 20 Lpcd compared with optimal access’ being 100-200 Lpcd (WHO 2003). The quantity of water required within households to meet basic health and sanitation needs (ie. indoor uses, excluding gardening) is well established. Sadly many people in the world, currently without access to water to meet basic health and sanitation needs, will not realise the goal of home access in the medium-term.

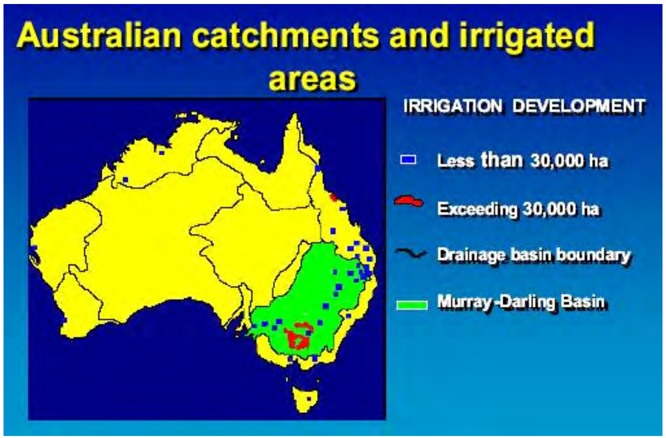
In other parts of the world, particularly industrialised countries, where water is readily accessible via large scale water developments, at little or no cost to the user, past respect (ie. consciousness) for water is commonly replaced by extravagant use. Today, in many industrialised countries, there is a significant difference between the amount used and the level needed. Further, with many communities around the world approaching or reaching the limits of their available water supplies, urban areas must alter the way in which water services are provided in order to be more sustainable (Newman & Mourtiz 1992; Fleming 1999; COA 2001). Smaller and/or locally based organisations such as community groups and local government, are often portrayed as having better records on sustainability, but are inherently limited in scale (Davis & Iyer 2002).

Urban water demand can be separated into domestic (people), industrial, commercial and institutional (public parks and gardens) use; however, only about 10% of the total water use demands high purity for drinking, cooking and other purposes. In Australia, urban centres are the second largest water use sector (after irrigated agriculture) accounting for about 12% water use (COA 2004). Urban water demand is subject to uncertainty being influenced by many factors; including population growth, consumer behaviour, household formation rates and density, business activity and climate (McLaren *et al.* 1987; WRSCMA 2001). For example, in Australia between 30% and 50% of the mean annual household water use is for garden watering (Pigram 1986) compared with 3% in the United Kingdom (COA 2002). This level of non-essential water use presents an attractive target for demand management (Murray-Leach 2003). By managing demands for non-essential water uses (ie. not required to meet basic health and sanitation needs), the potential exists for households to conserve water and support continued population growth. Chapter 3 provides a detailed examination of challenges facing the Australian urban water industry.

### 2.4.3 Water for Food (Agricultural Irrigation)

Irrigation plays an important role in producing enough food to meet global needs of a growing population. Irrigated agriculture accounts for nearly 20% of land under cultivation and produces 40% of the world's staple foods (WHO 2003; World Bank 2003). It is also the world's largest user of water accounting for 70% of global water use (World Bank 2003). The benefits of irrigated agriculture to a country include increasing the commercial value of the irrigated produce, the ability for the population to grow, and food security for the country. The area of irrigated land worldwide nearly doubled between 1900 and 1950 and more than doubled again between 1950 and 1990 (NCIE 1993; Fleming 1999). Further expansion of irrigated agriculture to new lands is unlikely in many countries (GTZ 2001; Lamm 2002).

In Australia, the area of irrigated crops and pastures is only 0.4% of the total area of agricultural holdings (MDBC 1997) but accounts for more than 70% of water use (COA 2004). Irrigated agriculture represents 22% of total exports from Australia or around $33.6 billion per annum (COA 2004) with almost 50% located within the Murray-Darling Basin as shown in Figure 7.



*As published on the Irrigation Association of Australia Website (2003).*
*Original source Dr Wayne Meyer, CSIRO Division of Land & Water*

**Figure 7 Irrigated Areas in Australia (IAA 2003)**

Environmental issues associated with irrigated agriculture are complex with far-reaching effects, particularly in terms of land and water salinisation. These interrelated problems threaten the viability of irrigated agriculture in the Murray-Darling Basin (MDBC 1997; Marohasy 2003). This water use sector offers the largest potential in terms of total volume of water savings that could be shared with other water use sectors. Rural communities can expect reduced agricultural output as water is returned to the environment and some agricultural land retired (Marohasy 2003). However, this debate is outside the scope of this investigation.

### 2.4.4 *Water for Nature (Environment)*

Environmental water requirements refer to the water requirements needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity. Water dependent ecosystems include water courses, wetlands, flood plains, estuaries, and aquifer systems. The social, economic and ecological wellbeing of a community depends not only on water quality and quantity, but also on maintaining the integrity of the ecological processes and diversity in these ecosystems. Past human development and practices have left the current generation a legacy of degraded water bodies and associated water dependent ecosystems that require remedial actions. Increasing levels of extraction from water resources, and the impact of stormwater and wastewater disposal in the water courses have contributed to these changes.

Deep public concern has been a major factor in generating political interest in the environment. There has been an increase in the level of wastewater treatment and a movement away from discharges to inland waterways (COA 2001). However, the condition of many ecosystems is still at risk of further deterioration (Pigram 1986; MDBC 1997; Fleming 1999; GSA 2000). The lesson is that there are limits to the sustainable use of our water resources and their dependent ecosystems. The environment is a legitimate water user (Fleming 1999) and is recognised as an important part of water allocation and management processes that balance social, economic and environmental needs. Water for the environment includes aquatic biodiversity, environmental flow requirements, water pollution control, and wetlands management (World Bank 2003). The allocation of water for the environment is an issue of socio-economic and environmental significance representing a major investment by the community. It has become an important policy issue in the Murray-Darling Basin, as outlined in Example 3 below.

**Example 3 Water for the Environment: River Murray, Australia**

> *In November 2003, State and Federal governments agreed to return up to 500 GL of water to the River Murray. While less than the 1,500 GL recommended the quantity is nevertheless significant. The water will be bought back from irrigators and can be expected to cost Australian taxpayers in excess of $600 million at current prices for irrigation water. This is not the first time that water has been given back to the River Murray. For example, the Barmah forest has enjoyed an environmental flow of 100 GL per year since 1993. Under the current plan, an additional 105 GL will bring the allocation to 205 GL per annum. This represents an investment of approximately $246 million for watering this forest.*
>
> *Source: Marohasy (2003)*

In Australia’s national context, the level of water required for sustaining aquatic ecosystems, including their processes and biological diversity, is a subject of ongoing national debate, but will most likely be sourced from within the current irrigation allocation (currently over 70% of water use in Australia). The costs and benefits of allocating water to the environment should be assessed alongside all other options to ensure that the least-cost approach that best meets the requirements is found.

### *2.4.5 Water for Other Uses (Industry)*

The availability of water of appropriate quantity and quality is fundamental to the operations of most forms of manufacturing, a major employer in any region. Water requirements for different industrial processes can vary widely depending upon the particular industrial undertaking, the manufacturing procedures involved, the extent of water reuse, and management practices. Industry is often more concerned with the security and consistency of supply than the actual quality (Polin 1977). The quality of water required therefore varies depending upon the intended use.

In Australia, industrial water use is recognised as a component of urban water supply because the bulk of Australia's manufacturing industry is located in urban centres. Many firms have expressed a willingness to accept non-potable water, especially if it is available at a lower price (Pigram 1986). Industrial processes can use recycled water or be designed to use less water. Water harvesting and reuse within the industry offers another opportunity to reduce potable water demand and has been implemented in many countries including Australia (Fleming 1999).

## 2.5 URBANISATION & HYDROLOGICAL CHANGE

The natural water cycle is disrupted when human activity intensifies and can result in pollution of the environment. Table 7 below summarises some of the many factors that determine the water quantity and quality in a given location.

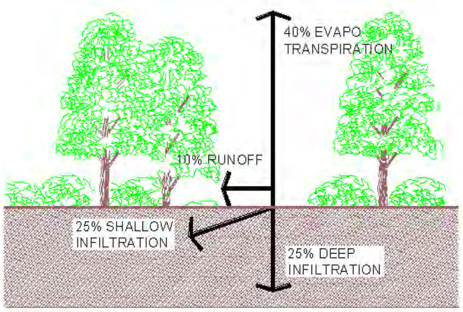
**Table 7 Basic Parameters of Water Occurrence**

| **Quantity** | **Quality** |
|---|---|
| • Volume<br>• Variability (reliability)<br>• Discharge<br>- sediment transport<br>- velocity of flow<br>• Runoff<br>- catchment area<br>- annual<br>- seasonal<br>- average<br>- minimum<br>- maximum<br>- fluctuation<br>- bank protection<br>- land use<br>• Water table<br>- depth<br>- fluctuation | • Physical indicators<br>- temperature<br>- turbidity<br>- true colour<br>- salinity<br>- suspended solids<br>• Chemical indicators<br>- pH<br>- dissolved oxygen<br>- biological oxygen demand (BOD)<br>- nutrients (phosphorus, nitrogen)<br>- heavy metals<br>• Biological indicators<br>- algae<br>- bacteria<br>• Aesthetic indicators<br>- taste<br>- odour<br>- floating matter<br>• Radioactive indicators |

The degree and impact of the operative factors vary depending on the type and characteristics of the source involved. The effects of human activities on the quantity and quality of water resources is felt over a wide range of space and time scales because these two dimensions are so closely linked.

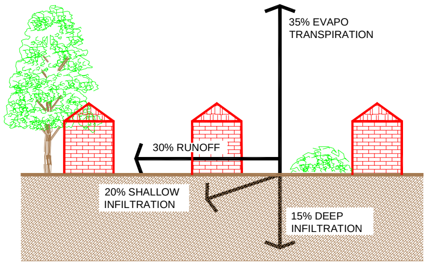
### *2.5.1 Impact on Quantity*

For many millennia, people lived in small communities and depended on their immediate environs for sustenance. Adverse environmental impacts, if any, occurred locally and went relatively unnoticed because the natural ecosystems were able to assimilate these local impacts (Fleming 1999). However, to make land available for agriculture and urban development involves removal of vegetation and wetlands. Urban centres tend to decrease evapotranspiration, increase stormwater runoff, and decrease infiltration to groundwater (WA WRC 1986). These effects are shown in Figure 8.



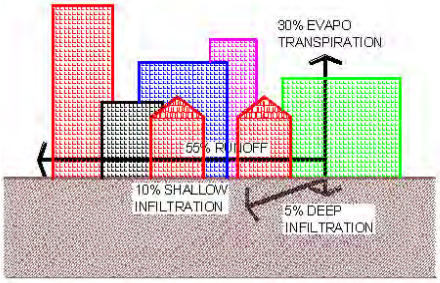
**Rural Area**

**Charleston, Adelaide Hills**



**Small Urban Settlements**

**Leigh Creek, South Australia**



**Large Urban Settlements (Cities)**

**Adelaide Central Business District**

**Figure 8 Impact of Urban Areas on Natural Water Cycle Processes**

Urban catchments are more efficient in shedding water from their surfaces than the natural landscape. The consequences of urbanisation on the water environment are (O'Loughlin *et al*. 1992):

- a higher proportion of rainfall runs off as stormwater;
- flow travel times are shortened due to low resistance to flow over surfaces that are smoother than natural and vegetated surfaces;
- dry weather flows in urban watercourses have been altered in their timing, quantity and quality; and
- capacity of higher flood flows and volumes to wash off and transport solid materials (ie. soil, litter) into receiving waters.

From the viewpoint of water quality and resource management, the increases in stormwater runoff and transport of solid materials are generally viewed as undesirable. The need to control the impact of urban development on the natural water cycle, with respect to quantity and quality of resources, increases as the scale of urban development increases. An outcome of urban development is management and disposal of stormwater runoff and sewage effluent, commonly referred to as '*urban wastewaters*'. Drainage systems are constructed to transport urban wastewaters away from urban centres to a point of discharge, sometimes impacting on the surrounding environment.

The increase in quantity and rate of stormwater runoff is associated with the extension of impervious areas and the introduction of gutters and stormwater pipes (Tomlinson *et al*. 1993; Clark *e. al*.1997; Codner *et al.* 1988). The corresponding decrease in catchment storage resulted in traditional stormwater management to be focused on flood control by way of formal drainage systems. These systems are efficient conveyers of stormwater and the pollutants therein to where they discharge (Clark *et al*. 1997; Hunter 1997). These phenomena can be observed in the shapes of the runoff hydrographs of two adjacent catchments, Giralang (urban) and Gunghalin (rural), in Canberra for one rainfall event in February 1981 presented in Figure 9. The peak flows observed from the urban catchment are three times higher and linked closely to the intensity of rainfall (ie. occurred earlier) in comparison to the runoff from the rural catchment.

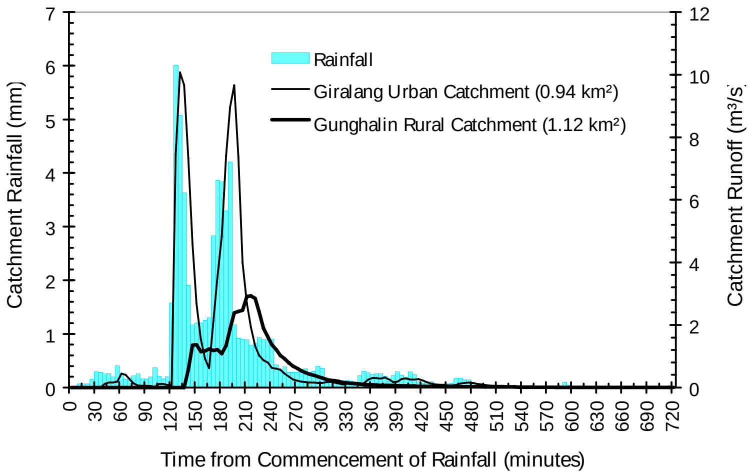


**Figure 9 Effect of Urban Areas on Runoff Quantity (Fleming 1999)**

Natural catchments have become effectively camouflaged by urban development. The cost of the traditional approach to stormwater management is now apparent and the side effects of the engineered solution, while ignored in earlier decades, are now perceived as having adverse impacts on other resources (O'Loughlin *et al*. 1992). The quality of urban stormwater depends on factors that include population density, land use, sanitation and waste disposal practices, soil types, climate and hydrology. In some cases, the changed hydrology will open opportunities for water reuse, particularly stormwater runoff and treated effluent, as volume of the urban wastewaters grows in proportion to the size of the urban centre.

Urban environments can be designed to make the most effective use of their rainfall and local water resources (WA WRC 1986). New water systems must be planned and designed with regard to long term sustainability. Many researchers conclude that a condensed village-style urban form is more sustainable than continued sprawling development patterns (Newman & Mouritz 1992; Hickinbotham 1997; Fleming 1999; Davis & Iyer 2002). Technology to support this concept is emerging, as are the new management approaches such as water-sensitive urban design, total water cycle management and integrated catchment management.

### *2.5.2 Impact on Water Quality*

Contaminants can be introduced into water from various sources throughout the water cycle. The decline in the quality of drinking water sources became a concern when population growth and industrial development produced a concentration of society’s wastes that imperilled public health. As a consequence, acute waterborne diseases, such as cholera and typhoid fever, were common in the late 1800s and early 1900s. Potential sources of contamination to water resources are numerous and can include the application of pesticides and fertilizers to cropland, direct discharges from sewage treatment plants, industrial facilities, and stormwater drains.

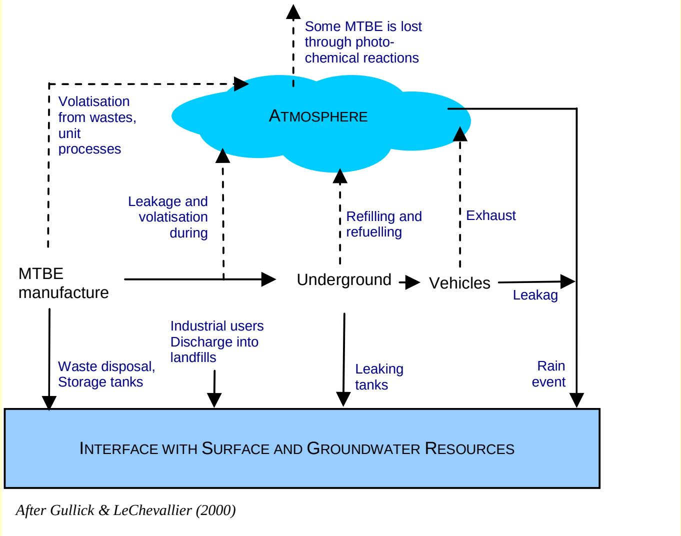
The quality of urban stormwater, for example, depends on factors that include population density, land use, sanitation and waste disposal practices, soil types, climate and hydrology. Impervious surfaces associated with urban development, such as roads, inadvertently collect quantities of solid materials. The collected solid material can include contaminants from roads, motor vehicles, litter, atmospheric dust, and nutrients from parks and residential gardens (Codner *et al*. 1988). These pollutants are washed off the surface by rainfall and runoff (Tomlinson *et al.* 1993; Hunter 1997) into other receiving water bodies such as rivers, lakes, estuaries or the sea. From here, the contaminants may be diluted, concentrated, or carried through the cycle with the water. However, the concentration of contaminants finding their way into water bodies is greater from urbanised areas because of the increased rate of runoff (see Figure 9 above). The pollution entering the receiving water bodies may cause damage to the aquatic environment for which the remedial costs are difficult to quantify in monetary terms.

Example 4 below shows how a contaminant, in this case methyl tertiary butyl ether (MTBE), can be introduced throughout the water cycle. MTBE has been added to petrol to replace lead since 1979 in the United States. This practice has resulted in air quality benefits; however, it has also produced water quality problems. MTBE is not added by Australian domestic refineries; however, it may be present in imported supplies (Duffett *pers. comm*. 2004).

### Example 4 Water Contamination & The Water Cycle: MTBE, USA

*Methyl tertiary butyl ether (MTBE) is used as an additive in petrol as a replacement for lead to reduce emissions of carbon monoxide and organic combustion products in concentrations up to 15%. Its use has resulted in reports of significant improvements in air quality; meanwhile evidence of its detrimental effect and contamination of drinking water supplies is mounting. Exposure to MTBE can occur through ingestion of potable water and recreational water. In addition, inhalation and skin absorption can occur when individuals shower with contaminated water. Although concentrations found in water supplies examined in the study were nearly all below the thresholds for taste and odour and health effects, the presence of MTBE is still a concern. Compared with other components of petrol, MTBE is more difficult to remove from contaminated water.*

*The main sources of localised MTBE contamination of groundwater supplies are leaking underground storage tanks and pipelines, spills, and MTBE manufacturing sites. The primary sources of MTBE in urban surface water supplies are releases from recreational watercraft and atmospheric deposition through precipitation of industrial or vehicular emissions. Atmospheric deposition in areas where MTBE is used may also result in a non-point source for the transport of MTBE into shallow groundwater. Stormwater contaminated with MTBE from petrol leaks and spills may also contribute to groundwater or surface water pollution. The potential pathways of MTBE contamination of the environment are summarised in Figure 10.*



*After Gullick & LeChevallier (2000)*

**Figure 10 Pathways for MTBE contamination (Gullick & LeChevallier 2000)**

*Source: Gullick & LeChevallier (2000)*

MTBE is of concern to the water industry because of its strong taste and odour effects, potential risk to human health, tendency to migrate rapidly in groundwater, and resistance to conventional water treatment processes. This example shows that availability of drinking water, in terms of quality, is open to change, depending on the treatment methods used and most importantly the constituents found in the source water (ie. its quality). Accordingly, the natural water cycle is an important consideration in the development of an effective water quality management strategy to protect water resources. Environmental security can only be ensured by integrated management of all water resources.

## 2.6 GLOBAL SECURITY ISSUES

Water is expected to be the most sought after natural resource in the 21st century, as continued growth of populations and economies is dependent on the quantity and quality of freshwater resources (Wolf 2003). The world's growing population remains a stumbling block to global sustainability in terms of food and water. Water is a key element to global sustainability, and is crucial to its social, economic and environmental dimensions (GTZ 2001).

### *2.6.1 Population Growth*

On a global scale, the limited availability of freshwater is a very real problem. Figure 11 shows the threefold increase in the annual water use along with population over a 50 year period (NCIE 1993; Brown 2002).

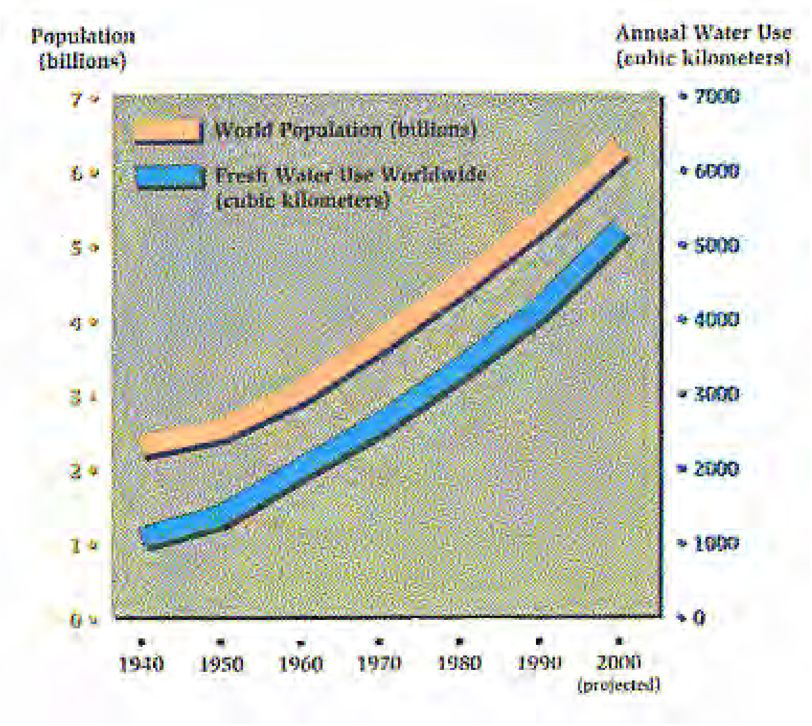


**Figure 11 Population & Water Use (NCIE 1993)**

Current trends indicated water scarcity is likely to threaten up to 50% of the world population in the next generation. Water scarcity is now the biggest single threat to global food production. Almost all of the projected population growth to an estimated 8.1 billion in 2030 and 8.9 billion in 2050 will occur in developing countries (Figueres *et al*. 2003). It is here that the major food security challenges are centred, as are the water resource challenges, because food is the largest water-consuming activity. For example, the production of every tonne of a food commodity such as wheat requires a water input of about 1ML (Figueres *et al*. 2003). If the water challenges facing poor communities in water scarce regions can be solved, there is a good chance of doing so in less water-scarce regions.

However, Fleming (1999) pointed out that human impact on ecosystems is not just about absolute numbers of people, but also how society (culture) consumes available resources. For example, many countries experience an increase in per capita water use (reduced water consciousness) where water supply infrastructure introduces people to new uses for water at little or no charge. In addition to economic measures, public awareness, education, and training are key components to changing human values and moving society toward sustainability.

### 2.6.2 Transboundary Management

The political stability of nations rests largely on their sustained supply of usable water (GTZ 2001). Such is the significance of water that basic principles of allocation and protection were contained early Jewish law (ie. the Bible and Talmudic texts). For example, the Talmud, a code of law written between the third and fourth centuries A.D, recognises public wells and the right for every traveller to use them (Starr 1993). Water scarcity has exacerbated political tensions around the globe, most notably between Arabs and Israelis, Indians and Pakistanis, and all ten riparians of the Nile River (Starr 1993; Wolf 1999).

There are over 260 international watersheds (catchments) and an untold number of aquifers are shared by two or more countries, which creates the potential for disputes (Wolf 1999). For example, Egypt, the last nation the Nile flows past, has little impact or control over the actions of the upstream governments that impact the quantity or quality of water. Management of these shared international water resources is complex as a result of the following factors (Wolf 1999):

- water migration ignores political and country boundaries;
- water fluctuates in both space and time;
- there are multiple and conflicting demands on the use of water; and
- international water law is poorly developed and difficult to enforce.

Water security (access and quality) may be the cause for conflict between countries; however, evidence favours it as a catalyst for cooperation. Wolf (1999) found nations have signed 3,600 water-related treaties since AD 805, while in the same period, there have been seven minor international water-related skirmishes (each of which includes non-water issues). In fact, water allocation is prominent in the existing peace treaty between Israel and Jordan, and the Oslo agreement between Israel and Palestine (Adar 2003).

Management of transboundary water resources must include sharing the available water and maintaining its quality to assure safe yields for future generations. A key element to long-term harmony with nature and neighbour is cooperative arrangements at the water basin level (GTZ 2001). Critical factors for management of transboundary water resources include a shared vision, sustained political commitment, public support and broad-based partnerships (AWA 2000). In Australia, collaborative arrangements are in place between the States for regulation, and equitable, efficient and sustainable use of surface and groundwater water resources that cross state boundaries. Most notably, the Murray-Darling Basin Agreement first signed in 1914 (after 20 years of negotiation) regulates the sharing of water from rivers in the basin to five States.

### 2.6.3 Climate Change

The impact of global warming and associated climate change is a significant environmental threat facing the world today (CSIRO 2003). During the 20th century, the Earth’s temperature increased by an estimated 0.6°C and sea levels rose about 150mm (CSIRO 2003). Most of the warming observed over the last 50 years is thought to be due to human influences. The associated increases in ambient temperatures, droughts and flooding will affect people's health and way of life. Scientists predict that continued increases in greenhouse gas levels will lead to regional climate change. This may impact on the performance of water infrastructure and agriculture to provide food for the growing populations.

Predictions of future climate are imperfect, being limited by uncertainties that stem from the natural variability of the climate, our inability to predict accurately future greenhouse emissions, the potential for unpredicted (ie. volcanic eruptions) or unrecognised factors (ie. new or unknown human influences) to upset atmospheric conditions, and our incomplete understanding of the total climate system. Cock (1992) suggests that the effects of climate change can be predicted by constructing a scenario of ‘*a plausible future*’. The ability of a model to predict the climate of the future can be measured by its success in simulating what is known to have happened in the past. Data that describe significant events in the past provide a test of the reliability of climate models.

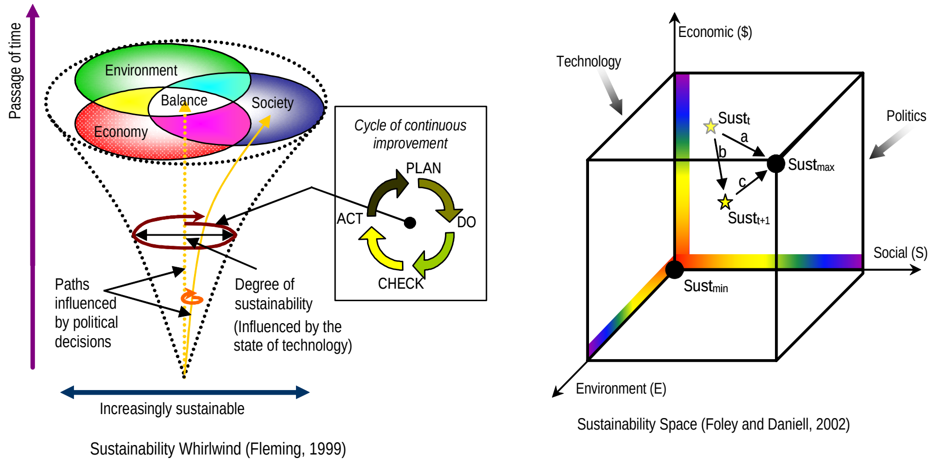
The major effect of global climate change in terms of water infrastructure and services is the redistribution and consequent change in availability of regional water resources. In Australia, the mean temperature has increased by an estimated 0.7°C from 1910 to 1999 (CSIRO 2003). The effect of continued warming on local weather patterns is uncertain, however, climate models predict an increase in temperature and evaporation, with a corresponding decrease in rainfall. Even small changes in rainfall can markedly affect what can be extracted on a sustainable basis from natural catchments (Fleming 1999). In addition, changes in local climates may be accompanied by modified demand for water and affect viability of agricultural production in a given region. Actively managing water demand can be insurance for future prosperity and growth, if it balances supply with demand.

## 2.7 SUSTAINABILITY

There is only one alternative to sustainability: unsustainability (Bossel 1999 in Bell & Morse 2003). Unsustainable use of society's resources needs to be addressed if society wants to ensure a future where children and grandchildren can provide for all without jeopardising the quality of future life. Intervention at a global level is required to limit environmental threats (such as climate change), to protect human health and safety from hazards, and to protect things which people need or value, such as wildlife and landscapes (Cocks 1992; Newman & Mouritz 1992; Fleming 1999; GTZ 2001; GWP 2003). For example, current trends indicate water scarcity is likely to threaten up to 50% of the world population in the next generation (Figueres *et al*. 2003). In the 1980s, the concept of sustainability evolved as a forced response to these concerns. Sustainability is essentially all about keeping the options open for the future (ie. the precautionary principle).

### *2.7.1 As a Theoretical Construct*

An understanding of the concept of sustainability is a precondition to assessing the sustainability of management, allocation and use of the world's water resources. The '*sustainability movement*' for development was conceived almost 20 years ago; however, the detail of what comprises sustainable development has continuously been the subject of debate. While many definitions have been proposed the central underlying elements of all definitions include changes over time (ie. current and future generations) and balancing use of resources to maintain the environment and support human life. Conceptual models of sustainability are useful to represent interactions between the main components of economic, social and environmental factors. Figure 12 shows two of the more advanced conceptual models, the *Sustainability Whirlwind* and *Sustainability Space Model*.



Sustainability Whirlwind (Fleming, 1999)

Sustainability Space (Foley and Daniell, 2002)

**Figure 12 Advanced Sustainability Models (Daniell *et al* 2004)**

The *Sustainability Whirlwind* model developed by Fleming (1999) attempts to demonstrate the importance of strategic planning and an integrated development framework to coordinate activities. At a given point in time, the envelope which describes the potentially achievable degree of sustainability is determined by the state of technology and level of political decision-making. Fleming (1999) concluded a longer and less sustainable path is followed when an unbalanced approach to economic, environmental and social issues is adopted. The *Sustainability Space Model* (also in Figure 12) developed by Foley and Daniell (2002 in Daniell *et al.* 2004) differs in that sustainability is measured as satisfying goals on each of three axes while accounting for time, political and technological advances. In this model, sustainability can be maximized by achieving predetermined goals for economic, social and environmental factors in the system under consideration. The point of maximum satisfaction ($\text{Sust}_{\text{max}}$) can move to represent changes in sustainability goals to reflect changing social values, technological improvements or political decisions. Thus, sustainable development is a conscious and continuous reflection; sustainability represents the process itself and not the end point of a process (COA 2002; Bell & Morse 2003). Life is a learning process and our beliefs, values and attitudes are not static but may change so as to alter what we perceive as quality of life.

### *2.7.2 As a Realistic Goal*

Although the concept of sustainability appears relatively simple, the task of implementing these principles - indefinitely and planet wide - may actually be an unachievable ideal. Any development expert intuitively knows that no single pattern of development is the most appropriate for all countries of the world at any specific point in history. Human needs and values are culturally and socially defined, therefore sustainable development means different things to different people and will be very context-specific. In order to design appropriate policies for sustainable development, goals must have specific indicators. However, these choices are subjective by nature and dependent on the cultural preferences of an individual, a community or a country. This implies that different societies with differing social, economic and cultural conditions may choose different sustainability criteria, and may even select different paths to sustainability (Raskin *et al*. 1998 in Figueres *et al*. 2003). The degree of sustainability that can be achieved is dependent upon the state of knowledge and management decisions of the country. Consequently there is no detailed global blueprint, only a broad statement of philosophy.

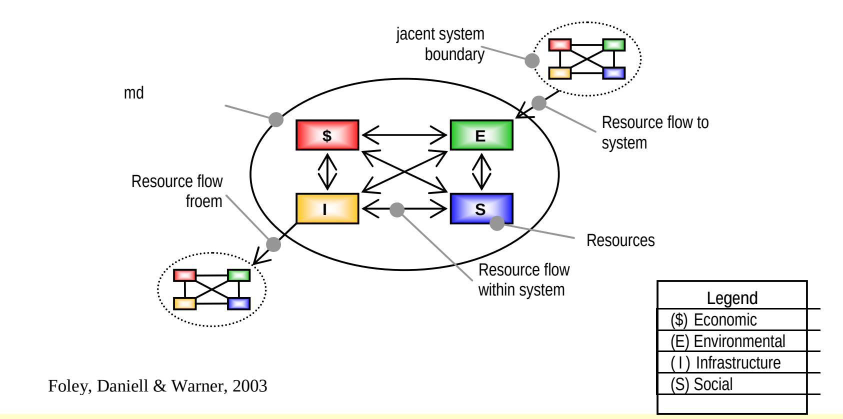
While concepts such as integrated water resources management or sustainable development have become popular and are extensively mentioned in national and/or regional policies, their effective incorporation and implementation have proved to be extremely difficult, irrespective of the country concerned (Figueres *et al.* 2003; Ashley *et al.* 2004). Rabone (2005a; Appendix 1) conducted a strategic literature review to outline the underlying conceptual issues and relevant aspects of sustainability associated with the provision of effective and water services to urban communities that can be sustained over time. As a result of this review, the concept of sustainability being a characteristic of a system has been adopted as the theoretical framework of this research.

### 2.7.3 Sustainability Assessment Framework

Applying systems of thinking to sustainability is becoming a widely accepted approach. Systems theory offers a good basis to describe and measure whether or not a system is sustainable, at least in relation to key resources of that system (Foley *et al.* 2003) and the importance of location to overall sustainability (Daniell *et al.* 2004). It also provides a means to reflect on the links between humans and their ecosystems within an integrated framework, and gives an understanding of the change processes arising from their interactions (Costanza *et al.* 1993 in Keen *et al.* 2005). Example 5 describes how systems thinking can be applied to measuring sustainability as a characteristic of a system.

**Example 5 Application of Systems Thinking to Sustainability**

*Human systems can be large and complex, for example, an industrial region with a high population exports consumer products and imports necessary resources. Other systems may be relatively simple and small such as a sparsely settled agricultural region. In all cases, it is important to identify the boundaries of the relevant system, as well as adjacent systems which interact with the one being studied (see Figure 13). The various components of the system and their interactions also need to be identified.*



Foley, Daniell & Warner, 2003

**Figure 13 System Representation (Foley *et. al.* 2003 in Daniell *et. al.* 2004)**

*To understand how any system behaves it is necessary to focus on the system resources. These include natural resources, human resources, financial resources and manufactured resources, ie. physical infrastructure and manufactured goods. The condition or state of the system can be expressed quantitatively in terms of a number of key variables that express quantity and quality of resources. These will alter over any given time increment, either increase, remain unchanged or be depleted, as the system processes the resources. The magnitude of the changes will depend in part on system characteristics such as processing efficiencies or ability to adapt to change, and partly on the management strategy adopted. The sustainability of a system depends on the level and quality of the key resources, and on the ability of the system to function effectively over time, without exhausting these resources.*

*Source: Foley, Daniell & Warner (2003)*

Renewable resources, such as water, should be used in ways that do not endanger the viability of the resource or cause damage or pollution to the environment (Cocks 1992; Fleming 1999). Importantly, a systems theory framework does not limit the assessment of sustainability solely to the maintenance and management of natural resources but also incorporates human resource, semi-permanent infrastructure of society and consumable products. Manufactured resources exist in all human systems and play an essential role in processing resources within a system (Foley & Daniell 2002). For example, the sustainability of the water supply system for a township is reliant on the infrastructure within the system. If the infrastructure fails it would affect the ability of the township to continue to function satisfactorily. Similarly, accepting sustainability as a characteristic of a system does not mean denying the use of non-renewable resources like oil and gas, but ensuring efficient use and that alternatives are developed to replace them (Cocks 1992).

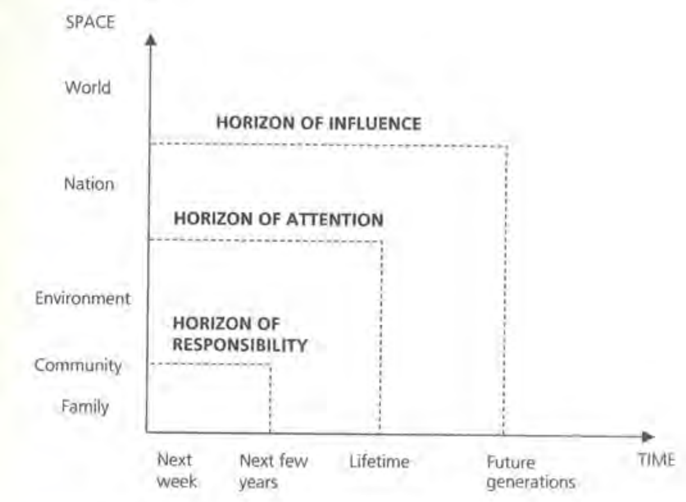
A limitation of the application of systems theory is defining the boundaries of any system, ie. those parts and interactions that are '*inside'* as against '*outside*', as these are always subjectively determined by the human observer (see Figure 13). Groups or individuals identifying ostensibly the same system will typically set differing boundaries and so perceive a slightly different system (Keen *et al*. 2005). This is because a system does not exist as a '*thing in the world*' but a '*system of interest*' to an individual, community or country (Dyball *pers comm*. 2005). In other words, systems are relationships between variables selected by an observer and, at least in part, are a result of the tradition of understanding the observer (Dyball *pers comm*. 2005). Systems are interrelated and dynamic with many elements. For these reasons, explicit definition of the system boundaries may be subject to debate and sensitivity analysis to determine the influence of decisions on the perceived sustainability of the system is warranted.

### *2.7.4 A Question of Ethics & Values*

Sustainability is a complex ethical issue; there is no easy answer or quick fix. The primary goal of a sustainable individual, community or country is to meet '*basic resource needs*' in ways that can be continued in the future. While it is logical to determine the '*basic resource need*' and how to meet those needs effectively, this does present some difficulties, particularly where there is a significant difference between the traditional amount of water used and the basic level needed. For example, Foley & Daniell (2002) estimate an average South Australian household without efficient fixtures or conservation attempts would use 175Lpcd whereas a water-conscious household would require about 100Lpcd (ie. equivalent to optimal access – see section 2.2.2). Another Australian review quoted 50Lpcd (ie intermediate access) as the basic water requirement for drinking, sanitation, bathing and cooking (COA 2002).

So then, what exactly are the '*basic resource needs*' of the present Australian generation as against the '*wants*' or '*desires*'. More importantly, is the Australian society at large likely to agree on the present '*basic resources needs*' (ie. $\mathrm{Sust}_{\mathrm{max}}$) particularly, where restrictive behavioural change is required.

Another impediment of the sustainability debate lies in the difficulty of predicting what ‘*people of the future*’ will need, ie. what resources will be valued and how they will be balanced at that time. There is also debate on which ‘*people of the future’* or how many generations ahead should we consider (ie. our grandchildren or those inhabiting the Earth in 500 years). Some have visualised various horizons (influence, attention and responsibility) that link time and space in sustainable development framework (see Figure 14).



| *Horizon of* | *Comprising* |
|---|---|
| Influence | Systems in time and space that are significantly affected by an actor's influence |
| Attention | Systems whose behaviour, development and/or fate is of some interest to an actor |
| Responsibility | Systems where an actor would be willing to carry some responsibility in order to see them survive or improve |

*Note:* For sustainable development the horizon of attention must not be smaller than the horizon of responsibility
*Source:* after Bossel, 1999

**Figure 14 Horizons of Sustainability (Bossel 1999 in Bell & Morse 2003)**

Further complicating our understanding is the behaviour of humans themselves; they do not necessarily respond the same way when subject to the same influences. The reactions can vary greatly across space and time in response to changing values, contexts, incentives or understandings (Keen *et al.* 2005). The demand on a system’s resources can be reduced by using efficient technologies, optimising the use of resources that exist within the system, reducing the dependence on adjacent systems, maximising the ability of the system to adapt to changing resources levels over time, and maximising the reuse of resources within the system (Foley *et al.* 2003). However, an individual, community or country may reject the required behavioural changes to accommodate the transformation to a more sustainable system. Answers rest not only on scientific knowledge but also on value judgements on issues such as '*quality of life*'. Education in all its forms will be essential to sustainable development because it can increase the capacities of people to transform their visions of society into operational realities. Human values are a driving factor in sustainability; consequently, learning to reconcile different perspectives will be an important element in moving towards a more sustainable point.

### 2.7.5 *Are we getting there?*

For any intervention to be effective it must have a plan for sustainability and equity built into the design, and some means of verifying the progress achieved once implementation gets under way (WSP 2003). Sustainability, like democracy or progress, is difficult to define and measure. Particularly, as a researcher is not separate from the researched (ie. an objective and natural observer) but has an integral relationship with the system being observed (Bell & Morse 2003). Nevertheless, society naturally needs to know whether an investment is (or has been) successful in terms of achieving the desired outcome or change. Even if the starting point is a statement of intent (rather than precisely defined) the requirement for implementing measures forces a critical analysis of what needs to be done, by whom, where, for how long and when.

#### 2.7.5.1 Link to Decision-Making Process

There is not much point finding out at the end whether or not the investment achieved sustainable and equitable outcomes. For instance, what questions should be asked to determine whether a proposed water infrastructure development will be sustainable or not? This is further complicated because often what is appropriate for one part of a city or region may not be a '*sustainable solution*' for another area once all the lifecycle impacts are taken into account. Progress towards sustainable water services requires integrating the understanding of the dimensions and their links into the decision-making process. Table 8 sets out the five interrelated dimensions of sustainability, each with specific equity perspectives, in relation to providing sustainable water services to a community.

**Table 8 Dimensions of Sustainability (WSP 2003)**

| | | |
|---|---|---|
| • | ***Technical*** | Reliable and correct functioning of the technology, ie. delivery of enough water of an acceptable quality for a water supply. |
| • | ***Financial*** | Systems can only function if financial resources meet at least the costs of operation and maintenance. |
| • | ***Institutional*** | Communities need institutions to keep systems operational, accessible and widely used. Institutions have cultural characteristics, agreed and valued procedures and rules for operation, and varying capacities for management and accountability |
| • | ***Social*** | Services will only be sustained by users if they satisfy expectations, ie. services match socio-cultural preferences and practices that users consider worth the cost they incur to obtain them. |
| • | ***Environment*** | Water resources face multiple threats; for example over extraction and contamination of water sources from irrigation, industry and wastewater disposal threaten reliable and safe drinking water supplies. |

*Source: Water & Sanitation Program (2003)*

Tools are available for analysis of environmental impact and resource utilisation, risk assessment and economic evaluation; however, methods for evaluating socio-cultural and functional criteria must be further developed (Ashley *et al.* 2004). Regardless of people's understanding of, and commitment to, sustainability outcomes, the institutional frameworks of society need to facilitate actions in keeping with sustainability (Harding 2005). Beyond these structural arrangements, economic and regulatory drivers are also needed to facilitate decisions in favour of sustainability outcomes. However, gauging the sustainability of an intervention or development before it has actually resulted can only be hypothetical at best. By accepting sustainability as a characteristic of a system rather than the end point of a process, the concept of change (ie. resource levels and levels of use) can serve as a gauge of progress towards sustainability goals (ie. $\text{Sust}_{\text{max}}$).

### 2.7.5.2 Gauging Progress

Tools and methodologies designed to help gauge progress towards sustainability exist, such as the concept of an ecological footprint based on the carrying capacity of the environment. But perhaps the most popular approach has been the use of indicators and indices (ie. a combination of more than one indicator). Indicators, whether qualitative or quantitative, are in fact used on a day-to-day basis by people for making decisions. For example, a blue sky in the morning indicates that the weather will be good and a T-shirt can be worn (Acton 2000 in Bell & Morse 2003). Indicators and indices also have a long record of use in the economics field. Here numbers that represent dimensions of change are used as measures to show; direction of change (space), pace or rate of change (time), scale of change (order of magnitude).

Therefore, the use of indicators to gauge progress towards sustainability may seem obvious; however, there are a number of key questions related to their development and application. These include (Bell & Morse 2003):

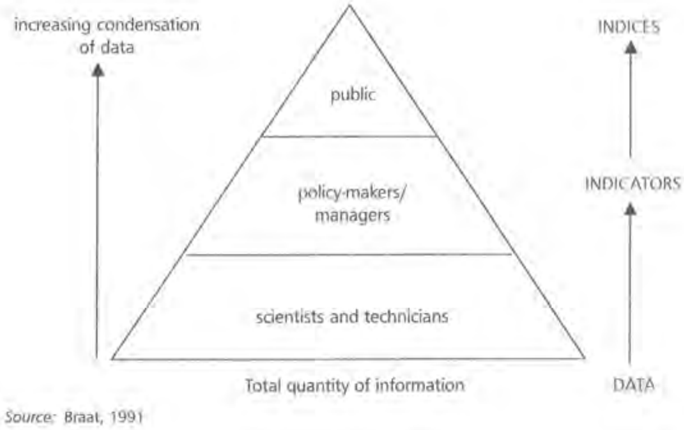
- What indicators should be selected to measure sustainability?
- Who selects them?
- Why are they selected?
- How are the various dimensions of sustainability balanced?
- How are the indicators measured?
- How are the indicators interpreted and by whom?
- How are the results communicated, to whom and for what purpose?
- How are the indicators to be used?

The above questions serve to highlight the complex and unbreakable connection between the '*concept of sustainability*' and people. Inevitably, each sustainability indicator reflects the base discipline (ie. environmental management, economic, engineering, etc.) from which it was developed. Whether we like it or not, sustainability is all about people and the difficult issues of multiple perspective and public participation are not optional extras to be tagged onto a science-based analysis; they are central to it. The decision is how to achieve this in practice. There still remains a gap between the generation of the indicator frameworks and putting these into practice in order to influence policy and behaviour.

It is not enough to just report the outcomes of an agreed monitoring program. It is also important to objectively analyse (evaluate) the observed change (or shift) and determine if this is good, bad or irrelevant. In other words, tracking change is an iterative process and relies on monitoring, evaluation and reporting (ie. communicating the change). Condensing complex information to allow digestion and interpretation by non-specialists, such as the public, politicians and decision-makers, is clearly desirable.

#### 2.7.5.3 Communicating Progress

Despite being a vital part of people's lives, the term '*indicator*' conjures up the idea of numbers and statistics that can only be used by specialist technocrats. Fortunately, indicators can be condensed and translated into less threatening visual forms for communicating change with non-specialist audiences (public, politicians and decision-makers). Figure 15 presents a relationship between data, indicators and indices.



*Source:* Braat, 1991

**Figure 15 The Information Pyramid (Braat 1991 in Bell & Morse 2003)**

The basis of the communication device employed is bound up with the uses to which it will be put (ie. compliance, awareness, performance, alerting, or review). That is, tailoring information to suit the intended target audience to take some action (intervention). Scientists and technicians are primarily interested in data presented as tables, graphs or raw uncondensed data. Decision-makers and managers typically require some condensation of data, primarily in terms of how it relates to goals and targets, which is capable of being unpacked to reveal underlying data. The public often prefer highly aggregated data and visual devices.

A number of effective communication devices are available to increase clarity for users including; tables, graphs, traffic lights, report cards, scorecards, simple arrows, GIS maps, spider webs, pyramids and the like. However, it is important to remember they are not tools for assessing progress towards sustainability but simply a way to communicate direction of change. Yet supplying information in a condensed form does not mean that the public, managers or policy-makers will act on it. In comparison to unemployment and crime rate indicators, government response linking sustainability indicators through policy is still in its infancy.

## 2.8 SUMMARY

Water scarcity is one of the most important issues facing the world today. Water is expected to be the most sought after natural resource in the 21st century. Although water is available in different amounts everywhere on earth and the total quantity never changes, the demands placed on are constantly increasing (Fleming 1999; Schoenfeldt 2000; GTZ 2001). Current trends indicate water scarcity is likely to threaten up to 50% of the world population in the next generation. The effect of continued global warming on local weather patterns is uncertain; however, climate models predict an increase in temperature and a decrease in rainfall in many areas of the world.

The complex issue of water distribution has far reaching social and economic ramifications. The ecological, social and economic wellbeing of a community depends not only on water quality and quantity, but also on maintaining the integrity of ecological processes and the diversity of these ecosystems. Human use of the world's limited natural freshwater resources has escalated, due to population increases and per capita water use increases (NCIE 1993 and CSIRO 2003). Deep public concern has been a major factor in generating political interest in the environment, including our use of water resources.

Water, poverty and health are closely linked. Lack of safe water leads to many serious diseases and causes almost 80% of the illness in the developing world (Starr 1993). Water supply issues are the biggest single threat to food production today. The majority of population growth over the next generation will occur in the developing world. The growth of economies in the developing world is dependent on the quality and quantity of the freshwater resources they can harvest and supply. To meet increasing demands from agricultural, social and industrial sectors, more extensive water infrastructure is usually developed. Unfortunately, this often leads to extravagant water use.

Water scarcity is one of the biggest social, political and environmental issues currently facing Australia and the world. Reliable water supply is integral to our manufacturing and agricultural industries, which make up a large proportion of the Australian economy. In Australia, urban centres are the second largest water use sector after irrigated agriculture. Between 30% and 50% of the mean annual household water use is for garden watering (Pigram 1986). Compared to other industrialised countries, this is a very high level of non-essential water usage. Our high per capita water use is due to both cultural and physical factors, including the predominantly arid climate extending over most of the country. Cultural factors are very difficult and slow to change. Successful cultural adaptation will not take place until industrialised societies are educated about the impact of their current lifestyles. Unfortunately, in the developed world, consumers are often disconnected with the true value of water because of the ease of supply.

With many communities throughout the world approaching the limits of their available water supplies, traditional water management practices need to be reappraised. Water is a key element of social, economic and environmental sustainability. There is potential for increased water use efficiency to ensure sustainable limits are achieved. Sustainability is a complex ethical issue; there is no easy answer or quick fix. There is a need to aim to meet 'basic resource needs' in a way that can be continued in the future, but defining what '*basic resource needs*' are for this generation and the next poses many problems.

Governments around the world have the primary responsibility for ensuring that adequate access to water is achieved everywhere, but the involvement of other stakeholders at all levels of industry, and the community is vital if this goal is ever going to be achieved. Unsustainable use of society's resources needs to be addressed if we want to ensure a future where people can continue providing for their basic needs. Although the concept of sustainability appears simple, implementing these principles on a global or local scale poses many difficulties. Smart water use and reuse is vital in meeting our world's demands. Substantial cultural changes and restrictive behavioural changes as well as strategic investment in appropriate infrastructure will be required, which poses many challenges to governments today.

# Chapter 3
# Water for Urban Australia

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> *"If we are going to stop being the 'lucky' country and start being the 'clever' country, we must recognise our own particular problems and opportunities. We must be prepared to understand the distinctiveness of our own society"*
>
> D. Horne
> Weekend Australian May 1991

## 3.1 INTRODUCTION

Water is one of Australia's largest industries, with assets valued at over $90 billion in replacement cost terms, with some $40 billion of these assets in country areas (Productivity Commission 1999). The overall water service strategy is simple; one pipe system delivers water to consumers, a separate pipe system collects discharged wastewater by them, and a third system transports stormwater away from the urban area. This investment in centralised water systems has improved the standard of living (ie. lifestyle) enjoyed by Australian communities (large and small). Access to continuous (ie. 24 hour) safe and affordable water services has become a normal expectation.

The urban water industry in Australia provides services to 13 million people, however the water supplied to households accounts for less than 10% of all water used (COA 2002). Water supplied to urban centres is used for a wide range of purposes by domestic, industrial, and commercial consumers. Typically, water services have been provided through development of the closest, most accessible, and best quality sources of water. Invariably, there will come a point at which the urban water demand cannot be met from developed resources. Established water systems in many Australian rural centres need to be upgraded just to meet existing demand. In addition, most Australian cities will face challenges over the next 20 years (COA 2002) as competing demands for the water increase.

In Australia, government is responsible for the management of natural and developed water resources to meet the competing needs from irrigated agriculture, households (domestic), industry and the environment. All levels of government have a responsibility to create conditions that bring about optimum use of water resources; that is, measures to modify urban water use patterns to maximise efficient use (ie. conservation) of developed resources. The current water economy is characterised by a sharply rising cost of supplying additional water, more direct and intensive competition among different kinds of users, the high (and rising) cost of subsidising water to rural communities. Over the last decade, the Australian water industry has undergone major reform.

Further extraction or diversion of more water from the environment is not currently supported by Australian communities. Consequently, the Australian urban water industry must adapt to incorporate new supply options, such as water harvesting and reuse or desalination, into water systems serving both established and new urban development. These alternatives represent safe and reliable new water supply that provides insurance against times of droughts or shortages in imported water. They also provide a foundation for maintaining and improving the quality of life in Australian urban and rural communities alike.

## 3.2 WATER GOVERNANCE

The supply of water for consumption was one of the earliest concerns of government. Water governance refers to the political, administrative, economic and social systems that exist to manage water resources and provide access to water services for domestic and productive purposes. Water infrastructure has been provided to Australian communities through the cooperation of Federal (Commonwealth), State and Local Government. In the Australian context, the global drive to improve the performance of water utilities means more efficient water services (ie. water, wastewater and stormwater) without putting the health, social and economic well-being of the community at risk. To ensure sustainable water use into the future, water governance must take into account all sectors dependent on water supply and not just the supply of urban (drinking) water.

### *3.2.1 System of Governance in Australia*

In Australia, all levels of government (ie. Federal, State and Local) are charged with the responsibility of maintaining a safe, healthy and prosperous environment for their communities (LGA 2000). Table 9 below summarises the relationship between the levels of government and the legislative (law making) powers vested in the Commonwealth and its States. Under Australia's system of government, responsibility for health, water supply (including natural and developed water resources), environment, generally resides in the State and Territory governments. In relation to water resources, the role includes protection, maintenance and, where appropriate, development. However, the local government has the most direct impact on facilities present in any given community.

All stakeholders (water users, water related agencies and government) are susceptible to incentives provided by the institutional arrangements around them. The institutional complexity associated with the three levels of government has resulted in institutional fragmentation within jurisdictions, particularly with regard to implementing and enforcing sustainable water use policy. Health departments, water resources departments, price regulation, agriculture, infrastructure and water suppliers are all involved, however these generally fall under different ministries with limited linkage (integration), either in law or in policy and regulations. This has led to considerable differences in regulation across Australia (Water 2000) and has been a barrier to achieving greater progress towards more sustainable water management in Australia (COA 2002).

**Table 9 Relationship between the Levels of Government**

| Federal Government | State Government | Local Government |
|---|---|---|
| **Exclusive Powers**<br>• defence<br>• taxation<br>***Deferred to Commonwealth (overrides State Legislation)***<br>• bankruptcy<br>• marriage and divorce<br>• immigration<br>• ***trade (interstate and international)***<br>• external affairs<br>• foreign, trading and financial corporations<br>• telecommunications<br>• postal services<br>• national highways<br>• interstate industrial arbitration<br>• ***meteorological observations***<br>• census and statistics<br>• copyrights, patents, and trade marks | **Exclusive Powers**<br>• education<br>• ***health***<br>• police<br>• electricity<br>• ***water supply***<br>• ***environment***<br>• transport<br>• ***main roads***<br>• ports<br>• public housing | **Statutory Duties (required by law)**<br>• ***town planning and building assessment***<br>• ***environmental health***<br>• fire prevention<br>• dog control<br>***Discretionary Services***<br>• ***local roads and footpaths***<br>• street lighting<br>• traffic and parking regulations<br>• ***stormwater drainage***<br>• ***local environmental management***<br>• waste management<br>• ***parks, sporting ovals and facilities***<br>• libraries<br>• social planning<br>• tourism |

*Compiled from information available at the following Web Sites:*
*1. Local Government Association: http://www.lga.sa.gov.au. Accessed 8/700. Modified 14/6/00*
*2. Commonwealth of Australia:*
*(i) http://www.aph.gov.au. Accessed April 2000. Modified December 1999.*
*(ii) http://law.gov.au. Accessed 3/01/01. Modified 19/12/00.*

Institutions and the manner in which they foster good governance determine the long term ability of a country to manage its water resources (Figueres *et al* 2003). During the 1980s, Australia's political leaders were of the opinion that to prosper as a nation, maintain and improve living standards and opportunities for Australian people, they had no choice but to improve the productivity and international competitiveness of the country's institutions and businesses. This meant that Australian organisations, irrespective of their size, location or ownership, needed to become more efficient, more innovative and more flexible (Hilmer *et al*. 1993).

Most areas of the economy were to be affected, with the greatest impact on sectors previously sheltered from competition such as major infrastructure industries (ie. water, gas, electricity, telecommunications, rail, airports) and some areas of agriculture. These industries (often called public utilities) involve networks that distribute products or services over geographic space and in most cases the networks are capital extensive and the investments are durable and immobile (Gomez-Ibanez 2003). In the closing years of the 20th century, all dimensions of this institutional framework came under challenge and all levels of government recognised the need for coordinated action.

## 3.2.2 Australia's Water Industry

Infrastructure has special characteristics (ie. capital extensive, natural monopoly, universal access to basic service) that have traditionally justified or encouraged government involvement (Gomez-Ibanez 2003). Further, provision of infrastructure is considered an important factor in local economic development. Along equity considerations, this view led governments in Australia (all levels) over the past 200 years to invest in more extensive water infrastructure (including irrigation schemes, dams, and major transfer pipelines) than could be financed with price that water users are willing to pay (Hilmer *et al*. 1993; Tasman 1997; Clark *et. al.* 1997; Fleming 1999). Governments have often required public enterprises to engage in cross subsidisation, generally for the benefit of the rural community.

The widespread practice of charging prices that are less than the real unit costs of providing water services (ie. underpricing and cross subsidisation) is problematic. Underpricing of water services has led to a disconnection between the value of water and water users (ie. inefficient water use patterns and behaviours). However, concern about '*public interest*' may explain why governments in Australia encouraged monopoly conditions. Further, it is not an offence, under the trade practices policy, for a firm simply to dominate a market or even to be a monopoly (Baumol *et al*. 1988). However, during the 1980s it was argued that publicly owned and operated water utilities lacked incentives to operate efficiently (Haarmeyer 1992; Gomez-Ibanez 2003). The general conclusion appeared to be that creating market competition would promote greater efficiency.

### 3.2.2.1 Forces Driving Reform

As one of Australia's largest industries, the potential economic gains by changing how the water industry was managed were considerable. The structure of the water industry and the regulatory regime in which it operates should encourage the industry to innovate and change (WRSMA 2001). Applying this viewpoint to the Australian water industry would not be straightforward, since the water infrastructure was already in place and monopolistic in nature. Further, although the dominant organisational structure - a statutory authority, with monopoly function, extensive power to tax and regulate - it was fragmented between jurisdictions (ie. legislative power vested in the States and Territories).

Events at a national level contributed to significant structural changes in the way government business enterprises operate and how water resources are managed around Australia. The major national events that have and continue to influence the Australian water industry are the:

- Review of Commonwealth Trade Practices Act (1992),
- Council of Australian Governments Water Reform Framework (1994), and
- National Competition Policy Reform (1995).

Additional information on the major directions, policies and guidelines is provided in Appendix 1.

#### 3.2.2.2 Reform Implementation

The Council of Australian Governments (COAG), the peak body for Federal-State negotiation, responded to the following finding s of the Industry Commission’s 1992 Review of Trade Practices Act in relation to water resource (WSAA 1998):

> *If reform in the Australian water sector is not accelerated, water will continue to be wasted, the community will continue to invest in poorly performing water assets and the environment will be placed in further jeopardy.*

The COAG response in 1994 was to agree to a framework to reform Australia's water industry that would be fully implemented by 2001. Elements of the water reform included separation of regulation and service delivery, cost recovery (ie. functional and investment efficiency), consumption based pricing, reduction in or transparency of subsidies, recognition of the needs of the environment, allocation and trading in water entitlements. Nevertheless, wastewater management, including reuse of treated wastewater, received limited attention in the reform package (Cooper *et al* 2005) as did the emerging practices of harvesting stormwater for non-potable use. The prime focus of these reforms was to create conditions that would encourage more efficient water use within urban and rural centres and by the irrigated agriculture industry.

The Federal government strengthened and sustained the pressures for change through financial incentives. From 1995 onwards, compliance with COAG water reform commitments became a requirement for States and Territories in order to receive their full share of the Commonwealth payments under the National Competition Policy (NCP) reform. Some observers alleged this arrangement made the water industry vulnerable to political pressures at State and/or Federal level (Gale 2000). On the other hand, water managers in Australia have been at the interface of politics since settlement (Hammerton 1986; MDBC 1997; COA 1999) and as such must understand and balance short term political commitments with longer term community needs.

The Productivity Commission (1999) noted the progress in implementing the water reforms varied markedly amongst the jurisdictions despite the tight link with significant financial incentives. Likely adverse social and economic impact of reforms on sectors of the community, particularly in country areas, proved to be a major stumbling block for many jurisdictions. As a consequence, the full suite of reforms was not able to be implemented by 2001 and the timeframe was subsequently extended to 2005 for certain aspects. Nevertheless, without a doubt the policy and institutional setting within the Australian water industry was vastly different to those in 1994.

#### 3.2.2.3 Changes Impacting Urban Water Supply

Australian water utilities in most jurisdictions are no longer simultaneously resource managers, service specifiers, regulators and service providers. A majority of water utilities (particularly ‘*major urban*’) have become corporate entities responsible for service delivery, with regulation responsibilities assigned to different arms of the respective State governments (Evans 2000). In other words, the provision of water services is by public or privately operated utilities and government is responsible for regulation (including resource management). This separation is designed to avoid any potential conflict of interest between price setting and setting of health and environmental standards (Gomez-Ibanez 2003; GWP 2003). Separation means that Australian water utilities can be more focused on delivering services to specified standards and their cost competitiveness. They can also avoid entanglement in any other concerns (ie. '*the public interest'*).

All Australian's rely on infrastructure services, they have a common interest in seeing that infrastructure is provided reasonably efficiently and priced not too much above cost. Efficiency seeking by water utilities (ie. reducing operating costs) yielded immediate productivity dividends in most jurisdictions (Evans 2000). However, costs within the water industry will remain dominated by infrastructure investment in the longer term. Accordingly, it is fundamental that the price path set reflects the full cost of providing water services (including externalities) to each community. However, is not easy to accept the notion that higher prices can serve the public interest better than lower ones, especially for something as basic as water services.

Advocacy of higher prices for any service to communities in regional Australia is seen as a mandate for political disaster, and therefore often rejected by politicians in favour of encouraging public enterprises to continue to provide services at a financial loss. For example, frequently the cost of providing water supplies is not covered by the income generated by water charges in many country communities in Australia. In the past, water utilities made up the loss by obtaining higher profits from its other sales (ie. cross subsidisation from their urban water business); a practice only possible where a public enterprise is protected from price competition and entry of new competitors.

This situation has changed as part of the water reform. Where government requires a public enterprise to meet public interest goals, it is now expected to specify this as a community service obligation (CSO) and provide compensation to the organisation. The payment (subsidy) is to be met by taxpayers in general, rather than by the targeted groups of water users and the amount of the subsidy should be a matter of public record. Similarly, low (subsidised) pricing is not considered a suitable (or sustainable) way to help low income people or people with large families; rather, it is a matter for social welfare policy (Dixon & Baker 1992). Even so, public or privately operated water utilities continue to respond to informal influences from government.

The reforms are gradually correcting the underpricing of water in Australia. The greatest challenges to the water industry reform may have been the application of commercial criteria to the evaluation of water agencies and defining of water users as '*customers*' (Colebatch 2005). However, with time and familiarity (ie. the decade of reform) these views have now become the way in which the water industry in Australia is understood (ie. part of normal expectations). The focus of the Australian water industry has moved away from increasing the quantity of water available towards more efficient water use and better management of Australia's resources.

#### 3.2.2.4 National Policy Directions

The national COAG water reform between 1994 and 2004 contributed to significant structural changes in the way government business enterprises operate around Australia. Additionally, demand management strategies introduced by water utilities as part of the reform have been very successful, particularly, in relation to urban water use (WSAA 2003). The observed improvement in water use efficiency was delivered through a combination of consumption based pricing structures (ie. financial incentive), technological change and education campaigns. The intention of the suite of measures is to encourage a sustained behavioural (ie. cultural) change in patterns of water use. Because the water industry is capital intensive, each dollar invested in water efficiency will reduce the amount of or defer investment required to increase the capacity of the existing water infrastructure.

In August 2004, under the pressure of prolonged drought conditions, environmental flows, growing value placed on the environment and increasing demand for water, COAG endorsed the National Water Initiative (NWI). This $2 billion initiative states what Australia’s governments have agreed to do to build on the achievements of the 1994 COAG framework. Expressly, the NWI seeks to maintain water industry productivity gains, stretch water use efficiency benefits to sustain growth in rural and urban communities, and guarantee the health of river and groundwater systems. Importantly, the NWI openly incorporates better use of stormwater harvesting and recycled water use in Australian cities (urban centres) into the water reform framework considerations (COA 2004; Cooper *et al* 2005).

Specific inclusion of non-conventional strategies was not the result of a ‘*decision*’ by an authoritative figure, but rather, as Colebatch (2005) comments, a shift in the institutionalisation of practice - that is, a response to changes over time in the way in which the activity is understood and normalised. For example, around thirty years ago Sloan (1977) remarked on the intellectual shock experienced by public health practitioners being asked to consider conditions under which beneficial use of wastewater might be allowed. At that time, the exclusion of wastewater from man’s food and water supplies had been actively promoted and pursued for more than a century. Yet today, there is a growing number of operational water harvesting and reuse projects around Australia, albeit principally focused on larger urban communities.

Open inclusion of water harvesting and reuse in the NWI is important because the practice is still a challenge in most jurisdictions to established institutions in Australian water industry. In cognitive terms, it reframes the ‘*water supply process*’ to officially encompass ‘*water cycle management*’ rather than just the traditional ‘*supply and disposal*’ matters (Colebatch 2005). This philosophical shift generates a somewhat different set of tasks and calls on different skills within the water industry. A parallel change in the water quality focus from ‘*pure*’ (drinking) water to ‘*fitness for use*’ also challenges customary ways of thinking about health and risk in relation to water (Colebatch 2005). In the end, good water governance has everything to do with skilled and capable water managers and policy emerges from the way they frame and address problems.

### 3.2.3 Australian Urban Water Utilities

The Australian Constitution leaves control of water to the State and Territory governments and this has led to the evolution of different service models in each jurisdiction. Table 10 provides a simplified summary of the predominant water service model predominant in each jurisdiction; there are exceptions.

**Table 10 Summary of Water Service Models in Australia (AWA 2002)**

| Water Service Model | Jurisdiction |
|---|---|
| • A single authority at the level of state government for water and wastewater services. | Australian Capital Territory,<br>Northern Territory,<br>South Australia, and<br>Western Australia. |
| • Responsibility for water and wastewater services vested primarily at the level of local government | New South Wales,<br>Queensland, and<br>Tasmania, |
| • Regional model with more than one utility often taking in multiple local government areas | Victoria |

*Source: AWA 2002*

The agency and infrastructure created through legislation is owned and controlled by the government. In recent decades, the traditional size of the public sector in Australia has significantly reduced due to contracting out of services.

#### 3.2.3.1 Size and Context

Australia has a total of nearly 300 urban water utilities serving a population of around 19 million. A majority of the water utilities in Australia are corporate entities focused on delivering cost competitive services to specified standards. Table 11 below provides a breakdown of Australia's urban water utilities by size. The breakdown shows that 200 (or 67%) of Australia's urban water utilities fall within the '*small*' category defined here as serving less than 10,000 connections (ie. 20,000 people or less) and about 13% of the Australian population.

**Table 11 Breakdown of Australian Urban Water Utilities (AWA 2002)**

| Breakdown of Australian Water Utilities | | | Population Served (% of Australian) |
|---|---|---|---|
| Category | Description | No. | |
| ***'major urban'*** | > 50,000 connections (or > 120,000 people) | 22 | about 70% |
| ***'non major urban'*** | between 10,000 & 50,000 connections (or 25,000 & 120,000 people) | 71 | about 17% |
| ***'small'*** | < 10,000 connections (or < 25,000 people) | 200 | about 13% |

*Source: AWA 2002*
*Note: Equivalent number of people was determined loosely assuming and occupancy rate of 2.4*

International comparisons and experience can provide useful insights for the Australian water industry. Australia's '*small*' water utilities can either appear small or large depending on whether the comparison made is between reported sizes of water utilities in the United Kingdom (UK) or the United States of America (USA). In the UK, 22 water utilities serve approximately 52.3 million people (Emery 2004); by Australian standards, a majority of UK water utilities fall into the '*major urban*' category. In stark contrast, in the USA more than 4,700 utilities supplied water to around 180 million people; of which around 97% of the water systems serve '*small*' communities of less than 10,000 people (AWWA 2004). It is also interesting that in USA, there is a move toward consolidation of existing small systems to help spread expenses over a larger number of customers (ACC 2004).

In Australia, sustainability of regional communities is linked to the long-term viability of numerous '*small*' water utilities. The Federal government argued the NWI reform will benefit regional Australia, provided it is properly implemented by State governments with appropriate responses by local government, business and communities (COA 2004). All the same, community resistance will be encountered as cost reflective pricing is rolled out to regional areas. Fortunately, most Australian authorities also realise there are economic limits that prevent most small communities from entirely funding water infrastructure. All levels of government have an obligation to develop policies that will uphold regional communities.

#### 3.2.3.2 Benchmarking Performance

The relative performance of a water utility and/or water supply system is sensitive to its size and context as a result of unavoidable cost drivers. Relative performance is primarily dependent on the relationship between capital and ongoing maintenance costs, which are a function of the size of the system, and its revenue customer base. Other influencing factors exist like the available water source(s) and associated treatment costs. For example, where groundwater is used, a utility can expect relatively consistent quality and quantity from year to year; however, the quality from each groundwater source may vary and require different methods of treatment. In contrast, surface water sources are subject to the vagaries of natural phenomena which can affect the quality, quantity and annual operating cost. Differences in cost drivers between individual utilities make comparison of the performance of utilities complex (Rabone 2004a).

Eggleton (1994) concluded that a systematic approach to performance benchmarking would benefit the Australian water industry because a shared language and a common set of relevant measures would be developed. To be successful selected performance measures need to be unambiguous and verifiable, consistent with long term incentives for compelling peak performance, and easy for the public to understand (Kingdom & Jagannathan 2001). As a general rule, trends of measures over time for a given utility or system provide the most reliable indicator of performance as differences in cost drivers are held constant (Rabone 2004a). However, the process of performance benchmarking remains subjective even where a systematic approach is adopted; for as Carrington (2004) points out customers (water users), utilities, and regulators have different perspectives and place different emphasis on certain performance measures.

Public performance reporting (as in regulated industries) makes service providers more accountable to the public and motivation for improvement is increased (Kingdom & Jagannathan 2001). The annual publication *WSAAfacts*, by Water Services Association of Australia, provides information to the Australian water industry. *WSAAfacts* reports on the performance of '*major*' water utilities against a common set of measures for use by utilities, regulatory authorities and the public alike. A similar publication *Performance Monitoring Report for Australian 'Non Major' Water Utilities* was published by the Australian Water Association (AWA) between 1997/98 and 2000/01 (AWA 2002). Regrettably, after the fourth year, Commonwealth government funding support for the publication was withdrawn. The requirement to collect good quality data and analyse performance on a regular basis for this type of publication is a valuable discipline for the water utilities involved.

There is clear absence of published performance information for '*non major*' and '*small*' water utilities; a significant majority of the industry in terms of total numbers in Australia. Without this point of reference, selection of suitable benchmarking partners and determination of an overall ranking of their comparative performance is problematic. In addition, many '*small*' water utilities would experience hardship in making resources available for collection and analysis of data. Despite these difficulties, where it can be implemented benchmarking can be a very powerful vehicle for driving peak performance of '*small*' water utilities.

### 3.2.4 National Organisations and Industry Associations

There are a large number of organisations and associations that look after the interests of various segments of the water industry in Australia. The group of national bodies includes:

- ***Australian Water Association (AWA)*** was established in 1962 as a not-for-profit association for individuals and organisations interested in water resources. AWA plays an important role in the Australian and international water industry.
- ***Water Industry Operators Association (WIOA)*** was established in 1972 for persons involved in operations and maintenance of public and private water infrastructure.
- ***Water Services Association of Australia (WSAA)***, represents '*major*' urban water authorities.
- ***Australian National Committee of Irrigation and Drainage (ANCID)*** represents irrigation authorities and agencies.
- ***Irrigation Association of Australia (IAA)*** represents all sectors of the irrigation industry from water users to retailers.
- ***Stormwater Industry Association of Australia (SIA)*** represents the diverse and multi-disciplinary interests of stormwater stakeholders.

- ***Australasian Bottled Water Institute (ABWI)*** represents water bottlers and promotes use of bottled water products.
- ***Waterwatch Australia*** is a network of individuals and community groups concerned with water quality protection of waterways and catchments. *Waterwatch* was established in 1993.
- ***Australian Water Partnership (AWP)*** was established in 2003 to link Australia to the Global Water Partnership (GWP).
- ***Masters Plumbers of Australia (MPA)*** represents installers of gas, water and irrigations systems, as well as fire, sanitation and drainage services.
- ***Urban Development Institute of Australia (UDIA)*** was established in 1972 to represent those involved in development (eg. developer, planners, and designers).
- ***Australian Council for Infrastructure Development (AUSCID)*** was established in 1993 to represent private sector development in public infrastructure
- ***Landcare Australia*** is not-for-profit organisation established in 1989 to raise sponsorship for projects to care for Australia's environment.

Despite the number of national organisations and industry associations, there is clear under-representation for the interests of '*non major*' and '*small*' water utilities in Australia. Apart from a special interest group of AWA for water recycling, no specific representation at the national level was identified for groundwater, rainwater or recycled water segments of the water industry. In addition, there is no mechanism for ensuring the established organisations act with the broad industry and community interest in mind. Gale (2000) reported that negotiations were being held to bring together the four major national players, being AWA, WSAA, ANCID and IAA, in a loose affiliation to coordinate the water advocacy and policy scene.

## 3.3 URBAN WATER USE SECTOR

At a national scale, the urban water sector consumes less than 20% of the total water use, with the majority (about 70%) being supplied to agriculture (AATSE 1999; Mitchell *et al.* 2002a; COA 2002; WSAA 2005). The urban water sector can be divided into two broad categories, with markedly different patterns water use, as follows; residential (household uses) and non-residential (ie. industrial, commercial and institutional uses). Overall, residential use in Australia accounts for less than 10% of total water used and is the dominant category in the urban water sector (COA 2002; WSAA 2005). The cost of urban water supply and competition for resources near towns and cities make this sector important. In addition, the intensity of competition is likely to increase as forecast reductions in rainfall connected to global climate change take effect. The obvious benefits to embracing water harvesting and reuse relate to being in a better position to deal with water shortages as well as boosting the environment and our economy.

### *3.3.1 Urban Water Services*

#### 3.3.1.1 Fundamental Management Philosophy

The supply of water to urban centres was one of the earliest concerns of governments in Australia, primarily by way of developing water resources to meet demand. Traditional patterns of urban water management were based on a simple '*supply and disposal*' process - that is, water delivered to urban users in one pipe system and two separate pipe systems remove wastewater ('*used water*') and stormwater ('*unused*') for disposal. This approach dates back to the 19th century, when authorities found a positive correlation between poor sanitation and high mortality (Mitchell *et al.* 1999; Millis 2003). However, the simple '*supply and disposal*' approach has caused serious - and unsustainable - impacts to water resources and the natural environment. Urban water infrastructure in all Australian cities has largely been based on this '*separate system*' approach.

Increasing populations, particularly in capital cities, generate a steadily rising demand for water, and at the same time a rising demand for the disposal of wastewater (COA 2002). There was a focus on reliable supply and removal of urban wastewaters with little concern for the environmental impact and the sustainability of this pattern of water use. These pressures combined with ageing water infrastructure and general financial burdens have forced a review of traditional water management practices (Fleming 1999). Over time, a philosophical shift in the process of urban water management to the current '*water cycle management*' view has occurred (Colebatch 2005). The transition from the traditional approach that prevailed between the 1880s and 1980s, and the contemporary focus (recently institutionalised in 2004 by the NWI) has spanned more than two decades in Australia.

Table 12 provides a summary of the primary water management focus for both the traditional and contemporary urban water supply frameworks. However, important traditional objectives of water infrastructure related to social and economic well-being of the community are preserved in each framework.

**Table 12 Changing Focus in Urban Water Management Philosophy**

| **Water Management System** | **Traditional** **'*Supply & Disposal*'** | **Contemporary** **'*Water Cycle Management*'** |
|---|---|---|
| Water Supply | • reliable supply (security)<br>• economic development<br>• '*pure*' (drinking) water | • efficient use (manage demand)<br>• sustainable development<br>• water *'fit for use'* (eg. different qualities for different uses) |
| Wastewater | • public health concern<br>• water supply by-product<br>• discharge to water body | • public health concern<br>• reliable source of water (reuse)<br>• environment protection |
| Stormwater | • nuisance by-product of development (eg. roads)<br>• flood protection<br>• '*out of town*' disposal | • seasonal water source (eg. harvest for beneficial use)<br>• flood protection<br>• environment protection |

New water supply systems developed in Australia must be planned and designed for long term sustainability. This is an obligatory responsibility, particularly for public infrastructure projects, where costs and benefits of development are distributed over long periods of time over the life of the asset (ie. often between 50 and 100 years). The long life of the public infrastructure has been an impediment to rapid improvement of the sustainability of water services.

#### 3.3.1.2 Security of Supply

Less than 1% of water supplied to Australian towns and cities is actually used for drinking or food preparation by households (COA 2002). That is, almost all water, generally treated to a potable (drinking) standard, is used for purposes that could be satisfied with non-potable water if available. In Australia, urban water systems are designed to provide a high level of security; that is, to maintain supply in all but the most severe drought years. It has been common practice to impose water restrictions every summer in many North American cities (Dandy 1989) but until very recently water restrictions have only been imposed in most Australian cities when prolonged drought conditions result in water shortages.

Application of water restrictions outside these times was considered an indicator of system failure (Hammerton 1986); something to be rectified to prevent repeat occurrences. For example, between 1960 and 1988, water restrictions were imposed in the cities of Perth and Melbourne for 35 months and 33 months respectively (Duncan & Kesari 1988 in Dandy 1989). Similarly, restrictions were imposed on Adelaide water consumers, either voluntarily or by decree, on occasions up to the last occurrence in 1967 (Clark 1989). Under pressure of the 1978-83 drought conditions, a number of small town water supply schemes failed completely in New South Wales leaving residents reliant on carted water (Samra 1989). Nevertheless, given the wide climate variation and arid nature of the Australian continent, it is surprising that water restrictions have not been imposed more often.

Reynolds *et al*. (1983) argued the practice of '*drought proofing*' a water supply to support non-essential activities (ie. irrigation of parks and gardens) is not in the public interest in the longer term. They maintained public infrastructure investment would be more efficient in situations where normal operation was not expected to cope with drought conditions. Residential gardens, public landscapes, golf courses, nurseries, and many industries all suffer losses when water use is restricted (Dandy 1989; Price 1990; WSAA 2005). During such times, separate contingency strategies would be engaged to minimise loses. Adjustments to allocation and charging systems could accommodate those prepared to pay a premium for reliability (Reynolds *et al*. 1983; Dandy 1989).

This approach allows water users to make informed decisions on their required security level (ie. relative lack of water restrictions) by balancing individual resultant costs as rates and water charges with perceived benefits of their pattern of water use. While restrictions would still be necessary from time to time, the approach acts to limit them in frequency, duration and severity. Political support for this position was cemented in the 1994 COAG water reform framework and resultant pricing reform has stabilised per capita consumption in the Australian urban water sector (AATSE 1999; WSAA 2005). However, except for the urban water sector, the degree of application has been limited to minimise the likely adverse social and economic impact of reforms on dependent sectors of the community.

After a period of drought there is renewed awareness in the value of water and communities are more inclined to support alternative water management strategies. Notably, the recent prolonged drought that afflicted much of Australia has exposed the fragile nature of the Murray-Darling Basin and focused attention on the water needs of the environment and the consequences of excessive water extraction (EPA 2003; Radcliffe 2004). In addition, during the 2003/04 summer, water restrictions were imposed in every Australian capital city, except Darwin (Radcliffe 2004; Marks 2005). Urban and rural communities alike are impacted as regulated use, water restrictions and water conservation measures come into force. The value of water to a user is the maximum amount the user is willing to pay for the use of the resource.

It is not possible to specify a single level of secure supply that would be appropriate for all Australian communities. The level of secure supply provided will depend on local circumstances including the availability of water resources, the cost of required works, the willingness of the community and the ability of the community to finance the works. Provision of high security water services to small rural towns is constrained by the need for water authorities to remain financially viable. Water harvesting and reuse represents a safe and reliable new water supply that can provide insurance against future droughts or shortages of water and as a foundation for maintaining and improving economic prosperity and quality of life in Australian communities.

### 3.3.2 Residential (Household) Water Use Category

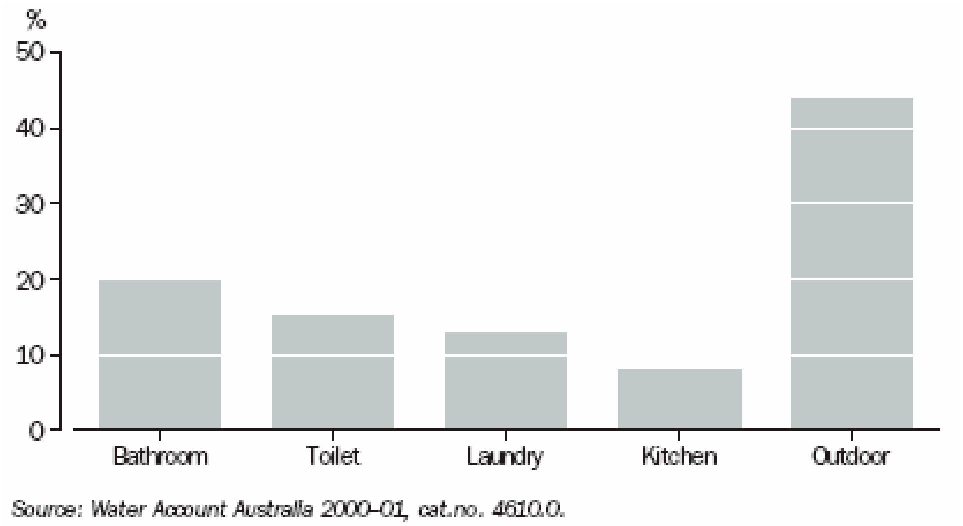
Patterns of urban water use are subject to uncertainty, being influenced by many factors including population growth, consumer behaviour (culture), household formation rates, population density, business activity, and climate (Liang 1998; WRSCMA 2001). The *Australia State of the Environment Report 2001* found climate and consumer behaviour (ie. level of water conservation practices) to be the stronger determinants of household water use throughout Australia (COA 2001). The development and management of Australia’s water resources has entered a period of decisive change. The ‘easy’ options for augmenting water supplies have been taken up and prospects for future expansion are limited. The residential water use category accounts for about 50% of the total of the demand within the urban water use sector (COA 2004). Therefore, changes in the patterns of water use by Australian households can have a significant impact on the total urban water sector demand.

#### 3.3.2.1 Location of Household Water Use

Australian households use water for a range of purposes including washing (personal, clothes and dishes), cooking, toilet flushing, lifestyle (swimming pools) and watering gardens. Outdoor water use is an integral part of the Australian lifestyle where residential gardens are a common feature of urban development.

Residential water consumption is made up of several components, including essential uses (hygiene, health, washing of clothes, dishes); non-essential uses (washing the car, watering plants in the garden); and wastage (leaks, wasteful behaviour) (Roseberg 1994).

The division of household water use into components helps to understand how water is used in the domestic sector. Figure 16 illustrates the allocation of water use in Australian households. Nationally, the majority of household water use is for outdoor purposes and less than 10% of water is used in the kitchen (COA 2002; ABS 2005; WSAA 2005).



Source: Water Account Australia 2000–01, cat.no. 4610.0.

**Figure 16 Typical Pattern of Water Use in Australian Households (ABS 2005)**

Water use varies between houses depending upon the number of people as well as the type and frequency of particular household appliances. Nevertheless, the pattern of indoor water use for bathroom, toilet, laundry and kitchen purposes is relatively constant throughout the year. Water used for these purposes is considered as a basic (essential) requirement; however, Foley & Daniell (2002) found there is a significant difference between the amount traditionally used in Australia and the actual level required to satisfy these needs.

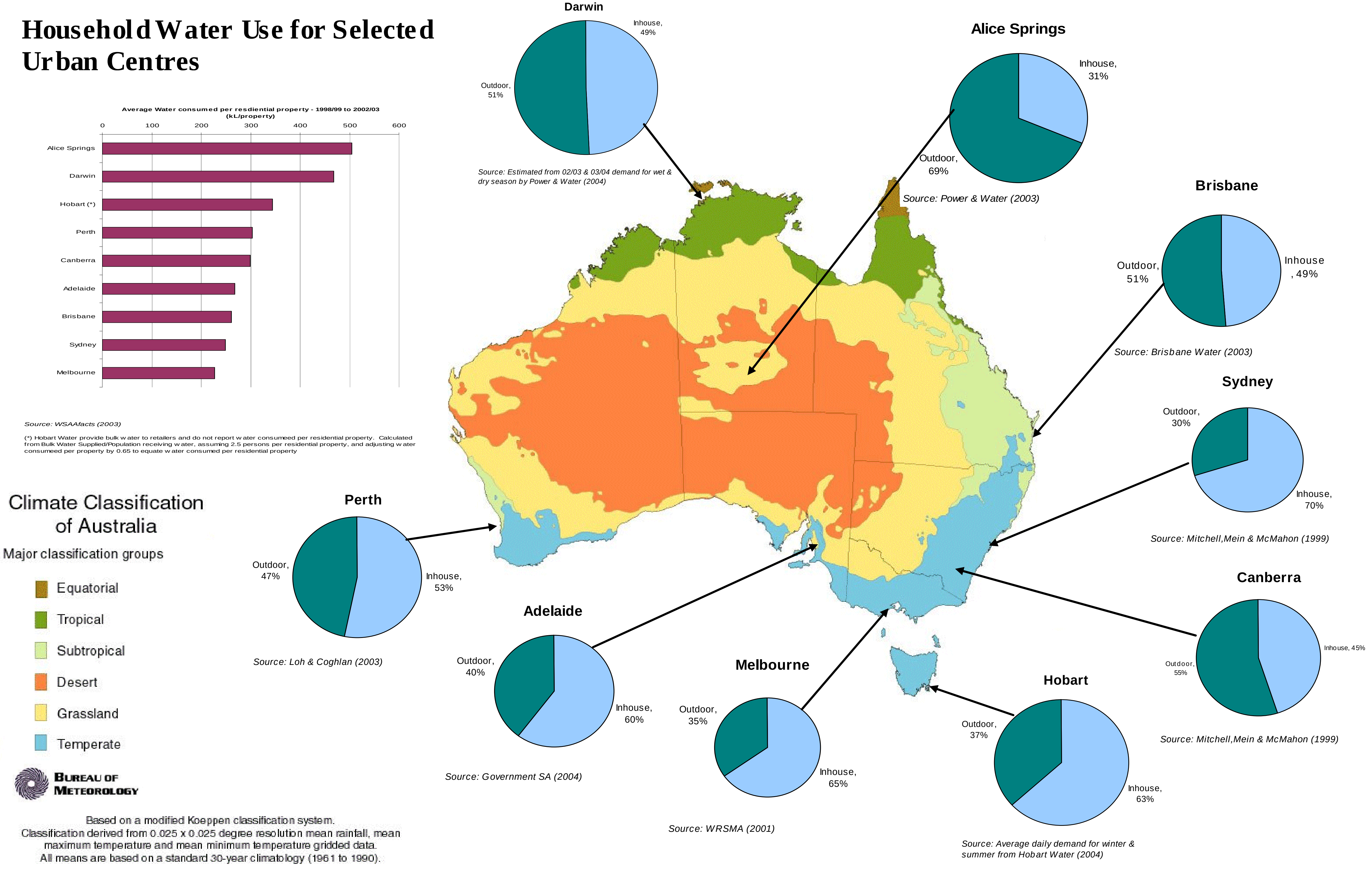
Gardens are cultural preferences; Australian gardening has significant historical roots and is heavily influenced by 19th Century British gardens (Murray-Leach 2003). This feature of Australian urban development makes Australian households heavy users of water compared their European counterparts. The pattern for outdoor (non-essential) use is seasonal, depends on the size and type of garden and influenced by the prevailing climate. Water required for gardening varies considerably between towns according to rainfall and evaporation. For instance, depending on the seasonal weather patterns, the outdoor water use component can fluctuate by plus or minus 8% in Melbourne (COA 2002) and rise or fall by 12% in Adelaide (GSA 2004).

Figure 17 presents the 5 year average household water use for 1998/99 to 2002/03 as well as the typical division of indoor and outdoor water use for selected Australian urban centres. The Köppen classification of world climates, as applied by the Bureau of Meteorology to Australia, is adopted to highlight the difference in patterns of household water use in relation to the prevailing climate. Australia is a big country, stretching from the tropics to the roaring forties, and it has a correspondingly wide range of climates. Under the climate classification system, Australia is divided into six major climatic regions on the basis of air temperature and humidity. The relative proportion of the average household outdoor water use varies from 30% in Sydney (temperate climate) to 70% in Alice Springs (grassland/desert climate) indicate that the Australian Garden has evolved with piped water and is not constrained by local climate. In the United Kingdom, a country with high rainfall and low evaporation, external water use is only 3% of the total residential water consumption (WSAA 2003). However, there is a low degree of confidence in such data because only very limited number of Australian studies have directly observed indoor/outdoor water use.

Nevertheless, these figures imply that current landscape and gardening practices are not well suited to the Australian arid or semi-arid environments and make residential outdoor water use an attractive target for consumption savings in the urban water use sector (Pigham 1986). The problem with outdoor water usage is that it is not amenable to easy general fixes for water efficiency. The answers lie in garden designs, paving rather than lawns, appropriate plants, responsible watering and urban planning. The solutions depend highly on the individual. Garden style can and has changed over the last hundred years, but influencing changes requires understanding of the current culture.

As residential customers use water more efficiently, patterns of water use will change and historic consumption information may no longer be reliable for long-term planning purposes.

On the basis of the pattern and location of household water use, it is possible to identify two distinct types of water quality requirements according to the end use. Potable (drinking) quality water, or water that is suitable for human consumption on a long-term basis, is needed for bathroom, laundry and kitchen purposes. The remainder of the household demand (non-potable uses) accounting for about 60% of the total water demand have less stringent quality requirements and do not require potable quality water. Given that a significant proportion of the potable water supplied to urban customers does not have to be of high quality; there is significant scope to use lower quality water for non-potable end uses. However, the established water system in most urban centres in Australia is designed to supply one quality of water to households. Even so, use of water in urban areas is to some extent discretionary and, at least for certain purposes such as garden watering should be sensitive to price changes.



*Source: WSAAfacts (2003)*

(*) Hobart Water provide bulk w ater to retailers and do not report w ater consumeed per residential property. Calculated from Bulk Water Supplied/Population receiving w ater, assuming 2.5 persons per residential property, and adjusting w ater consumeed per property by 0.65 to equate w ater consumed per residential property

Based on a modified Koeppen classification system.
Classification derived from 0.025 x 0.025 degree resolution mean rainfall, mean maximum temperature and mean minimum temperature gridded data.
All means are based on a standard 30-year climatology (1961 to 1990).

*Source: Estimated from 02/03 & 03/04 demand for wet & dry season by Power & Water (2004)*

*Source: Power & Water (2003)*

*Source: Brisbane Water (2003)*

*Source: Mitchell,Mein & McMahon (1999)*

*Source: Mitchell,Mein & McMahon (1999)*

*Source: Loh & Coghlan (2003)*

*Source: Government SA (2004)*

*Source: WRSMA (2001)*

*Source: Average daily demand for winter & summer from Hobart Water (2004)*

**Figure 17 Household Water Use in Selected Australian Cities (Rabone2004)**

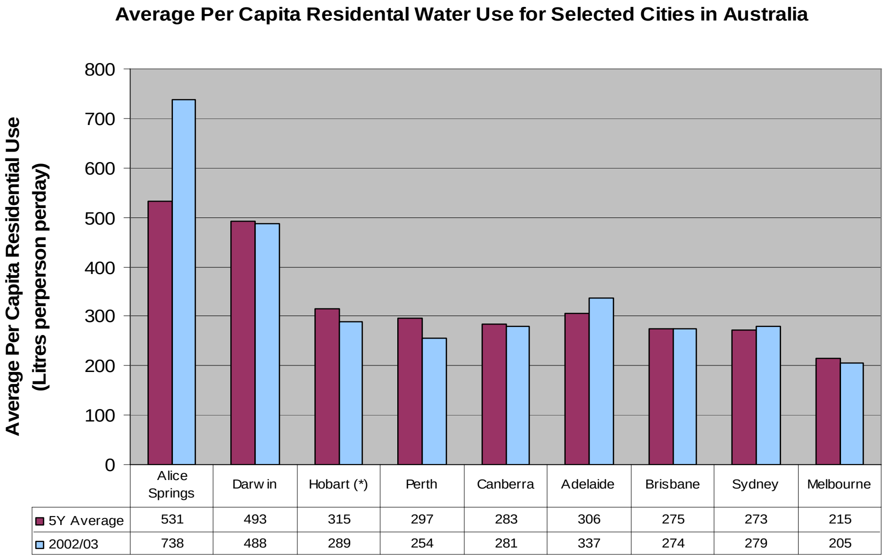
### 3.3.2.2 Level of Household Water Use

Water is essential to our health, our physical and spiritual needs, our comfort, our livelihoods, and our ecosystems (GTZ 2001). For these reasons, water demand by individuals has been of interest since ancient times for estimating water supply requirements. For example, analysis of the observations by Sextus Julius Frontinus, water commissioner of Rome, AD 97, indicate that the average water use of inhabitants of Rome, a city of one million people was 144 litres per capita per day (Hershel 1973 in McLellon 1991). In modern times, larger volumes of water are delivered by water supply systems because societal habits have changed; excessive water use is, in part, a cultural problem (WA WRC 1986; Fleming 1999; Murray-Leach 2003). Thus, effective water resource planning will increasingly rest on understanding the factors that shape society.

Figure 18 below provides a comparison of the 5 year average per capita use by the residential water use category (top graph) and the average annual household water use (bottom graph) for 1998/99 to 2002/03 for major urban centres around Australia. The top graph in Figure 18 shows the per capita residential water use (ie. excluding industry) in Australia ranges from 215 litres per person per day in Melbourne to more than 500 litres per person per day in Alice Springs. The bottom graph Figure 18 shows the 5 year average annual household water use in Australia ranges from 227 kilolitres per household per year in Melbourne to around 500 kilolitres per household per year in Alice Springs. The pattern of water use varies with seasons, with peak consumption in summer, except for Darwin which experiences peak consumption during its dry winter.

Demand management strategies introduced in the urban water use sector, as part of the national COAG water reform between 1994 and 2004 have been successful in relation to stabilising per capita consumption (AATSE 1999; WSAA 2003). For example, Sydney has been able to accommodate an additional 700,000 people without using more water (WSAA 2005). However, despite reductions the average household consumption in Australia remains approximately 30% higher than the 1997 OECD average of around 180 litres per person per day (COA 2004). When compared to the world standard for ‘optimal’ level of service of 100 to 200 litres per person per day the current level of water use in some Australian cities can be considered excessive.

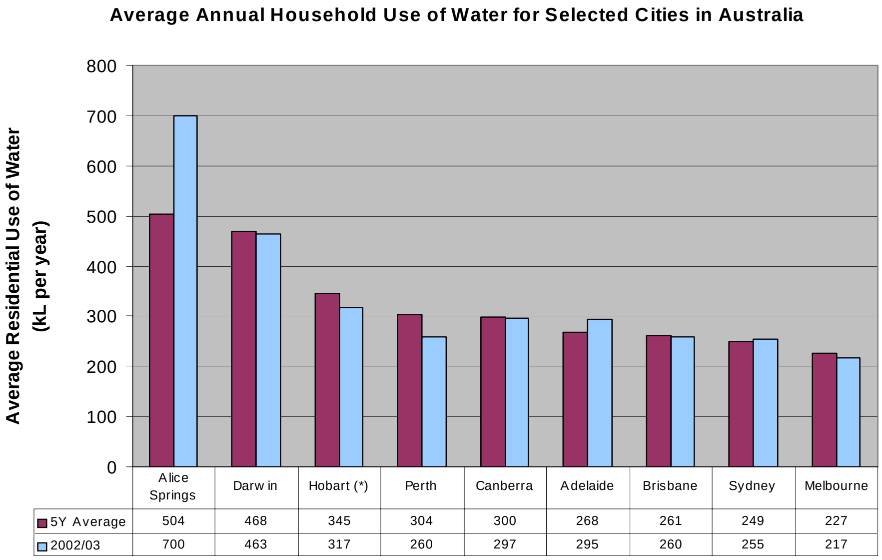
While there has been a significant reduction over the last two decades in the per capita consumption of water in major urban centres, the total water consumption is increasing as populations grow (COA 2002). There is scope for reduced residential demand in Australia with per capita consumption in many urban centres well above the level required to meet essential drinking, cooking and sanitation needs. WSAA (2005) cautions that consumption savings cannot be achieved indefinitely, that most of the easy measures have already been taken and that further limitations will be highly intrusive and likely to encounter community resistance.



| | Alice Springs | Darw in | Hobart (*) | Perth | Canberra | Adelaide | Brisbane | Sydney | Melbourne |
|---|---|---|---|---|---|---|---|---|---|
| 🟥 5Y Average | 531 | 493 | 315 | 297 | 283 | 306 | 275 | 273 | 215 |
| 🟦 2002/03 | 738 | 488 | 289 | 254 | 281 | 337 | 274 | 279 | 205 |

*Source: Australia State of the Environment Report 2001 (Human Settlements Theme Report) & WSAAfacts (2003)*

**Per Capita Water Use (Residential services only)**



| | Alice Springs | Darw in | Hobart (*) | Perth | Canberra | Adelaide | Brisbane | Sydney | Melbourne |
|---|---|---|---|---|---|---|---|---|---|
| 🟥 5Y Average | 504 | 468 | 345 | 304 | 300 | 268 | 261 | 249 | 227 |
| 🟦 2002/03 | 700 | 463 | 317 | 260 | 297 | 295 | 260 | 255 | 217 |

Source: WSAAfacts (2003)

* Hobart Water provide bulk w ater to retailers and do not report w ater consumeed per residential property. Calculated from Bulk Water Supplied/Population receiving w ater, assuming 2.5 persons per residential property, and adjusting w ater consumeed per property by 0.65 to equate w ater consumed per residential property

**Average Annual Household Water Use**

**Figure 18 Average Residential Water Use in Selected Australian Cities**

### 3.3.3 Non-residential water use

The pattern of water use by the non-residential customer category (ie. industry, business, and institutions) is markedly different from residential water use. Non-residential customers use larger volumes of water for a more diverse range of purposes. Businesses, industries, institutions, and other large non-residential water users often have the potential for significant contribution to conserving urban water supplies. However, potential water savings can only be achieved if these customers can be persuaded to change their usual ways of operation. If urban water utilities want to promote or require water conservation among non-residential customers efforts must be based on an understanding of how these customers use water and to address the needs of these customers.

#### 3.3.3.1 Industrial and Commercial Purposes

Industrial and commercial users are generally manufacturers, retail traders and office buildings. Water is used by industrial customers for three fundamental purposes: heat transfer, materials transfer, and as an ingredient (Ploeser *et al.* 1992). Many industries use potable water when lower quality water would be adequate for their purposes; that is potable water could be substituted with recycled water or stormwater. Non-potable commercial and industrial end uses include toilet and urinal flushing in building complexes, industrial applications such as cooling, boiler feed and process water and heavy construction (Mitchell *et al.* 2002a). The demand curve for industrial consumers follows a more linear relationship than residential customers.

As the cost of water rises, substitutes and alternatives are found, such as the recycling of cooling waters or changes in the manufacturing process (Roseberg 1994). The introduction of water and wastewater (trade waste) tariffs has led industries to cut their unit production water consumption rates. For example, between 1990/91 and 1998/99, the industrial water use in Sydney declined from 5,200kL per year to current levels of 3,180 kL per year (COA 2002). However, owners of businesses and industries are reluctant to change their methods of operation except where the conservation program has a reasonable payback period of the order of 5 to 7 years and protects propriety information (Ploeser *et al.* 1992). Few businesses in Sydney committed to implement the free water audit findings even where the potential gains were clear (COA 2002).

From the limited data available, commercial consumption exhibits low seasonal variability. Depending on their operation, urinals can be extremely high users of water and can be the largest single water consuming device in a commercial organisation (COA 2002). In other countries, it is increasingly common for in high rise buildings to be designed to conserve potable water as described in Example 6.

**Example 6 Onsite Water Reuse in High Rise Office Buildings**

*In highly populated urban areas, such as Tokyo, Japan and Seoul, Korea, individual building water reuse systems are being used for toilet and urinal flushing in high rise buildings to conserve potable water. These building are equipped with two separate wastewater lines to allow the water collected from the hand basin to be transferred to the treatment system that is usually located in the base of the building. The treated water is then used for toilet and urinal flushing before being discharged to the centralised municipal wastewater treatment plant.*

*Source: Anon (2003?)*

This type of onsite water reuse is not commonly incorporated in the design of high rise buildings in Australia. Waterless urinals have been developed but their use to date is rare (COA 2002).

The impact of water use restrictions is not always an adverse one – there are many opportunities arising for industry and commerce to profit from water conservation programs and benefit from the provision of goods and services designed to improve water use efficiency. For example, several South Australian based companies are developing soil water monitoring technologies, scheduling and control systems for sale (GSA 2005). In the longer term, sustaining reduced consumption is heavily dependent in water efficient appliances and fittings becoming the accepted norm in the marketplace (COA 2002). There is evidence to suggest that industrial and commercial users can still cost effectively reduce overall water use by 10% through a number of efficiency measures (GSA 2005).

The economics of commercial and industrial reuse vary depending on the type of project being developed, the degree of treatment required, and the proximity of the water treatment plant to the location where the recycled water will be used. Some industries harvest and reuse water from their own site or use treated effluent from a local wastewater treatment plant in their manufacturing processes, but currently this is only a minor component of total industrial use.

#### 3.3.3.2 Community (Institutional) Purposes

Water for community purposes includes water used by government agencies, universities, schools, local government, public parks and gardens, sporting grounds, places of worship and hospitals (GSA 2005). In some situations, potable water used for community purposes can be substituted with lower quality (non-potable) water such as recycled water, rainwater and stormwater. Non-potable community end uses include toilet and urinal flushing in institutional facilities, irrigation of sports fields, golf courses, parks and gardens, open spaces, and recreational and environmental uses such as ornamental water features, lakes and ponds, and stream flow augmentation (Mitchell *et al.* 2002a). Irrigation demand for water has high seasonal variability which is predominantly a function of the prevailing climate.

A great deal of community water use is not efficient, either through wasteful practices, poor design of landscapes, inefficient equipment or a combination of these. Water efficiency should be a primary consideration when irrigation systems are installed, renewed or undergoing significant maintenance (WSAA 1998). Adopting landscape designs and selection of drought resistant plants suited to the Australian environment would make reductions in community water consumption possible. Garden style can change but influencing changes requires understanding of the current culture (Murray-Leach 2003). Institutions and community organisations should be encouraged to replant with water-efficient vegetation. Through more efficient practices and installation of water efficient appliances in public and community buildings, there is the opportunity to reduce mains water use for public purposes by at least 12% (GSA 2005).

In addition to conservation measures, the use of non-potable water for landscape irrigation in Australian cities is also expected to increase in the future. The extent to which non-potable water is utilised depends on availability of suitable parks, sportsgrounds, golf courses, and cemeteries, in reasonable proximity to the sources of stormwater and wastewater. Irrigation requirements are seasonal and much of the stormwater and wastewater will not be utilised (ie. discharged to waste) unless large off-season storages are provided. Much of the focus on water harvesting and reuse has been on larger urban communities where the scale of engineering works is most likely to prove financially defensible (Cooper *et al* 2005).

Irrigation schemes for public and recreational purposes using local stormwater and wastewater resources is an attractive option for small communities as a means of improving their amenity at low cost. For example, trees and shrubs could be grown to create shelterbelts (windbreaks) that can deflect (or filter) hot drying winds around community facilities. Such initiatives may result in outdoor entertainment and play areas and enhancement of views for the town; however the benefits achieved will vary depending on local conditions (Zwar 1985). Strom (1985) estimated that water harvesting and reuse could be adopted benefiting more than 80 Australian towns.

## 3.4 LIMITATION OF SMALL SYSTEMS

Throughout the world, those responsible for supplying small towns with water have struggled to find ways to deliver good quality service at an affordable price. The small size of many regional towns in Australia, combined with small community budgets, has limited the delivery of mainstream services (ie. services comparable to urban centres). In general, rural communities are often disadvantaged in terms of their water supply, both in quantity and quality, and the smaller the town, the greater the disadvantage. Factors influencing the design and delivery of sustainable water services to small and remote communities might include affordability, technical appropriateness, current service delivery structures, and levels of skill and resources available in the community (HREOC 2001).

Many small towns have sufficient populations to benefit from the economies of scale offered by piped systems, but they are too small for conventional (mainstream) urban water utilities (WSP 2003). There is no common approach to delivering water services to small towns that meet the performance standards of good quality, affordability, sustainability and ability to expand to accommodate growth. The challenge is to undertake planning, management, and funding reform that will guarantee effective use of water resources, minimise adverse impact on the environment and provide long term sustainability of local economies. The degree of sustainability achieved is dependent upon the state of knowledge and therefore upon the evolution of appropriate technology (Fleming 1999).

### *3.4.1 Public Health Implications*

#### 3.4.1.1 Potential for Waterborne Disease Outbreak

Communities of all sizes are at risk of microbial infection without a safe water supply. In general, small water systems are more vulnerable to outbreaks of waterborne disease than larger systems. For example, in the United States, there have been nearly 600 reported outbreaks of waterborne diseases from water supply systems over the last 20 years (NAS 1998). The smallest systems, those serving less than 500 people (around 200 connections), violated drinking water standards more than twice as often as larger systems (US Water 1996; NAS 1998). In Australia, with the exception of the *Giardia* and *Cryptosporidium* scare in Sydney during 1998, '*major urban*' water utilities are rarely confronted with large outbreaks of waterborne diseases. However, it is widely recognised by Australian health and water authorities that provision of safe water to small communities is an ongoing challenge.

Economic constraints often mean that only untreated water can be supplied, or that treatment is limited in extent, and monitoring may be infrequent or absent (ADWG 1996). Public health is protected by reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the water, and controlling specified chemical constituents in the water. Health problems can arise by drinking water from any source (ie. reticulated supply, rainwater tank, or bore) that is not properly treated if it contains disease-causing organisms or other contaminants. Without chlorination or other disinfection processes, communities are at risk of contracting waterborne diseases. Gastroenteritis is the most common disease derived from water and the causal agent may be bacterial, viral or protozoan from human or animal faeces (Millis 2003).

Example 7 outlines the consequences of a reported outbreak of gastroenteritis in three communities served by a '*small*' Australian water utility.

### Example 7 Public Health: Sunbury Outbreak 1987; Victoria, Australia

*In October 1987, an outbreak of gastroenteritis occurred in the regional Victorian towns of Sunbury, Diggers Rest and Bulla, affecting over 5,000 residents (ie. about 30% of the population). The three towns were supplied by a common drinking water supply, without treatment or disinfection of the source water. People of all age groups were affected (refer to Figure 19 below) and experienced symptoms of vomiting, abdominal cramps, diarrhoea, fever, and malaise.*

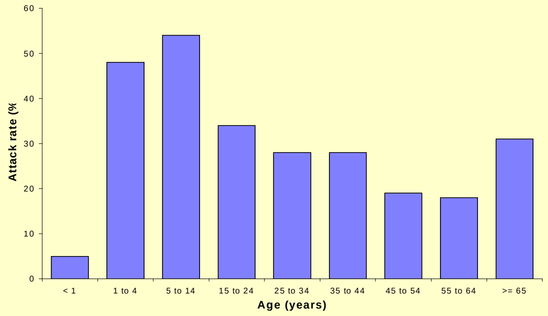


**Figure 19 Attack Rates for Vomiting, October 1987 (Kirk *et al.* 1999)**

*Investigations identified contaminated drinking water supplied to the three towns as the likely source of the epidemic. The outbreak ceased shortly after the water authority turned off the suspected water source and issued a 'boil water' notice to residents in the affected areas on 9 October (see Figure 20).*

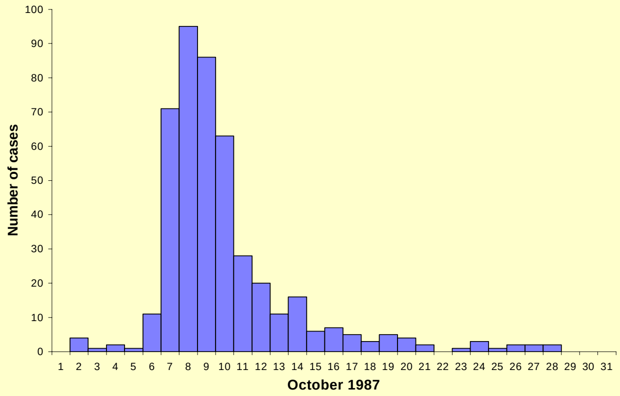


**Figure 20 Residents Suffering Vomiting October 1987 (Kirk *et al.* 1999)**

*Source: Kirk et. al. 1999*

When a waterborne disease outbreak occurs it causes considerable community disruption, illness and even death. Infants, elderly persons, and persons with illness are the most susceptible (Anon. 2003?; Millis 2003). The intense public and political pressure strains public confidence in the water supply itself and those concerned with its management. Therefore, it is critical that systems are in place to support water authorities and health agencies in managing such events (Kirk et al. 1999).

Disinfection is crucial to water system security, providing the '*front line*' of defence against biological contamination (CCC 2003). Example 8 describes the extended health threat from waterborne disease in Peru where a major causative factor was inadequate disinfection.

**Example 8 Public Health: Cholera Epidemic 1991-1996: Peru**

*In 1991, an outbreak occurred in Peru that resulted in a five year epidemic of cholera where the major causative factor was determined to be inadequate drinking water disinfection. The epidemic spread to 19 Latin American countries, causing more than one million illnesses and 12,000 deaths. After the outbreak, international health officials criticised Peruvian water officials for inadequate chlorination the water supply. The water officials in Peru and other the Latin American countries confirmed the inadequate chlorination was the result, at least in part, of concern over disinfection by-products and clearly misinterpreted the risks the by-product posed.*

*Sources: CCC (2003)*

In this case, the waterborne transmission of cholera was aided by the cessation of chlorination because the risk posed by chlorination by-products was misunderstood. Disinfection by-products (DBP) are compounds formed unintentionally when chlorine and other disinfectants react with matter in water. A report by the International Programme on Chemical Safety (2000 in CCC 2003) found

> "*the health risks from these by-products at the levels at which they occur in drinking water are extremely small in comparison with the risks associated with inadequate disinfection. Thus, it is important that disinfection not be compromised in attempting to control such by-products*"

Nevertheless, cost effective methods to reduce DBP formation are available and should be adopted where possible.

While appropriate treatment and disinfection can control the bacterial pathogens, the oocysts of *Cryptosporidium* and some viruses are known to be resistant to chlorine (Millis 2003). In April 1993, breakthrough (ie. failure of the water filtration system) of cysts, not failure of the disinfection system, caused the major diaster in Milwaukee, United States. More than 400,000 people were affected and over 100 deaths were attributed to this outbreak (CCC 2003). The Milwaukee incident highlights the devastating impact that inadequate water treatment (barriers) can have on public health even where disinfection is maintained.

In Australia, public health falls within the jurisdiction of State and Territory governments and state-based health authorities are responsible for ensuring that state standards for water quality and water treatment are consistently met. Water supply managers and treatment plant operators may be held personally liable for non-compliance where established guidelines are not followed. Example 9 below illustrates how failure to respond to clear warning signals and to exercise diligence resulted in an extremely serious incident in Canada.

**Example 9 Public Health: Walkerton Outbreak, May-June 2000: Canada**

*In May and June 2000, an outbreak of gastroenteritis occurred in the small town of Walkerton in Ontario. The source of drinking water for the town is groundwater that is chlorinated prior to distribution. The number of people affected by the outbreak was 2,300 and resulted in 65 people being admitted to hospital and 7 deaths, the largest multi-bacterial waterborne outbreak in Canada to date. Identification of the outbreak was initiated by the recognition of paediatric cases of bloody diarrhoea and severe abdominal cramps reported on 19 May. The onset for illness of the majority of reported cases occurred after 12 May and continued until late June 2000. Although most became ill between 16 and 26 May, several cases were identified with onset dates as early as 15 April 2000. The median age of reported cases was 29 years (range < 1 to 97 years); nearly 60% were female.*

*An enquiry after the incident into how the water supply was contaminated revealed that:*

- *heavy rainfall in early May and a well subject to surface water contamination was responsible for gross contamination of the water supply;*
- *coliform counts were often positive before the incident but no remedial action was taken by operators of the water supply;*
- *the chlorination plant for the contaminated well was unreliable (ie. not operating) due to inadequate maintenance and had been for months; and*
- *chlorine levels in the general water supply were overwhelmed by the influx of contaminated water from the well.*

*The water supply operators had failed to follow established guidelines on chlorine dosing, monitoring and recording chlorine residuals which could have prevented the outbreak. Alarmingly, it also found that despite the Boil Water Advisory and extensive publicity, some residents in Walkerton continued to expose themselves to the water though various routes, including brushing teeth and occasionally drinking it.*

*In March 2003, two former water supply managers were charged with public endangerment, fraud and breach of public duty (trust) for their part in the outbreak. In November 2004 both pleaded guilty. The Judge found them negligent in discharging their duties, although there was never any intent to harm anyone. The former utilities manager was sentenced to one year in jail and the water foreman was sentenced to nine month house arrest.*

*Sources: PHAC 2000; CCC 2003; Millis 2003; CBC 2004a, 2004b*

The Walkerton incident sends a '*sharp and clear message*' that those employed in an occupation of any kind where public safety is affected and fail to perform their legal duties '*there's a real risk you can be sentenced to jail*' (CBC 2004b).

### 3.4.1.2 Level of Monitoring

The previous examples emphasise the importance of secure water sources, adequate water treatment and disinfection in ensuring a safe water supply to a community. Bacterial monitoring can only identify a contaminated source after the contamination has spread through the water system and put the public at risk (PHAC 2000; Millis 2003). Therefore, the first requirement for effective management of a water supply system is to understand the individual system, the barriers in place to minimise the entry and transmission of contaminants, and the various processes and practices which can affect water quality within the system. The *Australian Drinking Water Guidelines* (1996) recommend that monitoring programs for public water supplies cover both the operational and system performance. Yet, for small communities the cost involved in carrying out all of the recommendations of the *Australian Drinking Water Guidelines* may not afford reasonable return on investment towards guaranteeing safe water supplies.

System performance monitoring is an assessment of the quality of water in the distribution system and as supplied to the customer. Table 13 sets out the minimum frequency, at which water samples should be collected and analysed for micro-organisms for systems serving different size populations. While public health considerations remain paramount, periodic sanitary surveys are likely to yield more information on the system performance than more frequent sampling for small water supply systems (ADWG 1996).

**Table 13 System Performance Monitoring Requirements (ADWG 1996)**

| Population Served | Number of Services | Minimum Number of Samples |
|---|---|---|
| > 100,000 | > 50,000 | 6 samples per week, plus 1 additional sample per month for each 10,000 above 100,000 |
| 5,000 to 100,000 | > 2,500 | 1 sample per week, plus 1 additional sample per month for each 5,000 above 5,000 |
| 1,000 to 5,000 | > 500 | Preferably 1 sample per week. If < 1 sample per week is taken see below. |
| <1,000 | < 250 | Regular sanitary inspections |

*Source: ADWG (1996)*

A number of measures can be taken in order to reduce the risk of an unsafe supply such as maintaining plant and equipment in good condition, particularly the disinfection equipment. Disinfection is the most important single activity in providing a safe water supply and it is vital that this step is adequately carried out. If chlorine is used, a residual of between 0.2mg/L and 0.5mg/L (known to have good bacteriological quality) should be maintained (ADWG 1996). The residual level of disinfection of water in pipelines is to prevent microbial regrowth and help protect treated water throughout the distribution system. Operational monitoring is used to check that the processes and equipment that have been put in place to protect water quality are working properly.

As a minimum, small community supplies should be monitored for the characteristics which best establish the hygienic state of the water and the potential for other problems to occur. The *Australian Drinking Water Guidelines* recommend the monitoring program should be directed towards characteristics set out in Table 14 below for populations of less than 1000 people.

**Table 14 Operational Monitoring for Small Water Supplies (ADWG 1996)**

| Characteristic | Water Source | Minimum Monitoring Frequency |
|---|---|---|
| Disinfectant residual | Any | Daily (or preferably continuous) |
| pH, | Any | Daily (or preferably continuous) |
| Turbidity | Any | Daily (or preferably continuous) |
| Faecal coliforms or alternatively E. Coli | Surface Water<br>Groundwater | 1 sample per week<br>1 sample per fortnight |

*Source: ADWG (1996)*

Regardless of size of the system an annual report should be prepared to give an account of the system performance in relation to agreed water quality goals. The report should include a summary of monitoring information, indicate water quality trends and problems, and a statement of system failures over the past year and action taken to resolve them. Reporting on water quality should be open and comprehensive if the public is to have confidence in the water authority. Large water systems that serve a number of towns should be divided into regions for the purpose of annual performance reporting and made publicly available to the related communities.

### *3.4.2 Appropriateness of Technology*

Appropriate technologies for water resource management and delivery should be available on an equitable basis to regions experiencing water related problems (GTZ 2001). Debate about appropriateness of technology has emerged in response to recognition that culture and other factors, such as prevailing socioeconomic and political conditions, are significant in the transfer of technology (Hazeltine & Bull 2003). Nevertheless, selection of appropriate technology can bring advantages to people living in small communities or remote locations. In the context of small communities, appropriate technology can be viewed as small-scale, energy efficient, environmentally sound, and self-sustaining. The degree of sustainability achieved is dependent upon the state of knowledge and therefore upon the evolution of appropriate technology (Fleming 1999). It should build on and strengthen existing local knowledge, cause little social disruption and be able to be maintained by people within the community (GTZ 2001). It is imperative that the design and implementation of systems that deliver water to Australia’s remote and indigenous communities reflects cooperative process of negotiation, community education, and cultural awareness (HREOC 2001).

### *3.4.3 Local Skill and Resources*

Water utilities operating small systems cannot reliably deliver services unless their operators are adequately trained even where appropriate technologies have been adopted. Accordingly, training local people to operate the system and maintain associated equipment is as important as establishing the technology itself. Attention should be paid to whether the specified equipment, especially sophisticated equipment, is in use elsewhere in the community. In addition to the problem of learning to use complex equipment, having a unique piece of equipment may mean that advice and spares will be difficult to find (ie. no local serviceperson). It is recommended that a strategy be developed for debugging, for training, for repairs, and for spare-parts and supplies when choosing any new equipment. Safety is also an important issue. One needs to think carefully about the ways a tool might be misused, especially by a careless or inexperienced worker, and prevent as many ways as possible.

Operation is often simplified by automated features, particularly where maintenance requirements are well documented in manuals provided by the manufacturer. Common automated devices found in package plants are effluent turbidimeters and chemical feed controls. Typical plant operation and maintenance manuals should contain operating principles, methods of establishing proper chemical dosages, operating instructions, and trouble shooting guides (Clark *et al.* 1994). It is especially important to do the recommended maintenance if the equipment is in a remote location where a breakdown cannot be repaired easily. The advantage of doing preventative maintenance, rather than waiting for a breakdown, is that it can be scheduled. Trained local personnel can carry out routine maintenance activities; however, some maintenance, such as a full over haul, needs to be done by a professional.

Periodic visits by the manufacturer should be scheduled to make adjustments to the plant, inspect the equipment operation, and performance. The first visit should be no more than 6 months after initial commissioning run-in period, the second should follow in another 6 months, and then annual visits should be sufficient (Clark *et al.* 1994). A final aspect of maintenance is preparing for an emergency failure; a plan is needed covering such matters as whom to call and what to do until the repairs are made. The number and kind of spare parts to be held in inventory is affected by how important the machine is to overall operations and how quickly spares can be sourced.

There is a need for the provision of technical support to small water supply operators to ensure delivery of safe water to small communities when usual situations arise and in the expansion of systems. In such situations, small water utilities are likely to hire consultant services to supplement their in-house technical capabilities. There may be an opportunity for several small water utilities to join together to obtain needed specialists and thereby benefit from economies of scale. Additionally, current training programs in Australia are disjointed and often fail to meet the needs of small water supply operators. The water industry should identify the knowledge and skills needed and work with independent organisations, to develop and deliver training programs to system owners and operators across the country. This might be achieved by the organisations that support the water industry (as discussed in section 3.2.4).

### 3.4.4 Financial Viability

The provision of services to small towns is constrained by the need for water authorities to remain financially viable. A major constraint for towns and rural communities is the small static rate base, limited scope for economic development and restricted opportunities for resource sharing between communities. Without the benefit of economies of scale, small system managers often find it difficult to keep qualified staff and afford the professional technical and commercial support needed to properly maintain systems and improve efficiency. Differences in the operational environment faced by water utilities can have a significant impact on their cost recovery capability. The challenge into the future for small water utilities serving towns is to undertake pricing and funding reform which will guarantee their long term sustainability and cost effectiveness.

#### 3.4.4.1 Capacity for Cost Recovery

Demand for water services is highly dependent on availability, price and a willingness to pay for water. The price paid by consumers generates obvious interest, but the structure under which the utility charges for services is more important. A key requirement of the national COAG water reforms was the introduction of a two tier pricing structure that includes separate fees for access (fixed) and usage (consumption). In general terms, utilities drawing most of their revenue from usage charges have comfortably achieved the COAG water reform requirements (AWA 2002a). Tariff structures around Australia have been changed to meet the COAG requirements, however governments may have retained a policy to set prices below those necessary to generate full cost recovery for water utilities operating in regional areas.

Most authorities realise that there are economic limits that prevent most small communities from funding such works in their entirety (ie. full cost recovery it is not feasible). For smaller water utilities to remain financially viable, revenue from community service obligation (CSO) payments is a necessary subsidy particularly where government provides water infrastructure to support development in regional Australia. About half of the '*non major urban*' water utilities received some revenue from CSOs (AWA 2002a). Income derived from CSOs for WSAA members (ie. '*major urban*' water utilities) was smaller as a proportion of total operational revenue (AWA 2002a). There is no publicly available comprehensive report for '*small*' water utilities; however, income from CSO payments or other industry subsidisies is also likely to be substantial.

The key objectives of an effective water pricing system are cost reflectivity, environment protection, and cost recovery (GWT 2003). The pricing system needs to generate revenues for the efficient operation (and debt service) of the present system and its future maintenance, modernisation and operation. A key condition is the government's willingness to price water services at a financially sustainable level (see previous Example 2). Nevertheless, pricing adjustments should be applied selectively, gradually and with sensitivity to minimise the adverse social and economic impacts of such reforms on some sectors of the community in regional Australia.

### 3.4.4.2 Micro-Financing for Capital Investment

Lenders do not like to take financial risks. For example, if a significant proportion of the financing debt is variable, there is a risk that rising interest rates may jeopardise a community's ability to service its debt. The payback period is the length of time in years until the initial investment is repaid and is a useful means to estimate of how long the utility and investor is at risk. To keep water prices affordable, the payback period for water infrastructure investments is usually amortised over 15 to 30 years (Figueres *et al.* 2003). Long-term financing is needed for water infrastructure projects, which is why the water sector is not very attractive for investors. Compared to international agencies, local Australian banking groups are relatively inexperienced in providing financing for small water supply infrastructure projects (ie. between $0.1m and $10m).

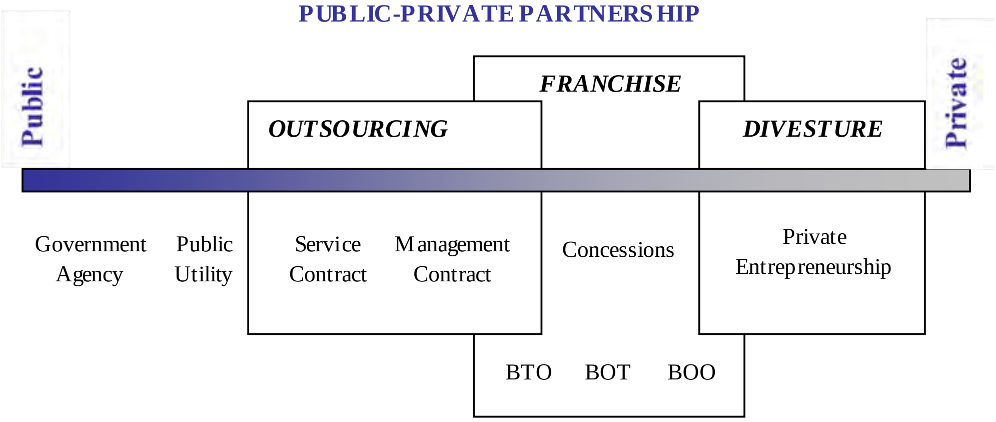
The perceived risks of the lender will be different from those of the infrastructure provider. Water supply projects can be considered low risk in terms of financing in that the business is a monopoly and the demand for water is always on the increase (Subramaniam 1993). Yet the current trend among most bankers is to assign the same risk and interest terms to water supply projects as housing (subject to the ups and downs of the market resulting in high financing risk) and other development projects. Furthermore, the financier requires the whole works, including the pipelines (which make up the greatest part of the project cost) to be insured against all risk (Subramaniam 1993). Matching water infrastructure projects and sources of finance is mainly a matter of identifying the right combination of risks for all parties.

Local small-scale financing can be used to support the development of water initiatives at the community level (Figueres *et al.* 2003). In developing countries, micro-financing is one of the driving forces behind economic development and an emerging industry throughout the world (Morse & Bell 2003). Micro-financing is the term used to describe a financial operation that provides small loans to struggling business people in order to expand their enterprises. Unlike commercial lenders, sustainability is the goal for this type of financial organisation rather than profit. Micro-financing operations provide various financial services similar to commercial banks but, due to the nature of the portfolio, loan procedures have been adjusted.

There is enough money in the world, just as there is enough water, but it is not always available at the right time and in the right place (Figueres *et al.* 2003). Observers still regularly call for donor agencies to support a larger number of smaller scale projects. With money, as with water, the challenge is to match resources with demand, taking into account both short and long term factors, social justice, politics and the needs of the environment (Figueres *et al.* 2003). It is obvious that funds to finance small-scale water projects in regional Australia must be increased in the coming years. Risks involved need to be better understood to improve the relationship between the financial world and the water industry sector.

## 3.5 MODELS FOR PROVISION OF INFRASTRUCTURE

Infrastructure has special characteristics that have traditionally justified or encouraged government involvement. There is a variety of alternative models for the delivery of water services ranging from public to private ownership with an array of public-private partnership (PPP) outsourcing and franchise models in between (Kopp 1997; Evans 2000). The continuum of models shown in Figure 21 represents the range of procurement processes for creation of infrastructure.



*Where*
*BTO – Build, Transfer & Operate*
*BOT – Build, Operate & Transfer*
*BOO – Build, Own & Operate*

*Adapted from Kessides 1993 in Kopp 1997*

**Figure 21 Models for Infrastructure Creation (Kessides 1993 in Kopp 1997)**

Operations may wholly or partially contracted out to a private company under any of the above management arrangements. In Australia, the water supply industry is expected to remain predominantly publicly owned, but some privatisation through leasing out facilities and contracting out of services will occur (COA 2002). On the other hand, private sector involvement is expected to increase in wastewater treatment and recycling activities which will form a larger component of the Australian water industry in the future.

### *3.5.1 Public Enterprises*

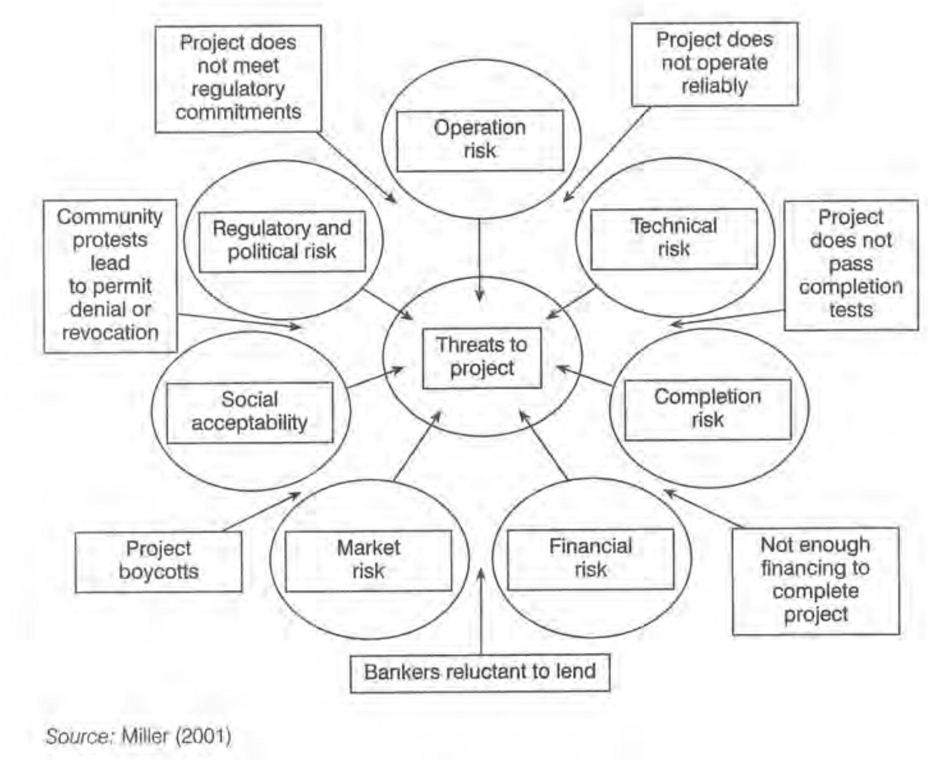
Infrastructure assets and the utility remains in public ownership. Government agencies are established through legislation and charged with the planning, construction and operation of water services to all or parts of a country. The agency and infrastructure created is owned and controlled by the government. Public utilities are formed as autonomous commercial enterprises with a board of directors. In recent decades, the traditional size of the public sector in Australia has significantly reduced due to contracting out of services. These changes are driven by a world wide trend for the reduction in size of government funded entities and increased sophistication of the private sector.

### 3.5.2 Public-Private Partnerships

Public-private partnerships (PPP) exist to create benefits for both the public and private partners. A key objective of a PPP is to allocate risk to the person best placed to manage and deal with the particular risk. Certain risks may be more effectively managed by the private sector rather than the public sector. The challenge for the public sector is to attract as much private capital as possible while ensuring that the facilities so produced create benefits for the pubic at least as great as those developed by traditional means (Kopp 1997). Importantly, PPP can also be viewed as a means of delivering services and not merely the asset enabling a service to be delivered. These types of agreements represent a potentially sustainable model based on private sector financing of water infrastructure.

#### 3.5.2.1 Risk Management & Private Financing

Matching water infrastructure projects and sources of finance is mainly a matter of identifying the right combination of risks for all parties. The development of financing agreements depends upon a good risk assessment that identifies all of the possible risks (Figueres *et al*. 2003). There are various kinds of risk: completion risk, technological risk, risk relating to the supply of raw materials, economic risk, financial risk, currency risk, political risk, environmental risk and risk of catastrophe (Finnerty 1996 in Figueres *et al.* 2003). Figure 22 presents an overview of the possible risks involved.



*Source:* Miller (2001)

**Figure 22 Possible risks in water projects (Miller 2001 in Figueres *et al.* 2003)**

The risks will depend upon the type of water project under consideration, which could be an urban or rural water supply system, a sewage treatment plant, an irrigation, drainage, water harvesting or reuse project. The risks also depend upon the scale of the project, for example, the size of the population or area involved.

#### 3.5.2.2 Outsourcing

In most jurisdictions in Australia, urban water authorities have been moved out of government departments and have become government enterprises (ie. public corporations). At the same time, cities also began to contract with private companies to operate and maintain existing systems and to build and operate new sewage and drinking water treatment plants. For example, in South Australia, a management contract has been in place to operate large parts of the water and wastewater system since 1996. SA Water, a State Government Corporation, entered into a 15 year contract with United Water for the management and operation of the Adelaide water and wastewater systems. SA Water and the people of South Australia remain the owners of all of the metropolitan water and wastewater assets (SA Water 1999d).

Operating and maintenance contracts anticipate little or no private investment, although it is important to provide an incentive for the contractor to do routine or preventative maintenance. The private firm is paid a set fee or a fee plus a share of the profits. The shorter the contract, the easier it is to avoid disputes by anticipating problems and contingencies. And as Gomez-Ibanez (2003) noted shorter contracts make bad contracts more tolerable. Contractual approaches rely on the integrity of the legal systems (ie. courts) used to enforce commercial contracts. Conventional contracts tend to be difficult for infrastructure monopolies because the lives of the investments tend to be long, and the longer the contract the harder it is to anticipate what will happen. Nevertheless, an explicit contract provides clearer protection against opportunism as long as the contract is complete.

#### 3.5.2.3 Concessions

Natural monopolies make competition within a market impractical for many utilities; however, the government can introduce competition for the market by competitively awarding a concession of limited duration to the bidder who offered the lowest prices and best service. The fact that the concession was competitively bid would ensure that the prices and service standards were fair to both consumers and investors. Under a concession contract, the private company finances investments, operations and maintenance from its own revenue at its own risk, for the 20-30 year concession period.

In Australia, the private sector is involved in the provision of infrastructure through build-own-operate-and-transfer (BOOT) schemes where the private sector undertakes the risk, financing and the ownership of the infrastructure for a fixed period. Ownership of the asset will be transferred to the government at the end of the concession. Usually a government regulatory agency monitors compliance with a concession contract, but the agency can not change the terms once the contract is awarded (Gomez-Ibanez 2003).

Example 10 describes the BOOT concession agreement to provide infrastructure to serve a number of towns in South Australia. This is a useful study because of geographical spread of infrastructure involved - some 10 sites and 650km road distance.

**Example 10 Private-Public Partnership; Regional South Australia**

*In August 1996, the South Australian government entered into the Water Treatment and Economic Development Agreement (WTEDA) with the private consortium Riverland Water Pty Ltd. The agreement delivered filtered water to parts of regional South Australia through a series of 10 privately financed small water treatment plants (see* Figure 23*).*

Figure 23 Locations Served by Regional WTP (SA Water 1999d)

*For the duration of the agreement, Riverland Water supplies treated water to SA Water at defined interface points downstream of each plant. Payment is based on two part tariff; an availability (fixed) and usage (variable) charge of approximately 84% to 16% respectively. The fixed component is set to cover 80% of the fixed operating and financing costs and provides Riverland Water with a predictable revenue stream. Riverland Water has virtually exclusive rights of supply to the 10 distribution areas.*

*Under the arrangement, SA Water is responsible for making raw water available and continues to be responsible for the distribution and customer relationships. To enable distribution of the filtered water into the existing supply systems SA Water financed to a value of $24M some pipelines, tanks, pumping station and associated works. Riverland Water assets are situated on land owned by SA Water and will transfer to SA Water control at the end of the term which is 25 years from the commissioning of the tenth plant.*

*The WTEDA enabled an economically justified infrastructure project to be successfully brought forward some five to ten years to benefit regional communities. At the same time, the level of financial, commercial and technical risks borne by SA Water was minimised. The last WTP was completed in 1999.*

*Source: Salkeld (1997) and SA Water (1999d)*

BOOT projects require complicated risk allocation and sharing arrangements between the parties. There are many risks that may financially ruin the project including changes in law, exclusivity, adverse government (in)action, termination of concession, and payment failure by government. Inflation and interest are two significant finance risks that can impact on all parties. A significant legal risk is financial failure or insolvency of the concession company. Investors will only take these risks under the right kind of market conditions and incentives in smaller towns, such as the aggregation of a number of projects.

It is widely acknowledged that private sector participation in water supply can improve service and efficiency, yet there are few models suitable for small town water supply. A major challenge for concession contracts is how to ensure coverage of the smallest, poorest towns whose revenue base is too small to attract the private sector. For example, Geranium, a small township in South Australia, with a total of 39 water services of which 24 are residential has an annual revenue of less than $15,000 (based on average 2002/03 water use of 308 kL per service and State-wide residential water tariff). However, results of international research by Roche *et al*. (2001) has suggested that there is a possibility of building a successful business around small town water supply services if commercial methods are used and technological support is available.

#### 3.5.2.4 Classic Franchising & Small Water Supply Systems

Franchising is arguably the most successful distribution strategy yet devised. In major western economies between 30% and 50% of all retail trade passes through franchised outlets in more than 60 different market sectors. Franschising also provides for replication between individual towns. Franchising is one model being investigated by the World Bank for application in small town water supply (WSP 2003). Roche *et al*. (2001) reviewed the potential of franchising in small town water supply as a means of providing incentives to local operators and introducing the type of professional support that is needed to improve service delivery, while keeping tariffs affordable. They argue the features that contribute to the economic impact of franchise operations are:

- Entrepreneurship;
- reputation of franchisor – quality and standardization; and
- joint advertising, purchasing power, training and management support.

Although composed of many independent units with relatively small revenue bases, a franchise network has the power and resources of a much larger enterprise (WSP 2003). By introducing an individual with entrepreneurial flair as the operator (franchisee), there is a built-in incentive to operate the water supply efficiently and in a business like way (Roche *at al.* 2001). Both parties commit to a long term relationship through a formal contract, the term of which is typically ten to twenty years and includes an exit strategy. Roche e*t al.* (2001) also recommend the franchise be open to competition every five years for the franchisees. This would encourage them to perform well so that they are re-awarded their contract for a further term (WSP 2003). Clearly, it is in the interest of all parties to maintain continuity where possible, but the option to not renew the contract maintains healthy competition.

While franchising in small town water supply is an untested area, it has been successfully applied to the bottled water industry, in relation to the delivery of bottled water, coolers and associated products to residential homes and businesses. Under the franchising arrangement, the franchisee (operator) has access to a trusted brand, industry knowledge, and long term residual income. The franchisor (asset owner) develops an operating plan and procedures under a brand name (or logo) which become synonymous with quality service, and commits to ongoing support and guidance to small scale private operators in critical areas of management and operation and maintenance, in exchange for a share of the revenue.

There are no franchises currently operating in the small water supply sector and therefore no direct examples to follow (Roche *at al.* 2001). They recognised there will be obstacles to developing and operating a franchise system for delivering water supply services to small communities. For example, to attract competent franchisees a clear legal framework for contracting between the owner of assets and the franchisees would need to be established. Franchisees would not be permitted to raise tariffs without community consultation and franchisor (owner) sanction (WSP 2003). Therefore, a system of regulation would need to be in place to protect customers as well as to deal with contract compliance and performance monitoring.

### *3.5.3 Private Enterprises (Divesture)*

Divesture is where the private sector undertakes the risk, financing and ownership of the infrastructure under a regulatory regime (Kopp 1997). This model is based around negotiation of private contracts between infrastructure companies and its customers. The British began privatising their utilities in the 1980s and found themselves forced to adopt a burdensome regulatory process in order to maintain political support for the efficiency incentives (Gomez-Ibanez 2003). Full private ownership in Australia will remain politically controversial particularly where some customers or sectors of the community remain vulnerable to opportunism.

## 3.6 REGULATING INFRASTRUCTURE

Concern over monopoly often leads the government either to provide infrastructure services itself or to regulate the prices and quality of service of private infrastructure (Gomez-Ibanez 2003). All markets are regulated in the sense that participants are constrained by private and public rules governing rights to act (Smith 1996; Baumol *et al.* 1988). Government regulation of, or intervention in, markets may range from social regulation (consumer protection, worker safety, environment protection, public health) to economic regulation (prices, profits). In Australia, government monopoly in delivering water services may have resulted in the low levels of sustainability and weak development of private sector. The challenge is to put in place principles of best practice regulation such that the decisions that emerge out of the regulatory process facilitate decisions in favour of sustainability outcomes (Harding 2005). Because regulation has an impact on everyone, it is important to decide both whether to regulate and how to regulate.

### 3.6.1 The Range of Solutions to Monopoly

Monopoly is defined as the lack of competition and the corrective implied is to make the market behave as if it were competitive. There are two basic reasons why a monopoly may exist - barriers to entry such as legal restrictions and patents, and cost advantages of large scale operation such as those that lead to natural monopoly (Baumol *et al.* 1988). The solutions to monopoly can be arrayed along a continuum according to the relative roles that markets and politics play in determining infrastructure prices and service quality as shown in Table 15. At one extreme prices and quality are determined largely by markets, at the other extreme largely by politics, and in between a mixture of the two. There are many variants along the continuum, but most can be assigned to one of four main groups or categories - private contracts, concession contracts, discretionary regulation, and public enterprise.

**Table 15 The Range of Solutions to Monopoly (Gomez-Ibanez 2003)**

| HOW PRICES AND SERVICE QUALITY ARE DETERMINED | STRATEGY FOR REGULATING MONOPOLY |
|---|---|
| **Markets** | ***Private Contracts***<br>Customers contract directly with private infrastructure supplier. |
| | ***Concession Contracts***<br>Governments contract with private infrastructure supplier on behalf of the customers. |
| | ***Discretionary Regulation***<br>Government regulators set the prices and service standards for private infrastructure suppliers. |
| **Politics** | ***Public Enterprises***<br>Government or non-profit agency assumes the primary responsibility. |

*Source: Gomez-Ibanez (2003) Figure 1.1*

Gomez-Ibanez (2003) assumes that private provision of infrastructure is generally desirable, particularly if the problems of regulating monopoly can be solved in a politically acceptable and economically sensible way. All things being equal (which they seldom are), private contracts are better than concession contracts and concession contracts are better than discretionary regulation. Gomez-Ibanez suggests one reason for this ranking is the stronger exposure to market forces, the greater the incentives to improve services and reduce costs. Another reason suggested for the ranking is that contracts enforced through the normal commercial courts usually provide a clearer and stronger form of commitment than specialised regulatory institutions.

Market-oriented solutions are more stable because they raise fewer concerns about the use of government powers and the fairness of regulatory proceedings, and thus are less likely to generate the kinds of political controversies that lead to intervention and broken commitments (WSP 2002). Nevertheless, it is important to choose the regulatory scheme carefully if private infrastructure is to survive

(Harding 2005). According to Gomez-Ibanez (2003) this means relying on private and contractual solutions where practical, since they generally increase the level of commitment and the chances that consumers will get the infrastructure services they value. But it also means being realistic about when private or contractual solutions will work, adopting discretionary schemes where necessary, or not privatising at all where no regulatory scheme seems workable.

### *3.6.2 Discretionary Regulation*

Where there is little prospect for competition, specific controls are required to mimic the effects of competition and ensure that prices are minimised through; removal of abnormal profits and maximising efficiency improvements. The introduction of independent economic regulation poses a number of challenges in terms of designing a regulatory approach that delivers the desired outcomes. The best known examples of discretionary regulation are cost-of-service regulation as developed in the United States and price-cap regulation as developed in the United Kingdom. Both methods of regulation aim to provide regulated business with an adequate rate of return but the resulting risk/reward profile faced by the regulated business is different.

The cost-of-service methods focus on limiting abnormal profits, while price-cap regulation aims to maximise incentives for efficiency gains. A price cap control limits the year on year increases in prices to inflation plus or minus a predetermined X factor, applicable for a period of several years (the capping period). Under a cost-of-service system, the regulator establishes a permissible rate-of-return, which is enough to cover the company’s costs plus a reasonable profit. The need to estimate what the efficient market solution would have been in the absence of transaction costs makes discretionary regulation technically challenging. The tariff-setting task is complicated by the fact that the regulator inevitably has less information and analytic staff than the firm has.

Gomez-Ibanez (2003) observed that a lot has been learned about regulation in the last 150 years, the most fundamental lesson being that it is hard to regulate well. Therefore, Gomez-Ibanez recommends regulation only when it is essential and with the simplest and least intrusive scheme possible. Discretionary regulation has its shortcomings too, notably the risk of ‘capture’ by special interests, including the regulated firms, customers and others and misuse of regulatory powers. The future of private infrastructure depends on our ability to devise regulatory systems that treat both the consumers and the investors fairly. The perception of fairness is as important as the reality so that regulation is as much a political as a technical act.

## 3.7 SUMMARY

Water is one of Australia's largest and most important industries. Provision of water is of integral importance to economic development and essential in protecting public health. Traditional patterns of urban water management were based on a simple 'supply and disposal' process, the remnants of which dominate our infrastructure and attitudes in the community today. There was a focus on reliable supply, with little concern about environmental impact and sustainability. A philosophical shift in the process of urban water management to the current 'water cycle management' view has occurred in Australia, and was institutionalised in 2004 by the NWI. New water supply systems developed in Australia must be planned and designed with a view towards sustainability.

Nationally, the majority of household water is used for outdoor purposes and less than 10% of water is used in the kitchen (COA 2002; ABS 2005; WSAA 2005). Less than 1% of water supplied to Australian towns and cities is actually used for drinking or food preparation (COA 2002). Urban water supply is the second most significant water consumption sector in Australia, exceeded only by irrigation for agriculture. The intensity of competition for water resources near towns and cities is likely to increase as forecast reductions in rainfall connected to global climate change take effect. Changing water supply practices in Australia has been and will continue to be difficult, with environmental, financial and political barriers delaying progress.

In Australia, all levels of government are responsible for different aspects of water management (LGA 2000). The water supply industry is predominantly publicly owned, but some privatisation through leasing of facilities and contracting out of services has occurred (COA 2002). Water services are provided by public or privately operated utilities and the Government (predominantly the State Government) is responsible for regulation and resource management. Private sector involvement is expected to increase in wastewater treatment and recycling activities. Natural monopolies make competition within a market impractical for utilities, however the government can introduce competition by competitively awarding financial concession with a limited duration to the bidder who offers the lowest price and best service.

Traditional water management practices have been reviewed over the past two decades in Australia as it has been recognised that they are not sustainable (Fleming 1999) leading to significant reform. Some consumption is highly price sensitive, and this has been used to regulate demand. Tariff structures around Australia have been changed to meet COAG requirements. Governments have, however, retained the power to set prices below a rate necessary for cost recovery for water utilities operating in regional areas. The pricing system needs to generate revenues for the efficient operation of the present system and its future maintenance. Pricing adjustments should always be applied selectively, gradually and with sensitivity to minimise potential social and economic impacts on the community. It is not easy for communities to accept the notion that higher prices can serve the public interest, especially for something as fundamental as water. Advocacy for higher prices for any service to communities in regional Australia is a mandate for political disaster. Reforms have started to correct the underpricing of water in Australia, but this is a slow and politically sensitive process.

Rural communities are often disadvantaged in terms of their water supply, both in quantity and quality. Factors influencing the delivery of water to small communities include affordability, technical appropriateness, levels of skilled workers, current infrastructure, and resource availability (HREOC 2001). Water utilities operating small systems cannot reliably deliver services unless their operators are adequately trained, even where appropriate technologies have been adopted. Operation is often simplified by automated features, particularly where maintenance requirements are well documented. There is a need for the provision of technical support to small water supply operators to ensure delivery of safe water.

The provision of services to small towns is constrained by the need for water authorities to remain financially viable. Most water authorities realise that there are economic limits which prevent most small communities from funding works in their entirety. Towns and rural communities have a small, static base of rate payers, limited scope for economic development and restricted opportunities for resource sharing between communities. These factors influencing regional water utilities can have a significant impact on their cost recovery capability. Additionally, many ‘small’ water utilities find it difficult to make accurate data available for analysis. This makes development of water resource management strategies more difficult and makes accurate risk management almost impossible.

Despite reductions, Australian consumption remains approximately 30% higher than the 1997 OECD average of around 180 Lpcd (COA 2004). Excessive water use is influenced by cultural factors (WA WRC 1986; Fleming 1999; Murray-Leach 2003) as well as policy and infrastructure. Popular garden designs in Australia encourage high levels of water consumption. Residential outdoor water use is an area where there is clear potential for consumption reduction. Much water use in urban areas is discretionary and is sensitive to price changes. Pricing structures have already taken advantage of this, but there is room to capitalise further. As the cost of water rises, substitutes and alternatives are usually found. The easy gains for consumption reduction have already been implemented. Further increases in efficiency and consumption reduction are going to require more radical social, political and infrastructure reform.

Water policy has changed significantly in Australia in the past two decades. During the decades of reform, a new understanding of water management with a view to sustainability has been adopted, improving urban water consumption by domestic and commercial users. The focus of the Australian water industry has moved away from increasing the quantity of water available towards more efficient water use. The improvement in efficiency was delivered through a combination of consumption based pricing structures, technological change and education campaigns. While there has been a significant reduction in per capita consumption of water in major urban centres, there is still a need for improvement as the total water consumption is increasing with population growth (COA 2002) and regional areas have significant room for improvement.

# Chapter 4
# More Sustainable Water Services

> *"We will only know the worth of water when the well is dry."*
>
> Benjamin Franklin (1785)

## 4.1 INTRODUCTION

The current generation in Australia enjoys the benefits associated with the provision of a reliable and safe water supply, adequate waste disposal system, improved health of communities and high standard of living by world standards. At the same time, this generation has inherited a range of problems associated with the form of the existing infrastructure not the least being degradation of a number of water dependent ecosystems. The growing population in Australia expects that sufficient water continues to be provided for its consumption, as well as implementation of alternative patterns of development that can act to mitigate acknowledged environmental problems. It is widely acknowledged that in order to be more sustainable, urban areas must alter the way in which water services are provided (Newman & Mouritz 1992; Fleming 1999; COA 2001). The complexity is increased by having an established system as a starting point.

Water supply will continue to be primarily about developing water resources to meet demand and systems will continue to be designed to obtain water from a source and deliver it to various users. The emphasis of water policies has shifted in most jurisdictions from infrastructure development to sustainability (AATSE 1999). Some aspects of sustainability have long been central to the development of water supply infrastructure, for example, water supply objectives traditionally related to social and economic well-being of the community being served. Nevertheless, explicitly incorporating sustainability into solving the traditional 'supply-demand problem' poses many challenges (Bell & Morse 2003; Figures *et al*. 2003; Hall *et al*. 2004). A key challenge in terms of provision of sustainable water infrastructure and services will be in transforming existing systems, often with an asset life between 50 and 100 years, into more sustainable forms while maintaining a high level of services to customers.

The introduction of alternative water management practices to achieve sustainability will require changes in deeply held attitudes in individuals, institutions, professionals and social organisations within society (Figueres *et al.* 2003; GWP 2003). Government can provide leadership and direction, however it is equally important that each Australian takes a collective responsibility for protecting and enhancing our environment (EPA 2003). Each person has a responsibility to reduce consumption of resources and protect the environment for our children and future generations.

Urban areas represent concentrated demands for water that compete with other demands, such as agriculture and environmental flows, as well as placing stress on the surrounding environment. Most urban areas have already fully exploited the readily available water resources and are now obliged to develop and treat sources of lower quality or travel long distances to develop new supplies, both options are costly. Invariably, there will come a point at which the demand for water cannot be met from the developed water resources. Fundamentally, water managers need to consider options of decreasing urban water demand, finding extra water supplies, or both. However, the '*easy*' options for augmenting water supplies have been taken up and prospects for future expansion are limited.

'M*ajor*' urban water utilities in Australia are responding to the challenge by promoting greater efficiency in water use (ie. demand modification) and looking beyond improvement of conventional sources of supply (ie. considering alternative sources of water). For example, in 2001 the *Water Resources Strategy for the Melbourne Area* (WRSMA) summarised the key issues for public discussion around the four broad options (see Figure 24 below).

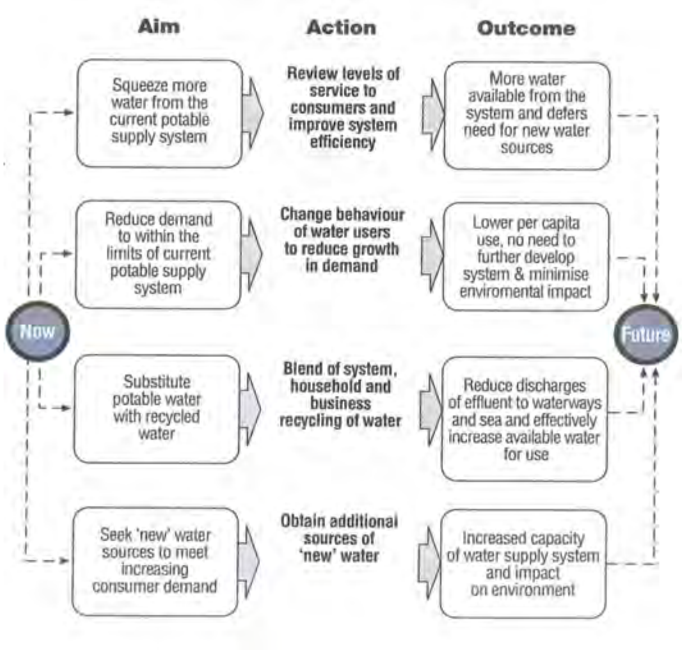


**Figure 24 Future Options for the Melbourne Water Area (WRSMA 2001)**

The first two options relate primarily to managing the demand for water within Melbourne and the remaining options relate to finding additional water supplies to meet growing demands. The options are not mutually exclusive and the strategy may well be based on a mix of different actions (WRSMA 2001). Another recent example in Australia is the 20 year *Water Proofing Adelaide* strategy published in 2005 by the South Australian Government. The three key issues identified by this study were; management of our existing resources, responsible water use, and additional water supplies. In addition to balancing the supply and demand, protection of quality of water resources for Adelaide was stressed to ensure that they remain healthy and sustainable well into the future.

The general conclusion is that achieving sustainable water use for Australia's growing urban centres will require a mix of options that need to be complemented by responsible water use by individuals and businesses. These will include demand management (ie. water efficiency and conservation), water sensitive urban design and development (ie. policies and practices), and supply augmentation (ie. natural and recycled). The three key measures are discussed below.

## 4.2 DEMAND MANAGEMENT

Demand management focuses on improving the efficiency of water use and reducing per capita demand by changing the way our urban society uses water (Akkad 1990; Vickers 1990; Kinzelbach & Kuntsmann 1999; Langford 2003). For example, water efficient appliances in houses (ie. toilets, showers, clothes washers) and water efficient gardens. In Australia, there is a strong desire within the political and general public arena for water demand to be actively managed, and water use efficiency increased in all water use sectors, including irrigation, industry and domestic purposes. The more that demand for potable water can be reduced the more water will be available for future generations and to flow down our rivers and streams. More efficient use of water could be the cheapest, as well as the most environmentally benign means of augmenting and improving the quality of water supplies.

### *4.2.1 Benefits of Demand Management*

Demand management is usually the first choice due to the cost effectiveness of these measures and that ability to influence the whole urban system. Demand management can be considered as a resource. Although it does not involve developing new sources of water, it does allow the developed water resources to support an increased population and economic development. Figure 25 below shows the potential contribution that a successful demand management strategy can make in delaying or eliminating the need to expand potable water supplies.

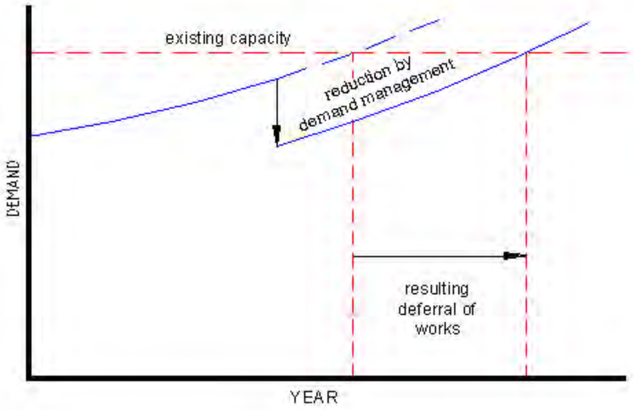


**Figure 25 Benefit of Demand Management (Turcotte 1997)**

Demand management measures can reduce water utility costs, primarily through avoiding or deferring the need for new capital works and also by reducing operating costs associated with pumping and water treatment. The benefits of demand management will be greatest in areas where the water supply system is constrained through growth in demand, the capital or environmental cost of new or increased supplies. Demand management may also reduce the volume of wastewater flow and defer augmentation of wastewater systems and treatment plants. Thus, as Figure 25 suggested efficient water use can provide an outcome equivalent to augmenting the water supply system and helps to balance supply with demand. However, Broad and Holroyde (1989) caution that savings achieved as a result of deferment of source amplification can render water supply systems more vulnerable under severe drought conditions.

### *4.2.2 Elements of Demand Management Strategy*

The Australian urban water industry is committed to reducing per capita water consumption, reducing water wastage and ensuring that water-use is efficient. Variability in water usage patterns and geographic conditions across Australia means that no one strategy will be appropriate for all communities (COA 2002). This means understanding the constraints: analysing how much water is used, when, for what purpose and at what level of efficiency; determining the potential reduction in water use that can occur through improvements to water using equipment and behaviour; and developing programs to achieve these improvements (WSAA 1998). Strategic planning is the key aspect of a successful demand management strategy.

Demand management for urban water supply encompasses a range of possible measures and will typically include the following elements (McLaren *et al*. 1987; Akkad 1990; Gilbert *et al*. 1990; Fleming 1999):

- Economic instruments such as appropriate water pricing policies;
- Physical methods (voluntary and mandatory) such as water meters and water saving appliances, ie. toilets, showers, clothes washers, gardening systems; and
- Societal behaviour changes (customer advisory and education services).

All of these elements can be combined to reduce demand for urban water and to achieve more efficient water use. The sequence in which measures are implemented is also important. For example, it is not possible to establish a fair and efficient pricing system for water unless all customers are metered.

Example 11 below describes the water conservation effort undertaken by one town in the USA over three years from 1987 to 1989, and the importance of combining all of these elements. This example highlights that voluntary conservation was not as effective as regulated water use (ie. mandatory conservation). The sustained reduction in water use was a direct result of giving out water efficient appliances and the corresponding high level of up take. It also demonstrates changing behaviour is a fundamental factor in a successful demand management program.

**Example 11 Demand Management: East Bay, USA**

*In March 1987, the East Bay Municipal Utility District (EBMUD) began a concerted effort to curtail water consumption after having experienced a dry winter with only 51% the normal rainfall average. A voluntary conservation program was begun to minimise demand with a goal of 12% reduction in case a second dry winter occurred. However, only a resulting decrease in consumption of 4% was achieved during this period. The voluntary program was heavily promoted to acquaint EBMUD's 340,000 accounts with methods of conservation that could be mandated if conditions did not improve.*

*A subsequent second dry winter was experienced in 1988 with only 56% of normal rainfall which lowered storage levels to a crisis trigger point. A full scale conservation program was then needed that would ensure compliance by all customers with a revised reduction in water consumption from 12% to 25% in 1988. An extensive advertising campaign was conducted, with conservation education programs in local schools, and additional publications including the use of a sympathetic press corps to provided daily reminders of shortage conditions. In addition, a drought ordinance was passed that included the following conditions:*

- *vehicles could not be washed without the use of a shutoff nozzle;*
- *new turfs could not be installed and only drought tolerant planting allowed;*
- *new service connections must adhere to a written drought compliance agreement;*
- *a waste watcher patrol established to identify violations; and*
- *flow restricting devices installed in the event of prolonged non-compliance.*

*More than 55,000 conservation kits containing low flow shower heads and toilet tank inserts were distributed to customers free of charge. A survey of recipients conducted by the municipal utility office indicated that 90% installed the devices, which should have a lasting effect on consumption. At the end of the 1988 summer period, the drought performance measurement actually decreased consumption by 30% (5% above the original goal of 25%). Through the following winter of 1989, there were signals that the drought had eased and a decision was made to reduce conservation effort to 15%, but the community actually achieved a reduction of 27%.*

*The resulting reduction in water consumption was arrived by using three major instruments, being a US$2.5m education and awareness campaign, changes in the pricing structure and mandatory regulation regarding water usage.*

*Source: Gilbert et. al. 1990*

Sustained reduction in demand is equivalent to the addition of that amount of reliable yield to the supply system; however, there is debate about whether reductions can be sustained over the longer term. Demand management by the Australian urban water industry over the last 20 years has been very successful. However, despite reductions in individual consumption, as the population grows the total water consumption levels continue to increase and put pressure on water resources. WSAA (2005) caution that consumption savings cannot be achieved indefinitely, that most of the easy measures have been targeted and further limitations will be highly intrusive and likely to encounter community resistance.

### 4.2.3 Appropriate Water Pricing

One of the most effective methods to encourage consumers to conserve resources is through economic incentives. For example, if the price of water is set '*too low*' water users will receive the '*wrong*' signals and be encouraged to consume more water (ie. support inefficient water use practices). Paying for water makes people more responsible for their demand, as people often ask for more than they really need. The use of water in urban areas is discretionary at least for certain purposes such as garden watering. The price of water provides the clearest message to customers allowing them to achieve an appropriate balance between the benefits and costs of usage of water services (WSAA 1998). Naturally, consumers are concerned with keeping tariffs affordable and often fail to appreciate their long term interest in supporting the investments needed to maintain the capacity and quality of the services they enjoy.

Application of cost reflective pricing would generate revenue for the efficient operation (and servicing debts) of the present system, its maintenance, and future replacement. Costs should be determined and cost recovery implemented region by region. Increasing the cost of water too quickly, or with too little regard for possible social and economic repercussions, may cause unacceptable disruption to local economies and communities. Water pricing must recognise capacity to pay, and therefore users should not be required to meet full costs where this would be clearly beyond their capacity. Nevertheless, water prices should not be regarded as an instrument for modifying income distribution; this is a matter for social welfare policy (ie. rebates in appropriate circumstances). Government funds should be provided to meet the balance of costs in such cases.

Both willingness and capacity to pay can be surprisingly elastic, depending on what options are being offered, at what immediate and longer term costs, and how clearly this information is communicated to all potential consumers of services (WSP 2003). Appendix 3 discusses the impact of water pricing reform between 1990 and 2003 on residential water use in South Australia. Establishing an appropriate pricing structure for water supply is one of the most important tasks in a demand management strategy. In Australia, low price for potable water services has been an impediment to development of water harvesting and reuse projects.

### 4.2.4 Water Saving Appliances

Water conservation (efficient use of water) is an essential element in sustainable water resource management and should be practised at all times, not just during drought emergencies. Every new home or building equipped with water saving appliances (plumbing fixtures) can potentially provide additional water supply and wastewater capacity for future development without overburdening existing systems. The extent of water saving devices such as low flow shower roses can also have an impact on peak flow (Hoffrichter *et al*. 1999). By choosing water efficient products householders can conserve water as well as and save money through reduced water bills. In the past, an important barrier to water conservation was the lack of readily accessible and simple information for consumers (WA WRC 1986).

### 4.2.4.1 Indoor Household Products

In 1997, Water Services Association of Australia initiated a voluntary efficiency labelling for water using appliances (WSAA 1998). The National Water Conservation Rating and Labelling Scheme is a voluntary certification program that awards an appropriate A-rating to water efficient products that comply with the requirements of standard AS/NZS6400 *Water efficient products – Rating and labelling*. Products that can be covered by the voluntary scheme include:

- Shower heads;
- Dishwashers;
- Clothes washing machines;
- Urinal operating mechanisms;
- Taps and tap outlets;
- Toilet suites or matched cistern and pan sets; and
- Flow regulators.

Once a product is certified under the scheme, it is eligible to display the appropriate label to enable consumers to easily identify and select water efficient products. Until July 2006, products can be rated as indicated in the labels below.

A moderate level of water efficiency

A good level of water efficiency

A high level of water efficiency

A very high level of water efficiency

An excellent level of water efficiency

In 2005, the Commonwealth Government, in collaboration with State and Territory governments, introduced the Water Efficiency Labelling and Standards (WELS) scheme. The WELS scheme draws on the experience of the mandatory energy efficiency labelling system which has been in place across Australia for over a decade. From July 2006, it will be applied as the mandatory national water efficiency labelling and minium performance standard for household water using products (excluding domestic garden watering equipment). The mandatory WELS scheme will supersede the Water Services Association of Australia's voluntary National Water Conservation Rating and Labelling Scheme. The WELS scheme will be overseen by a regulator located within the Commonwealth Department of the Environment and Heritage.

The WELS label (see Figure 26) features a six star rating that gives a quick comparative assessment of the products water efficiency and a water consumption figure for the product. These two features will assist purchasers of household water using products to compare the relative water efficiency. These WELS labels will begin to appear on water using products from July 2005, however until July 2006, the 'AAAAA' label may continue to appear on products for sale. It should be noted that the 'As' on the old label do not equate to the stars on the new label.

**Figure 26 National WELS scheme label (www.waterrating.gov.au)**

This information should be made available as part of an overall water strategy for country towns to help ensure their limited water supplies are used wisely.

### 4.2.4.2 Outdoor Products

In Australian cities, between 30 – 70% of household water is used outdoors and until recently there was no national program to provide advice to consumers on ways to save water used outdoors or to recognise services and organisations that are committed to saving water in this area. The Smart Approved WaterMark scheme is managed by a Steering Committee formed by the Water Services Association of Australia (WSAA), the Irrigation Association of Australia (IAA), the Nursery and Garden Industry Australia (NGIA) and the Australian Water Association (AWA).

Smart
Approved
WaterMark

The nationally endorsed Smart Approved WaterMark water conservation labelling scheme has emerged to meet this need.

The Smart Approved WaterMark label can be applied to:

- outdoor water using/saving products;
- outdoor water related services; and
- outdoor water related organisations

Estimates of the effectiveness of water conservation measures vary widely and are subject to considerable uncertainty due to limited reliable data. Social research is essential to ensure that technical conservation methods are taken up; including designing devices around people’s needs and marketing them (Murray-Leach 2003). Technical assistance should be offered with respect to the cost of installing and maintaining devices that reduce water use. Many conservation measures are already in place in country towns, particularly where there is poor quality supply, substantial reliance on roof water, or high water charges. Therefore, any survey conducted on community water usage habits to provide an indication of the potential benefit of a conservation program needs to include a review of the extent of water saving appliances currently in use.

### 4.2.5 Changing Water Use Behaviour

Actions of society have direct consequences on the health of the environment; therefore, human behaviours, needs and priorities can be considered central elements of sustainable resource management. After all, it is human needs that designate part of the natural environment as a '*resource*', and demand its '*management*' according to human values (MDBC 1988). Most people consider only themselves when making choices and are unaware of the often far-reaching impacts of their daily choices (Fleming 1999). Fleming concluded that it is culture and not the natural environment that must be managed to protect the natural environment and preserve a decent standard of living for future generations. Cultural adaptation will not take place until society is educated about the deficiencies of the current lifestyle. However, the impact of social change instruments is rarely neutral. For this reason, it is important to ask '*change from what to what?*' as well as '*how can changes take place?*' A further complication is the behaviour of humans as they are not compelled to respond in the same way when subject to the same influences.

Changing water supply practices to achieve sustainable water resource management will require adjustment of deeply held attitudes in institutions, professionals and individuals alike. Education is widely recognised as the primary agent in driving generational change towards sustainable development practices (GTZ 2001; WSP 2003; EPA 2003). Yet, even with new understanding of environmental matters, individuals and organisations retain old habits, patterns and practices. These need to be removed and replaced by more sustainable practices. There are no instant habits so it is unrealistic to expect them to go away immediately (Warren 2002). There is only one way to re-develop water conscious habits in society – practice to unlearn wasteful habits – and it will take time. Learning-by-doing must be encouraged (World Bank 2002). Participatory approaches can be influential instruments for social change as they offer people the chance to claim rights and take on the consequent responsibilities. Building and sustaining a social connection is a key component of delivering a new culture. Primary education can make positive contributions towards combating the problems of environmental degradation and improvement of water use efficiency. Today's children are the custodians of tomorrow's environment.

Another prerequisite for sustainable water management is strong research and easy access to the resulting information. An informed public can make a substantial difference in determining the behaviour of governments in response to sustainable developments (Fleming 1999). Progress depends upon the products of educated minds - research, invention, innovation and adaptation. Over time, education can affect cultures and societies, increasing their concern over unsustainable practices and their capacities to confront and master change. Education is a means for disseminating knowledge and developing skills to bring about desired changes in behaviours, values and lifestyles, and for promoting public support for the continuing and fundamental changes that will be required. The key to modifying urban water use behaviour in Australia is to change the mindset of water users; this will require education programs that target all levels of society. Combined with the current concern for the environment, public acceptance of water harvesting and reuse should increase.

## 4.3 SUPPLY AUGMENTATION

Supply management is primarily about developing water resources to meet demand. Imposition of restrictions in the form of water use or development embargos can impair community living standards and inhibit prospects for attracting industry (Pigram 1986). Nevertheless, population growth in Australia over the past 20 years has generally been serviced without the construction of new storages due to reductions in per capita demand through effective demand management measures (WSAA 2005). Invariably, there will come a point where, even with further demand management measures, developed water resources will not be able to satisfy the demands of Australia's growing cities. Most cities and towns have exploited readily available water resources and will be obliged to develop lower quality water sources or travel long distances to develop new freshwater source to meet existing demand and accommodate future growth.

There are a number of potentially viable opportunities to provide additional water for urban centres and provide benefits to the environment at the same time. For example, one way of increasing water supplies and reducing the discharge of contaminants to the natural environment is to harvest and reuse stormwater and wastewater effluent, both commonly referred to as '*urban wastewaters*'. CSIRO (2003) estimated that 97% of urban stormwater runoff and 86% of wastewater effluent is being discharged directly into oceans or freshwater systems. Additionally, the volume of these '*urban wastewaters*' grows in proportion to the size of the urban centre making them an important resource alongside current demand management measures. In general, undervalued or untapped water resources within urban centres in Australia include rainwater harvesting, treated wastewater, stormwater runoff, and seawater. The extent of use and potential of each of these resources is discussed below.

### *4.3.1 Rainwater*

For millennia people have relied on rainwater harvesting to supply water for household and livestock uses. Harvesting rainwater simply involves the collection of water from surfaces on which rain falls, and subsequently storing this water for later use. This simple concept is shown in Figure 27. In rural Australia, it is common practice to capture rainwater from the rooves of buildings and direct the flow of rainwater into a rainwater storage tank.

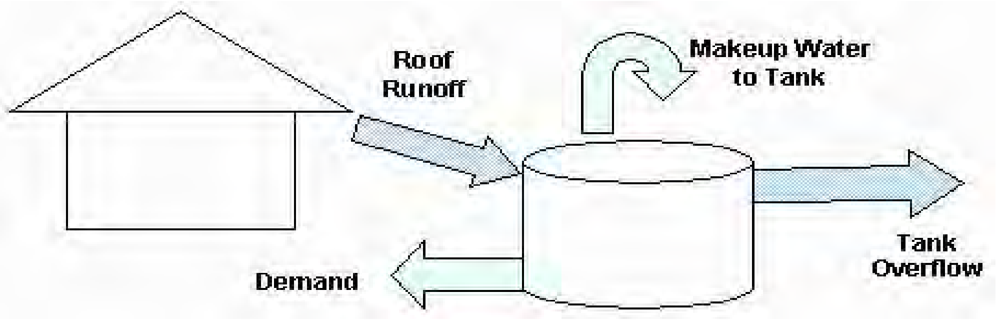
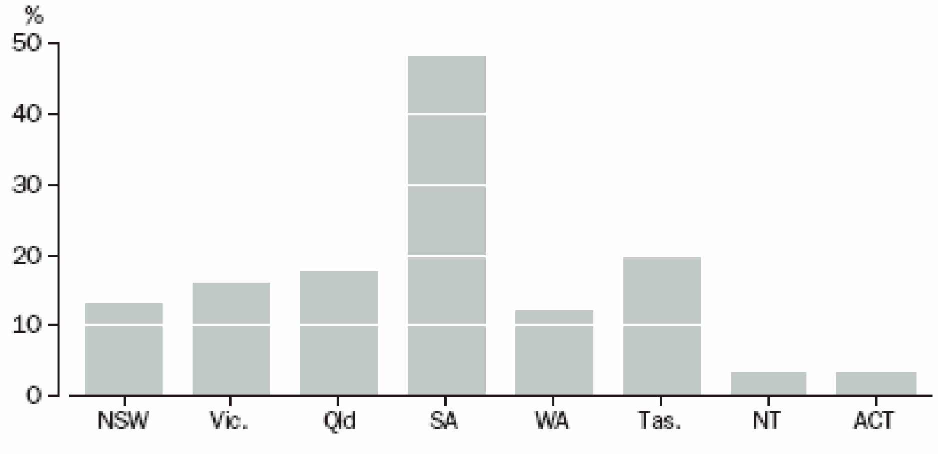


**Figure 27 Basic principles of Small-Scale Rainfall Harvesting System**

In the absence of potable town water supplies, rainwater tanks are still a source of domestic water supply for isolated properties and small communities. For such locations, tanks need to be relatively large (and domestic water demand management a constant concern), so there is a security of supply even during prolonged periods of low rainfall (Lang *et al.* 2000?). The benefits of rainwater tanks are well understood in low density rural areas that have limited or no access to reticulated potable water supplies.

### 4.3.1.1 Extent of Use

In 2004, only 17% of households in Australia sourced water from a rainwater tank (ABS 2005). As there is no compulsion for householders in Australia to use this water this rainwater resource may not be fully utilised. Studies have shown that to maximise contribution of rainwater harvesting to meeting household demands requires plumbing the tank into toilet flushing, laundry or other uses (DWLBC 2005). Figure 28 shows that around 48% of households in South Australia already have rainwater tanks installed.



*Source: Environmental Issues: People's Views and Practices, cat. no. 4602.0.*

**Figure 28 Australian Households with Rainwater Tanks (ABS 2005)**

Substantial levels of public and private resources have been committed to provision of reticulated and domestic rainwater supplies in South Australian towns. Heyworth *et al.* (1998) found rainwater collected in domestic tanks to be an important source of potable water for rural South Australia, with 77 to 84% of households, depending upon the region, using rainwater from tanks as a source of water. They also found that 81.5% of consumers in country regions do not use mains water as their main source of drinking water, even where one is provided. The private facilities should not be overlooked (Hoffrichter *et al.* 1999). For example, private dams and rainwater tanks can act to increase the capacity of established water infrastructure. These supplementary storage facilities can have a significant impact on the ability of to a community to endure during peak demand periods. The benefits of a rainwater tank include self-sufficiency, providing backup supply in case of water restrictions or water quality problems. It therefore seems appropriate to review the roles of rainwater storages as part of the overall water supply in Australian towns. The addition of a private rainwater harvesting system provides the household with a dual supply of water.

### 4.3.1.2 Potential in Urban Areas

The collection of rainwater from roofs of buildings can take place within cities and towns and replace a substantial proportion of a household's potable water needs. In major urban centres, being largely self-sufficient in water supply is possible for a vast majority of Australian households and buildings (Coombes *et al* 2002; Gardner 2003). Domestic rainwater tanks were standard in cities established in the nineteenth century, but once reticulated water supplies were developed, the need to secure and maintain an independent water supply diminished. Consequently, in many urban centres the traditional rainwater harvesting systems have been all but forgotten. However, when applied in the urban context, rainwater tanks can still provide an opportunity to significantly reduce demand on potable (drinking water) supplies in certain areas of use.

Studies have found that from a homeowner's perspective rainwater tanks are not cost effective when compared with reticulated mains water, particularly, if the rainwater is used only for drinking purposes. Currently, this is the most common use of rainwater in Adelaide (Lang *et al*. 2000?). In terms of efficient rainwater harvesting, it is better to maximise winter use, which is the predominant rainfall season in Southern Australia. This can be achieved by supplementing in-house water demand; that is, plumbing the rainwater for all in-house supply or selectively plumbing for toilet flushing, clothes washing or hot water supply. Other than the roof, which is an assumed cost in most building projects or a sunk cost in existing buildings, the storage tank represents the largest investment in the rainwater harvesting system. It is a common misconception that the larger the tank the greater the volume of water available for use. Of more importance are the rate of use, rainfall and the roof area connected to the tank. The smaller the roof area the higher the level of reliance on the town water especially, in years of below average rainfall.

Example 12 below describes operational experiences of a dual water supply system (rainwater and mains water) installed at an established house in Maryville, an inner city suburb of Newcastle in New South Wales.

**Example 12 Dual Rainwater & Mains Supply: Newcastle, New South Wales**

*An old house in Maryville was fitted with an aboveground 9kL rainwater tank to supply hot water, toilet and outdoor uses to the household that consists of an average of three people. It has a galvanised iron roof with an area of 135m$^2$ and an allotment of 255m$^2$. Rainfall from a portion of the roof with an area of 115m$^2$ is directed to the rainwater tank and supplied via a small pump directly to the hot water service and the toilet cistern. Rainwater for outdoor uses is drawn either directly from the tank or from the mains supply. Mains water is supplied to the remainder of the house and is used to top up the rainwater tank when water levels are low. An air gap is used for backflow prevention in accordance with Australian standards.*

*The dual water supply system was installed during August 1999 and use of the system commenced during October 2000. The total cost to install the rainwater system was less than $2,000 including the tank, pump and pressure control, plumber, fitting, float system, concrete slab and electrician. The development approval process was delayed by the Council requiring approval from the Hunter Water Corporation to install the dual* *system and until an undertaking was given to monitor the quality of water from the rainwater tank. A monitoring program was established to observe the water quality in the rainwater tank and at the household taps, and water use.*

*The automated monitoring program to measure rainfall and water levels in the tank commenced 15 December 2000. The majority of parameters tested (12 samples from the tank) complied with the Australian Drinking Water Guidelines although the average values for total coliform, pH and zinc in the water exceeded the recommended drinking water guideline. However, because the rainwater is not used directly for drinking, the quality may be acceptable provided water from the hot water service meets the drinking water guidelines (as it may find potable uses). The water quality results from 5 samples show that the hot water quality complied with the exception of pH and zinc.*

*After around 250 days in operation the rainwater tank significantly reduced the volumes of stormwater runoff discharging from the roof to the street drainage system. Stormwater runoff from the allotment was reduced by around 39% and reduced the peak stormwater discharge by 86%. The rainwater tank was also able to reliably meet water demand during the monitoring period with minimal top-up from the mains water supply, with a 52% reduction in mains water use observed. Analysis of the long-term performance revealed that the use of the rainwater tank was expected to provide a 63% reduction in mains water demand. The cost of rainwater has been found to be $0.30/kL which is less than the price of mains water.*

*Source: Coombes et al. 2002*

The example demonstrates it is possible to replace at least a substantial portion of the freshwater requirements where rainwater is used before potable water. Generalising these results for the long term or for different locations, roof areas, and tank volumes requires water balance modelling. In the example the security of rainwater supply is not a critical concern, as mains water back-up is available if the tank is emptied. Rainwater tanks may be fed from the mains supply by use of a control valve and an approved air gap. Tank placement should also take into consideration the possible need to add water to the tank from an auxiliary source, such as the mains water system or a water truck, in the event your water supply is depleted due to over use or drought conditions.

#### 4.3.1.3 Water Quality Issues

Wherever rainwater is used, there must be a long term commitment to its proper operation and maintenance to avoid endangering the health of users (EWS 1990; Liang 1998; Heyworth *et al.* 1998; Bowden 1999). This responsibility is particularly important in areas dominated by localised industrial emissions from heavy industry or in agricultural regions where crop dusting is prevalent. Where rainwater is to be used for human consumption (drinking, brushing teeth or cooking) filtration and some form of disinfection is the minimum recommended treatment (TWDB 1997). Table 16 sets outs some common methods of treatment units used in rainwater harvesting systems.

**Table 16 Commonly Used Rainwater Treatment Units (TWDB 1997)**

| Method | Location | Result |
|---|---|---|
| **SCREENING** | | |
| Leaf Screens<br>First Flush Devices | Gutters & leaders | Prevent leaves and other debris from entering tank |
| **SETTLING** | | |
| Sedimentation | Within tank | Settle particulate matter |
| **FILTERING** | | |
| Inline/Multi-cartridge | After pump | Sieves sediment |
| Activated charcoal | At tap | Removes chlorine (should only be used after chlorine or iodine) |
| Reverse osmosis | At tap | |
| Mixed media | Separate tank | |
| Slow sand | Separate tank | |
| **DISINFECTING** | | |
| Boiling/Distilling | Before use | Kills micro-organisms |
| Chemical Treatments (Chlorine or Iodine) | Within tank or at pump (liquid, tablet or granule) | Kills micro-organisms |
| Ultraviolet Light | Between activated carbon filter and tap | Kills micro-organisms |
| Ozonation | Before tap | Kills micro-organisms |

*Source: TWDB (1997)*

In the past, some homeowners have not always accepted this responsibility conscientiously. Consequently, there is a general reluctance by health authorities in Australia to endorse rainwater tanks for potable uses in urban areas because of concern from contaminants washing off the roof (Gardner 2003). As rooves collect debris, dust and bird droppings, it is desirable to have a device to discard the first run-off after a dry spell. However, first flush devices will reduce sludge accumulation in storage tanks but will not necessarily improve water quality.

For instance, despite the first flush device in the Healthy Home (refer Example 19 on page 116), frequent intervals when coliform levels in the rainwater tank exceeded the ADWG standard were observed, with peak values occurring after heavy rainfall events. Gardner (2003) reported this was rectified by fitting a small UV system to the rainwater tank. Coombes et al. (2000 in Gardner 2003) also reported similar high concentrations of coliform for rainwater tanks in cluster housing at Newcastle. Coombes et al. (2002) also reported coliform at the Maryville site (see Example 12 above) however in this case rainwater is not used for drinking purposes and the rainwater from the hot water service was compliant with Australian drinking water standards.

Rainwater tanks without proper management are subject to contamination and therefore a potential health risk exists. For example, if the rainwater is intended for use inside the household, either for potable uses such as drinking and cooking or for non-potable uses including showering and toilet flushing, appropriate filtration and disinfection practices should be employed. If the rainwater is to be used outside for landscape irrigation, where human consumption of the water is less likely, the presence of contaminants may not be of major concern and the treatment requirements can be less stringent or not required at all.

The reliability of rainwater supply systems in Australia is strongly affected by the prevailing climate, particularly where rainfall variability is high (COA 1989). Some costs and benefits will vary from region to region due to the differences in annual rainfall (hence tank yield), rainfall intensities (impacts on rainwater tank ability to reduce peak storm flow) and some other factors (Lang *et al.* c2000). However, the security of rainwater supply is not a critical concern, as mains water back-up is available.

### 4.3.2 Wastewater

Effluent reuse is not a new concept. Controlled wastewater irrigation has been practised on sewage farms in Europe, America and Australia since the turn of the 20th Century. Tougher environmental standards for discharging effluent into some waterways have led to improvements in the quality of that water to the point where those standards are on par with or better than the quality of the water required for many industrial, domestic and irrigation purposes. Once wastewater is treated it has many valuable uses. The value of wastewater for crop irrigation is becoming increasingly recognised in arid and semi-arid countries (Pescod 1985). In Australia, treated effluent is now being used to irrigate crops and pastures, vineyards, recreational areas, golf courses and woodlots.

The change in perceived value and wider acceptance of treated effluent as a resource in Australia has essentially occurred in a 30 year period. Polin (1977) observed that irrigation for tree growth was uncommon and the use of treated effluent for this purpose even more uncommon. Projects like that described in Example 13 show just how far we have come. Treated wastewater from the Gumeracha Wastewater Treatment Plant, which once flowed into the River Torrens, is now being used to grow high quality timber for housing and furniture (SA Water 1999d).

**Example 13 Local Water Reuse for Commercial Irrigation: Gumeracha**

*Since 1996, the entire 25ML outflow from the Gumeracha wastewater treatment plant, which once flowed into the River Torrens, has been used to grow quality timber for housing and furniture. The treated wastewater is pumped just over a kilometre to irrigate a 15 hectare pine plantation (on land owned by SA Water) at Mount Crawford Forest. It involved construction of a new pumping station and rising main to the forest, a fully automated reticulation control system and 64 kilometres of dripper pipework. The $400,000 reuse scheme was the first of its type to be implemented in the Adelaide Hills, and incorporates an ongoing soil and water monitoring program.*

*The first logging is expected to take place in about 2010, providing a quicker than usual return, because of accelerated plantation growth resulting from increased irrigation and the nutrient rich nature of the water. In addition to removing a significant nutrient load from the River Torrens, the innovative project will provide premium logging for South Australia’s housing industry and timber for vineyard posts, plywood and packing cases.*

*Source: SA Water 1999d*

Reuse of wastewater is an effective means of increasing total available water supply, particularly, where it can be used in preference to potable water. In addition, annual effluent production is relatively stable making treated wastewater a reliable source of water. An obvious benefit associated with reuse of treated effluent, as well as boosting the environment, is the reliability of supply and ability to deal with periods of water shortages.

#### 4.3.2.1 Present Reuse Situation

Radcliffe (2004) estimates the proportion of treated effluent currently being reused in Australia to be about 9.1% with the majority of municipal wastewater produced disposed of to the ocean or other water courses or evaporation. This value may appear small nevertheless it demonstrates almost 200% increase in level of wastewater reuse in Australia over the last two decades. In 1982, wastewater reuse amounted to less than 5% of the total annual sewage flow in Australia (COA 1983). This excludes the land treatment at Melbourne's Werribee sewage farm which involves application of raw sewage to land to achieve treatment rather than the reuse of effluent (Strom 1985).

Table 17 presents the recycled water reuse from water utility treatment plants in states and capital cities expressed as a percentage of sewage effluent treated. South Australia has achieved the highest percentage of wastewater reuse, however considerable scope still exists to increase the level and conserve the State’s water resources.

**Table 17 Summary of Water Reuse in Australia**

| State | Wastewater Reuse (%) | | Capital | Wastewater Reuse (%) | |
|---|---|---|---|---|---|
| | 1982(1) | 2004(4) | | 1982(1) | 2004(4) |
| ACT | - | 5.6 | Canberra | - | - |
| NSW | 2.5 | 8.9 | Sydney | 0.5 | 2.3 |
| NT | 33.3(2) | 4.8 | Darwin | - | - |
| QLD | 2.5 | 11.2 | Brisbane | - | 6 |
| SA | 6.8 | 15.1 | Adelaide | 8.2 | 11.1 |
| TAS | 0 | 6.7 | Hobart | 0 | 0.1 |
| VIC | 6.6(3) | 6.7 | Melbourne | 0.2(3) | 2 |
| WA | 13.3 | 10 | Perth | 0 | 3.3 |
| **Australia** | **4.6%** | **9.1%** | | | |

*(1) Estimates of 1982 sewage flow reuse (%) as reported in COA 1983 & Strom 1985*
*(2) Estimate included projects in construction*
*(3) Estimate excludes Werribee Sewage Farm*
*(4) Radcliffe (2004), Tables 2 & 3*

The amount of wastewater reused in Australia is low compared to water reuse overseas. For example, in Florida around 34% and in California 63% of treated effluent produced within these states is used (COA 2002). It should be noted that since 1928, the California State Constitution has prohibited waste or unreasonable use of water, encouraging water reuse wherever safe and practical (Price 1990). This legislation has served to encourage matching water quality to intended water use. Nevertheless, some regional Australian water authorities are doing well, for example, in Victoria, Goulburn Valley Water (centred around Shepparton) recycles 68% of its wastewater, and Coliban Water (centred around Bendigo) recycles 39% (WSAA 2001 in Farmhand 2004).

#### 4.3.2.2 Potential for Further Development

The number of water reuse schemes in Australia is small and mainly restricted to market gardens, recreational spaces and some limited industrial processes (Tasman 1997). The cost of producing recycled water is frequently a deterrent to developing a successful project even for larger scale projects. Example 14 describes the findings of the feasibility investigation into the use of treated effluent (non-potable) supply to irrigate parks and gardens in the vicinity of the Subiaco WWTP in Perth, Western Australia. While the proposal was found to be technically feasible, based on the current economics, the public water authority would bear the bulk of the capital cost of the scheme unless other sources of funds (ie. Commonwealth programs or joint ventures) could be obtained.

**Example 14 Evaluation of Effluent Reuse for Irrigation: Subiaco, Perth**

*The Subiaco Wastewater Treatment Plant (WWTP) discharges 52 ML/d of secondary treated wastewater to the ocean. The Western Australian Water Corporation commissioned a feasibility study to identify non-residential areas close to the Subiaco WWTP where treated effluent could used (responsibly) for irrigation, determine the interest and demand for treated effluent, assess additional treatment requirements, estimate costs, and assess environmental and social issues.*

*A total of 85 local councils, golf courses and other major water users were identified as potential users of treated effluent to irrigate urban parks, gardens and golf courses within 15km from the Subiaco WWTP. All of these currently use groundwater for irrigation with operating and maintenance costs of about $0.20/kL.*

*Through meetings and questionnaires, current irrigation application rates were found to vary between 2 and 35 ML/ha/year, with the average being 10 ML/ha/year. Based on this application rate, the immediate demand for treated effluent (ie. users who expressed interest and a willingness to pay more than they pay for other water) is 4.5 ML/d (ie. <10% of treated effluent available). If the price was no greater than the cost of using groundwater, the potential demand for treated effluent increases to 65% of available treated effluent (or 35 ML/d).*

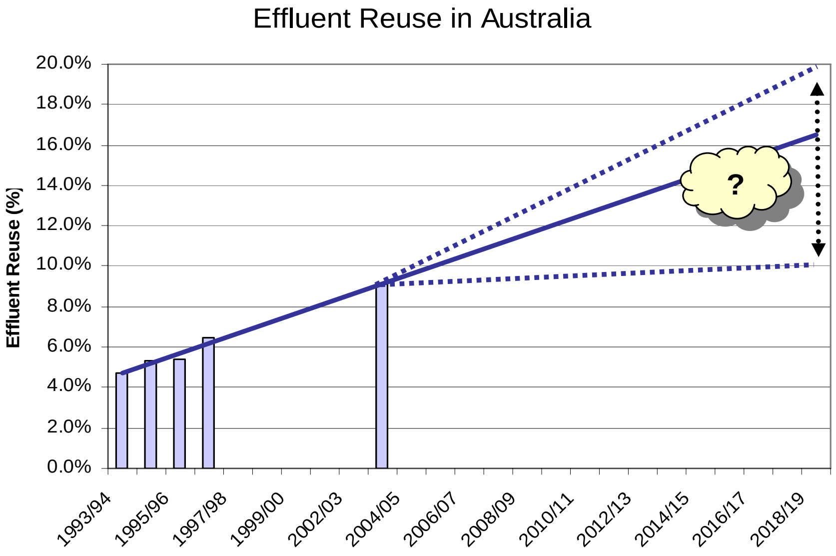
*Several options for distribution of the non-potable water to the potential users were examined. The most economical option was to store treated effluent in a 25ML lined and covered dam at the Subiaco WWTP and to supply it on demand over an 8 hour irrigation period (between 8pm and 4am). Based on a likely irrigation application rates, there was also a need* *to upgrade to meet nitrogen and phosphorus nutrient loading requirements. The capital cost for the WWTP upgrade, trunk and subsidiary mains, reclaimed water storage, power supply, and pumps to supply 35ML/d of reclaimed water was estimated to be $28M. Operation and maintenance costs including pumping, treatment chemical costs and monitoring were estimated to be about $900,000 per annum.*

*The unit cost to recover both capital and operating costs of supplying treated effluent to all potential users was determined to be $0.44/kL (based on a 30 year financial analysis and a discount rate of 8%). The unit cost to recover operating and maintenance costs alone was $0.12/kL. Compared to the public water supply charge of $0.61–0.68/kL the treated effluent unit costs are attractive. However, at double the cost of existing groundwater they are too high for substitution by most of the potential users.*

*Source: Wajon, Kenway & Maus (1999)*

The economics of reuse feasibility are site specific and depend on several factors including the cost of developing other sources of water, the costs to treat and dispose of wastewater, and the costs to treat, store and distribute water reuse. Other factors can include the distance of potential reclaimed water supplies, the availability of their alternative water supplies, and the type of reclaimed water available and needed. Regulators indicate support for treated effluent reuse, but the conditions imposed continue to make reuse complex, difficult and costly (Wajon *et al.* 1999). In addition, it can take as long as five to ten years to fully implement water reuse facilities (Turcotte 1997; Sickerdick & Desmier 2000).

Figure 29 shows the proportion of wastewater reuse in Australia is growing despite the challenges mentioned above. However, compared to water reuse overseas experience the amount reused is low.



Effluent Reuse in Australia

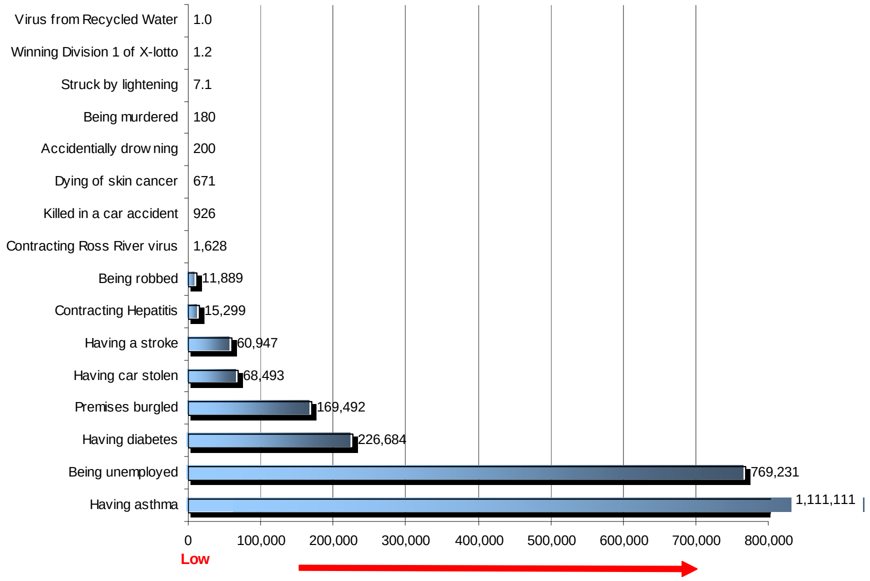
*Sources: Australia State of the Environment Report 2001 Table 66 and Radcliffe (2004)*

**Figure 29 Growth of Wastewater Reuse in Australia**

More extensive reuse of treated wastewater in Australia is feasible but dependent on a greater awareness of its value as a resource, and greater acceptance by the authorities and the public to its use. CSIRO researchers have predicted that the proportion of wastewater reuse will rise by a further 200% in the period 1994 to 2020 (Mitchell *et al*. 1999). This will translate to a rise in wastewater reuse from around 5% to nearly 15% of the total output (see Figure 29). Many agencies have been resourceful in obtaining federal, state and local grants and/or low cost loans that help to defray the cost of recycled water and make it more competitive with other sources. However, expansion of water reuse will require substantial investment and is likely to be constrained by the ability to raise capital. Sound evaluations are important to ensure that the community receives value for money, that is, the ‘right’ scheme is built and that it is neither too large nor too small to satisfy needs for a reasonable period of time.

#### 4.3.2.3 Water Quality Concerns

There are still concerns about long-term safety of reclaimed water, despite development of advanced wastewater treatment technologies producing high quality water. As for any water source that is not properly treated, health problems could arise from drinking or being exposed to recycled water if it contains disease-causing organisms or other contaminants. National guidelines have been developed for the use of reclaimed water that sets standards for water quality, level of treatment, safeguard controls and monitoring. Figure 30 sets out the risk of a number of events including risk of infection from a properly operated recycled water system. According to Figure 30, there is a higher likelihood of contracting Hepatitis than a virus from recycled water.



*Source: Ireland 2003 in Radcliffe 2004*

**Figure 30 Recycled Water Infection Risk (Ireland 2003 in Radcliffe 2004)**

Public health is protected by reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the water, controlling specified chemical constituents in the water, or limiting public exposure to the water (Hickinbotham 1994). The occurrence of illness is the result of a series of complex interrelationships between the hosts and the infectious agents. The mere presence of an infectious agent in an effluent is not sufficient cause to declare the water unsafe. Even the most dreaded hazard poses no risk if people are not exposed to it. It is important, therefore, in assessing the health hazards of wastewater reuse to establish the relative importance of various routes of transmission from direct contact with the wastewater, through food or air, to indirect contact. State and Federal regulatory oversight has successfully provided a framework to ensure the safety of the many water recycling projects.

### *4.3.3 Stormwater*

Harvesting and storing stormwater runoff can have many benefits for the local community and the environment. For example, replacing some freshwater use with stormwater can alleviate the need to extract more freshwater from rivers and aquifers as well as save the cost of treating and piping it long distances into towns and cities. The possible uses for stormwater are the same as those for any freshwater source, including potable water, irrigation and industrial uses. However, stormwater runoff is subject to pollution from a wide range of catchment activities and its management involves controlling both the quantity and quality of the runoff. Ownership and maintenance responsibility for most stormwater drainage systems in Australia is fragmented between local and state government organisations. This can inhibit implementation of catchment-based management strategies for urban stormwater.

#### 4.3.3.1 Extent of Use

Stormwater is an obvious alternative source of water that has not been exploited to any large extent in Australia. Compared to wastewater flows, little is known about the quality or volume of stormwater flows from towns and cities or the percentage that is used for beneficial purposes (COA 2001). Gerges *et al.* (2002) reported that about 3% of the stormwater runoff generated in Adelaide is harvested for beneficial use and of the Australian state capitals Adelaide ranked second (after Perth) in stormwater harvesting. There appears to be considerable potential to better utilise stormwater resources to the benefit of present and future populations in Australia.

#### 4.3.3.2 Characteristics of Flows

Traditionally, stormwater management focused on flood mitigation through the use of formal drainage systems to convey stormwater, and the pollutants therein, away from urban centres. The high level of paving (degree of imperviousness) in towns and cities has increased the amount and speed with which runoff enters nearby waterways. In addition, most of the current stormwater systems do not treat the water before it is discharged into riverine or marine environments (Farmhand 2004). Thus, runoff that can not be harvested for local purposes must be properly managed to reduce the pollutant loading on receiving waters. The major difficulty in treatment of stormwater is the large discharges which occur for very short periods of time with long periods between flows. The issues in stormwater management vary from one urban centre to another, depending on climate, soil and the urban water environment. In large urban centres, a major challenge in maximising the use of stormwater is availability of space to capture, treat and store large volumes of water (Fleming 1999). Space is not generally a limiting factor in small towns. The management of stormwater quality is a different matter and some form of treatment will be required.

#### 4.3.3.3 Pollution Control Practices

The quality of urban stormwater depends on factors that include population density, land use, sanitation and waste disposal practices, soil types, climate and hydrology (O'Loughlin *et al*. 1992). Materials transported typically include dust, soil, litter, garden rubbish, animal waste, paints, oil, fertilisers, pesticides and other street refuse. It is difficult to give typical pollutant concentrations for stormwater because of their high variability. This variability is caused by hydrological variability (rainfall duration and intensity) and pollutant availability. The high volume and variability of stormwater flows can make high-rate physical (structural) treatments more suitable than biological systems (Mitchell *et al*. 2002a). There is no uniform answer or system for effective urban stormwater management.

Stormwater may be managed using a combination of source control, mid pipe and end of pipe measures, depending on the circumstances and the management requirements of the catchment. Structural stormwater quality control practices targeting pollutants mobilised by runoff can be categorised as follows (Hunter 1998):

| ***Practice*** | ***Description*** |
|---|---|
| • Management | ways of doing business to prevent pollutants releases. |
| • Source control | specific actions taken at potential sources to prevent pollutants from entering runoff or removing them before they are conveyed into the natural drainage system. |
| • Sediment control | methods used to control sediment being transported off-site. These are source controls utilised during the construction phase of development, and devices such as silt fences. |
| • End of line treatment | facilities that remove pollutants at the terminal point of the formal drainage system. |

One of the best ways to address the problems of urban water management is to use treatment trains, or the sequencing of best management practices. No one practice provides the solution to all pollution problems associated with stormwater runoff. The characteristics of a catchment or drainage system will dictate a design solution that is, in many cases, particular to that catchment (Hunter 1998; GSA 2002). For example, some sites are less suitable than others for detaining or retaining stormwater runoff because of topography or other constraints. Water sensitive design and development (WSUDD) focus is on addressing pollution problems at the source rather than constructing expensive engineered add-ons further downstream and incorporates best practice in various combinations to suit the particular constraints and challenges of individual sites (COA 2002).

Pollutant traps come in various designs that provide a physical barrier to the pollutants while allowing water to flow through. These are designed to treat litter/gross pollutants, sediment and vegetation to varying degrees; however certain traps are promoted as having high capture rates for other stormwater pollutants including fine sediment material, suspended solids, nutrients, heavy metals, oil and grease. The appropriate type of trap depends on whereabouts in the catchment it is to be installed. Example 15 describes the combination of stormwater practices located just prior to discharge to sea (ie. end of line).

**Example 15 End of Line Stormwater Treatment: Wellington St, Adelaide**

*At this site, the Port Adelaide-Enfield Council runs stormwater from a 150 hectare catchment into a detention basin before pumping the stormwater out over the sea wall. The ground level for much of the area is below sea level which has caused the council some difficulty in disposing of stormwater. These stormwater pumping units are protected by two trash racks that have been installed in parallel. In April 1998, a CDS unit was installed (4m by 8m deep) on the stormwater inlet at a cost of $230,000. The stormwater pumps are used to maintain a relatively constant water level in the detention basin to ensure there is a differential head across the CDS unit. The level of debris collected in the unit is monitored on a monthly basis and emptied when full or around four times a year (on average).*

*Source: Mr Peter Diprose,CDS Technologies pers comm. (1998)*

The above example demonstrates how some large end of line treatments can have high installation costs and high maintenance costs for litter removal (ie labour and hire of specialised lifting equipment/trucks). At-source stormwater pollutant traps (ASPT) can provide an alternative to the end of line treatment practices the other end of the drainage system (Chrispijn 2003). Source controls can provide the opportunity to reduce costs by keeping structural controls small, unobtrusive and maintainable (Hunter 1998). These ASPT devices can be installed in roadside stormwater drains to trap sediment and floating pollutants. ASPT devices consist of a basket/filter bag insert that is installed into the individual drainage entrances. ASPT can provide treatment for the entire catchment area if fitted to all these drainage entrances.

The development of pollution control facilities can provide a source of treated water that can be attractive for use as a replacement for more conventional water supplies. The selection, placement and sequencing (ie. treatment train) of practices are important to optimise beneficial outcomes. Local communities could manage and control the use of stormwater (Farmhand 2004). This will enhance the sense of local ownership that is essential to increase the efficiency of water projects and small-scale projects make it easier to find local funds to finance them. In addition to capital costs, pollution control assets require funds in order to continue to operate as designed. Design solutions should therefore consider the most cost effective approach and seek to maximise the social and environmental benefits (GSA 2002). Conventional drainage works also require ongoing maintenance for which local governments are required to set aside funds in their budgets.

The management of stormwater requires the use of a significant proportion of a community's financial resources. In some situations, the conjunctive use of stormwater and wastewater provides an approach that performs more successfully than the exclusive use of one or the other. In comparison with stormwater, treated wastewater is very consistent in quantity and quality but has higher salinity which can limit its use. This is due to several reasons, such as the increased quantity of water available, the balancing of fluctuations in the supply of stormwater, and the diluting effect of stormwater on the quality of some wastewater sources (Mitchell *et al.* 2002a). Blending stormwater with treated effluent can optimise applications for both water resources.

#### 4.3.3.4 Performance Verification Trials

In Australia, a range of ASPTs are available; however, there is concern that claims made by various manufacturers of pollutant traps are not being evaluated (COA 2002). In Hobart, one local council undertook a trial of commercially available ASPTs to determine the performance of the units. The results of the trial are discussed in Example 16. The potential of benefits of independent verification of emerging technologies are discussed further in section 4.5.4.1.

**Example 16 At-Source Pollution Control Unit Trial: Hobart, Tasmania**

*Site constraints in the Sullivan’s Cove stormwater catchment and the Brooker Highway make them unsuitable for many of the end of line stormwater treatment methods currently available. An alternative option considered was at-source stormwater pollutant traps (ASPT). There are a total of 310 stormwater side entry pits (SEPs) in the Sullivan’s Cove catchment and 30 SEPs on the Brooker Highway that drain into Cornelian Bay. The trial involved between 11 and 32 units from a number of proprietary businesses. These were installed in comparable locations and the pollutant retention performance (litter/gross pollutants, sediment, and vegetation) was monitored between January and August 2002. The traps were selected based on laboratory and/or field trials and the manufacturer's claims. On a monthly basis, the load captured in each installed trap was removed (on the same day) and weighed for gross wet weight. Capture loads are expressed as a mean kg/ha/year.*

***Sullivan’s Cove***

*At a cost of $40,600, a total of 63 ASPTS were purchased and installed for the Sullivan’s Cove trial comprising; 20 Enviropod Filter units with a cleanable 200micron filter bag, 11 Ecosol RSF100 units with a removable 3mm filtration liner, and 32 side entry pit traps (SEPTs) with one-piece stainless steel baskets made of 33mm mesh (designed by Hobart City Council). Enviropod and Ecosol units had significantly higher capture loads (1,711 and 1,427kg/ha/year) compared to the councils SEPTs at 878kg/ha/year. The capture load for all types of trap was typically higher for catchment areas of less than 300m*$^2$ *than catchment areas between 600 and 2,000m*$^2$ *(39% lower). The polluted material was manually separated into litter and sediment/vegetation categories to determine retention performance. Sediment/vegetation represented 96% (wet mass) of all* *material collectively retained by the 63 traps.*

***Brooker Highway***

*In this catchment, the comparison was between 18 SPIs (stormwater pollution interceptor) and 65 Enviropods units, in addition to the 20 Enviropod units installed for the Sullivans Cove trial, over four months from July to November 2003 (ongoing). The SPIs are specialised ASPT and heavy duty, disposable liners to collect fine sediments laden with heavy metals were purchased and installed at a total cost of $23,875. Enviropods had higher capture loads (3,800kg/ha/year) compared to SPIs with 2,340kg/ha/year. For both types the smaller catchment areas of less than 300m$^2$ had a higher capture load while larger catchments of 600 and 2,000m$^2$ had a reduced capture load (38-42% lower). The captured material was not separated as part of this trial.*

***Outcome***

*Based on the results:*

- *a further 45 Envirpods will be installed at Sullivans Cove by December 2003 and the 32 SEPTs will be removed and replaced; and*
- *The design of the SPIs may be modified to reduce the remobilisation of captured loads. After these changes the SPIS will be further monitored to assess if they have increased their retention of road runoff.*

*Source: Chrispijn (2003)*

### *4.3.4 Seawater*

### 4.3.4.1 Seawater (Dual) Supply Systems

Seawater can be used to provide a reliable water supply in places where conventional water resources, ie. surface water and groundwater is limited or unreliable. For example, in Hong Kong, seawater and treated effluent is used widely as a secondary source of water mainly in the flushing of toilets (Fleming 1999). Gibraltar also has a seawater supply system which is described below.

**Example 17 Seawater Supply System: Gibraltar**

*Since around 1870, every household in Gibraltar has enjoyed a dual water supply system, one for potable water and the other seawater. Seawater is pumped from two intakes to various storages at different levels on the rock. The seawater distribution system parallels the potable water system providing the second supply for households. The seawater system is also used for fire fighting, street cleaning, sewer flushing and other purposes where the use of potable water is not essential. From a maintenance point of view, the seawater distribution system is problematic in comparison to the potable supply, especially since the older cast iron mains (up to 125 years) are badly corroded. These old mains are progressively being replaced as part of a mains replacement program. The use of better materials such as uPVC, plastic coating and sulphate resistant cement linings should alleviate the maintenance problems over time.*

*Source: Lyonnaise des Eaux (Gibraltar) Ltd (pers. comm. March 2003)*

In addition, desalinated seawater is blended with Gibraltar's limited surface water resources to provide the potable water supply. Theoretically, desalination of seawater could also be a reliable source of freshwater - at least for wealthy nations with access to seawater - but it falls far short of sustainability (PAI 1993).

#### 4.3.4.2 Source of Freshwater

Desalination of brackish water for domestic and industrial use is employed in some sixty locations around Australia, mainly in small plants associated with isolated mining and tourist developments (AATCE 1998). High capital and energy requirements combine to make unit costs for desalinated water several times more than conventional water sources. Nevertheless, the cost of seawater desalination has significantly reduced over the past decade and can now be considered as a legitimate future supply option for Australia (WSAA 2003). Example 18 below describes a large scale desalination operation. A number of factors raise significant questions about the mainstreaming of desalination for general water-supply augmentation purposes. In addition to cost, two important environmental problems are associated with desalination technology, specifically carbon dioxide ($CO_2$) release from the energy it requires, and the production of concentrated brine with a host of management problems (Figueres *et al.* 2003).

**Example 18 Seawater Desalination: Burrup Peninsula, Western Australia**

*The Western Australian government funded the $67M seawater desalination scheme to supply a number of industries on the Burrup Peninsula. It is the biggest seawater desalination scheme built in Australia in one of the hottest regions. Infrastructure planning in consultation with prospective customers took three years. The scheme consists of:*

- *a major pumping station;*
- *4,400m seawater 280ML/d intake pipe of 1,422mm diameter;*
- *a 2ML storage tank;*
- *4,000m brine return pipe and 1,400m ocean outfall;*
- *3 by 1.2ML/d mechanical vapour compression (MVC) units; and*
- *4,400m long 33kV transmission line.*

*Seawater will be collected in a storage tank 3km inland where it will be filtered and chlorinated. It will then be pumped to a holding tank in the desalination plant before being processed by the MVC units. The MVC process achieves distillate by evaporating seawater under vacuum conditions, which lowers the operating temperature of the process. The remaining concentrated seawater (brine) is then returned to the ocean.*

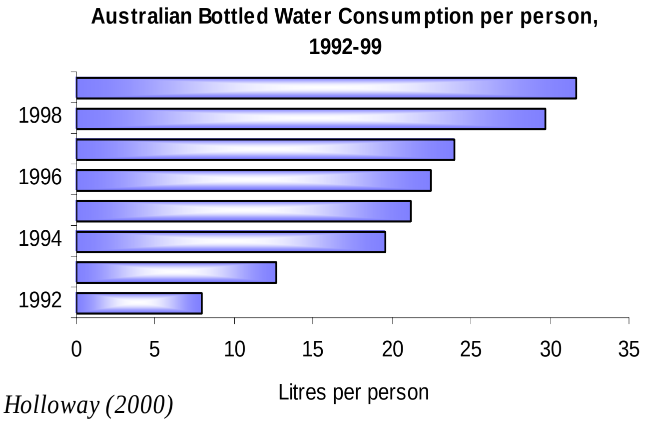
*Source: Cummings (2003)*

### *4.3.5 Bottled Water*

The origin of the bottled water market in Australia began with the supply of water to remote homesteads and even urban residential districts that were either not mains supplied or to which the quality was either poor or variable (Holloway 2000). Many consumers choose bottled water as their primary refreshment drink due to consistency of quality and taste, as compared to reticulated (tap) water supply where chlorine (used to disinfect it) and other products may leave aftertastes (ABWI n.d.). Heyworth *et al* (1998) report that the use of bottled water as a main source of drinking water was 14% and still growing.

### 4.3.5.1 Extent of Use

Figure 31 shows the rapid growth in consumption in bottled water over the 8 year period between 1992 and 1999. Holloway (2000) theorises that the 50% growth forecast for years 2000-2005 for the bottled water sector may be modest. By 2005, bottled water sales would be equivalent to around 45 litres per person per year (Holloway 2000), which exceeds the basic water requirements for drinking (previously discussed in section 2.2.2). A factor that has contributed to the advance of the bottled water industry in Australia has been the success of home and office delivery, especially home delivery. For a market of only 600 ML per year, Australia has a high bulk penetration (compared with other countries), with pack sizes over 10 litres accounting for 45% of the total (Holloway 2000).



*Holloway (2000)*

**Figure 31 Per Capita Consumption Bottled Water 1992-99 (Holloway (2000)**

### 4.3.5.2 Affordability

Figure 32 provides a comparison of the cost (in 1998 dollars) of reticulated drinking water and other beverages. .

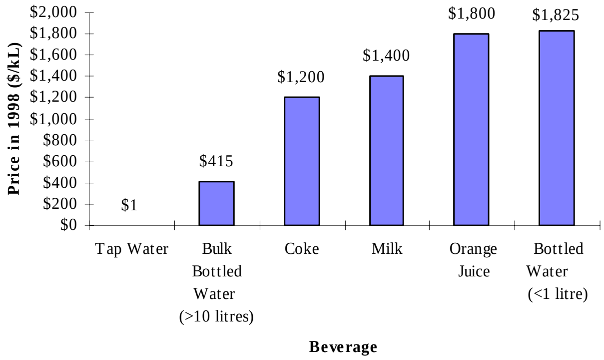


**Figure 32 Comparison of the Cost of Drinks (Rabone 1998)**

Clearly, people are willing to pay for water services that are perceived to be of high quality. Despite the cost of bulk (greater than 8 litres) packaged water being 42% lower than in 1993 it remains an expensive option for consumers. Appendix 5 contains additional information on the changes in consumers' purchasing and the price of bottled water between 1993 and 1998. In communities where non-potable supplies are reticulated, the provision of bottled drinking water may be a realistic option to alleviating or deferring the need for capital expenditure for treatment facilities to achieve a potable water supply.

## 4.4 WATER SENSITIVE URBAN DESIGN & DEVELOPMENT

Water Sensitive Urban Design and Development (WSUDD) is about integration of water cycle management into urban planning and design. Water cycle management covers drinking water, stormwater runoff, waterway health, wastewater and reuse. Water cycle management is an important consideration for urban development that contributes to an ecologically sustainable city. Sustainability is about keeping the options open for the future (ie. precautionary principle). However, wide spread introduction of WSUDD principles is complicated by having an established system as a starting point.

### *4.4.1 The Approach*

Water sensitive urban design & development (WSUDD) is an approach to urban planning and design that offers sustainable solutions for integrating the natural water cycle and land development (Lloyd 2002). WSUDD emerged in Australia during the 1990s out of a wider movement at an international level. It takes into account the whole water cycle from an urban perspective and attempts to maintain services and make best use of available resources, while minimising environmental impacts (WSAA 2003). There is growing enthusiasm and support for a fundamental change in the way urban water resources are managed.

A number of urban developments incorporating elements of WSUDD have been completed in Australia over the last decade. For example, two subdivisions in South Australia that incorporate local stormwater management and dual reticulation water supply are New Haven Village (62 allotments) and Mawson Lakes (3,400 allotments) commissioned in 1998 and 2005 respectively. There has been tension between introducing more sustainable water system and minimising the impact of change on the developer, council, owners and occupiers of allotments, and the wider community (Mitchell *et al*. 2002b).

Developers readily adopt features of WSUDD that have lower capital costs compared with traditional designs and are attractive to buyers (Lloyd 2002; COA 2003). However, some WSUDD infrastructure may have increased maintenance costs compared with traditional designs which may shift costs from the developer to local government. There is limited quantitative data on the long-term performance of WSUDD technology; however, over time WSUDD projects will provide information to enable assessment of their performance against traditional design from a sustainability perspective. Results from such assessments may change the shape of future urban water systems.

Physical attributes of a site such as climate, geology, drainage patterns and significant natural features (ie. wetlands, low lying areas, shallow groundwater) will impact the selection of appropriate WSUDD measures. For example, large urban centres seek measures to minimise stormwater runoff and wastewater discharge to the environment. On the other hand, regional townships often search for measures that maximise opportunities for water harvesting and reuse. Individual WSUDD principles may not be appropriate under all conditions.

WSUDD principles can also be applied to the design of a single building, a whole subdivision or township. Example 19 describes how the incorporation of WSUDD principles into the design of an average detached house on the Gold Coast can reduce demand on reticulated town water supply from 300kL to about 100kL.

**Example 19 WSUDD Household Scale: Gold Coast, Queensland**

*The Healthy Home is a water and energy efficient home on a 420m$^2$ allotment in a high density beachside suburb in Queensland. It is a joint undertaking by the home owners, University of Queensland and Queensland Department of Natural Resources and Mines.*

*The plumbing in the home allows rainwater for potable use and treated grey water (excludes sewage) for toilet flushing and garden irrigation. Other water conserving strategies in use include low flow showers, dual flush toilets, permaculture garden, and simple soil water monitors to schedule and terminate irrigation.*

*The water use consumption of the residents (two adults and three children) was monitored for 24 months during 2000 and 2001, which were both years well below average rainfall (15 percentile & 26 percentile rainfall years respectively). Despite the low rainfall over the two year period, rainwater supplied 36% of the total water consumption by the household.*

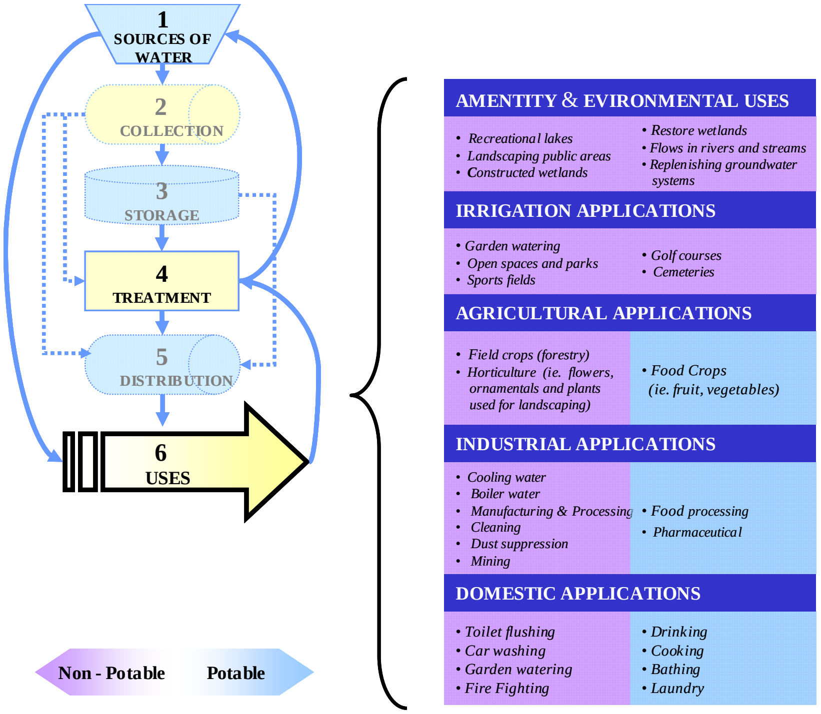
*In an average rainfall year, the level of independence of town water is expected to be in the order of 65%. Further, the demand on town water reduces to near zero using the rainwater twice (the second time as grey water to flush the toilet and garden watering) in an average rainfall year. However the $5,500 grey water system at the Healthy Home has an infinite payback period and the $2,600 rainwater system has a 74 year payback, assuming that town water is purchased for the current price of $1.10 per kL.*

*Despite the installation of a first flush device to divert the first millimetre of roof runoff to waste, fortnightly water quality sampling showed there were frequent intervals when faecal and total coliform levels in the rainwater exceeded the NHMRC drinking water standard, with peak values as high as 500CFU/100ml occurring after heavy rainfall events. Following the installation of a 40W Trojan UV system to the rainwater tank in August 2001, all subsequent fortnightly samplings returned zero values for faecal and total coliform.*

*Source: Gardner (2003)*

### 4.4.2 Matching Water Quality & Intended Use

In general, Australian households are provided with one water service and have access to a single quality of water for all purposes. However, urban water quality requirements can be divided into two main categories - potable and non-potable - according to the end use. Non-potable uses do not require such high quality water, and have less stringent quality requirements. Figure 33 shows the uses of water supplied to urban centres that could be satisfied with non-potable water if available.



**AMENTITY & EVIRONMENTAL USES**

- *Recreational lakes*
- *Landscaping public areas*
- *Constructed wetlands*
- *Restore wetlands*
- *Flows in rivers and streams*
- *Replenishing groundwater systems*

**IRRIGATION APPLICATIONS**

- *Garden watering*
- *Open spaces and parks*
- *Sports fields*
- *Golf courses*
- *Cemeteries*

**AGRICULTURAL APPLICATIONS**

- *Field crops (forestry)*
- *Horticulture (ie. flowers, ornamentals and plants used for landscaping)*
- *Food Crops (ie. fruit, vegetables)*

**INDUSTRIAL APPLICATIONS**

- *Cooling water*
- *Boiler water*
- *Manufacturing & Processing*
- *Cleaning*
- *Dust suppression*
- *Mining*
- *Food processing*
- *Pharmaceutical*

**DOMESTIC APPLICATIONS**

- *Toilet flushing*
- *Car washing*
- *Garden watering*
- *Fire Fighting*
- *Drinking*
- *Cooking*
- *Bathing*
- *Laundry*

**Figure 33 Matching Water Quality and Intended Use**

The degree of any water treatment prior to use varies according to the specific end use application and water quality (Polin 1977; ADWG 1996; Law 1999). Almost fifty years ago, Australia agreed in principle that "*No higher quality water, unless there is surplus of it, should be used for a purpose that can tolerate a lower grade*" (United Nations 1958 in NHMRC, ANZECC & ARMCANZ 1996). Nevertheless, with the exception of Western Australia, there is no requirement in Australia for lower grade waters to be preferentially substituted (where available) for freshwater. In Western Australia, towns can only use public water supplies on their parks or recreation grounds if all other avenues, including treated effluent, had been explored first. In 1972, Merridin was the first town to commence water reuse. Storm (1985) noted that some 35 country towns in Western Australia, representing most of the inland towns with central wastewater services, use locally derived non-potable water supplies to maintain public or school sportsgrounds.

The main output of the water supply system should be water in a condition that is compatible with its destined uses. Many observers suggest that water management practices be redirected towards water infrastructure systems that incorporate innovative technologies for water harvesting and reuse at the local or regional scale and can supply water at different qualities for different uses (Newman & Mourtiz 1992; Clark *et al.* 1997; Fleming 1999). From a public health standpoint, it is logical that a greater assurance of reliability is required for a system producing treated water for uses where direct human contact is likely (ie. bathing), compared to water treated by a scheme where the possibility of contact is remote (ie. toilet flushing).

### *4.4.3 Alternative Water Service Delivery Options*

Moving towards a more sustainable approach will require adopting alternative or new configurations of water infrastructure systems. The manner in which water is treated, distributed and used in Australian urban centres is under constant review. A variety of potential models for delivery of water services can be considered. The number and applicability may be different under different circumstances (ie large urban, small town, or remote community). The attributes of some of the more familiar alternative delivery options are summarised in Table 18 (below).

**Table 18 Variety of Alternative Water Delivery Options**

| ATTRIBUTES | POTENTIAL DELIVERY OPTIONS | | | | |
|---|---|---|---|---|---|
| | BAU | SAFE | URBAN | LOCAL | DIRECT |
| **Water Use Applications** | | | | | |
| • *Drinking* | ✓ | ✗(1) | ✓ | ✓(1) | ✓ |
| • *Personal Uses (Contact)* | ✓ | ✓ | ✓ | ✓ | ✓ |
| • *Non-potable* | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Reticulation Infrastructure** | | | | | |
| • *Existing water system* | ✓ | ✓ | ✓ | ✓ | ✓ |
| • *Dual water supply system* | | | ✓ | | |
| • *Dedicated water pipeline* | | | | ✓ | |
| • *Existing wastewater network* | ✓ | ✓ | ✓ | ✓ | ✓ |
| • *Existing stormwater drains* | ✓ | ✓ | ✓ | ✓ | ✓ |
| • *Integrated stormwater mgt* | | | ✓ | ✓ | ✓ |
| **Water Treatment** | | | | | |
| • *Centralised WTP* | ✓ | ✓ | ✓ | ✓ | ✓ |
| • *Centralised WWTP* | ✓ | ✓ | ✓ | ✓(2) | ✓ |
| • *Decentralised WWTP/SWTP* | | | ✓(3) | ✓(3) | |

*Notes:*

*(1) Water used for drinking and cooking to be obtained from other sources, ie. rainwater tank or bottled water.*

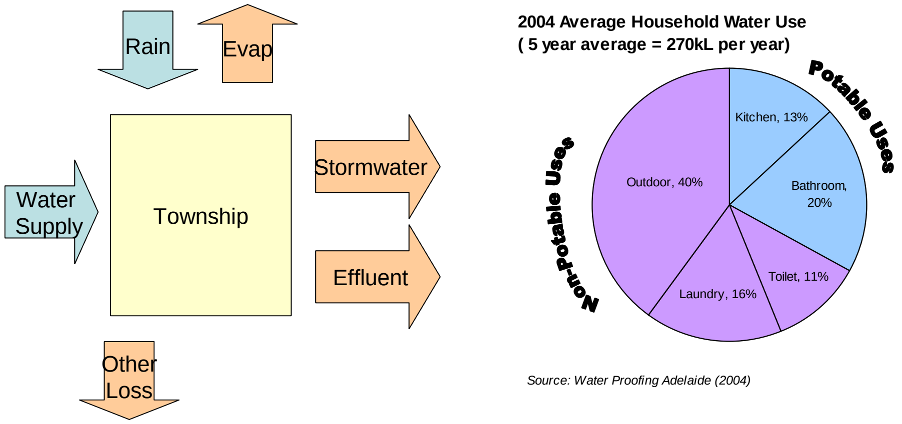
*(2) More suitable for towns and other small communities*

*(3) May be more suitable for large urban centres to collect and treat wastewater and stormwater near demand points*

| *KEY* | |
|---|---|
| *BAU* | *'Business as Usual'* |
| *SAFE* | *'Safe Water'* |
| *URBAN* | *'Urban Reuse'* |
| *LOCAL* | *'Local Reuse'* |
| *DIRECT* | *'Direct Potable Reuse'* |

### 4.4.3.1 Business as Usual

The '*Business as Usual*' scenario is the term used to describe the traditional water delivery option. In Australia, this means the supply of a single quality of water (ie. potable) for all water uses. Figure 34 shows that potable water (drinking quality) is imported to the urban centre (township) in one pipe system and wastewater (effluent) and stormwater are removed using another two separate pipe systems. Figure 34 also shows that non-potable end use typically represents more than 65% of the total household demand with less than 35% requiring potable water quality (of which only around 5% is actually ingested).



*Source: Water Proofing Adelaide (2004)*

**Figure 34 Traditional Water Infrastructure in Australia**

This approach dates back to the 19th Century, when authorities found a positive correlation between poor sanitation and high mortality, and prompted the development of piped water supply, drainage and sewers in towns and cities (Millis 2003). In addition, to the volume of stormwater generated from impervious surfaces within the urban centre, Mitchell *et al.* (1999) estimate that about 75% of the water imported into urban centres is eventually discharged as wastewater effluent. The sustainability of the traditional '*Business as Usual'* approach of separating water supply and disposal systems is being questioned. Water supply engineers and urban planners are beginning to evaluate alternatives to traditional water supply and disposal methods.

### 4.4.3.2 Safe Water

The '*Safe Water*' option is identical to the '*Business as Usual*' with the exception that the single quality water supply is not suitable for drinking purposes (ie. deemed non-potable). Under rural conditions, treatment of potable (drinking) quality standards can be expensive and also requires trained supervision which may not be available if it is to be reliable. Under this scenario, householders make alternative arrangements (ie. rainwater, bottled water or bores) to meet their potable water demands. Traditionally, rainwater has been a source of drinking water for isolated properties and small communities in the absence of potable town water supplies. Currently, in South Australia 19 rural communities (ie small towns or locales) are supplied by SA Water with safe but non-potable reticulated water supplies (Sweet *pers comm*. 2005).

Rainwater is especially important to households and communities not connected to a potable water supply. Around 48% of South Australian households (ABS 2005) and about 80% of houses in rural South Australia have rainwater tanks, many of which also have access to potable water (Heyworth *et al.* 1998; Lang *et al.* 2000?). However, studies have concluded the resources (ie. private infrastructure and collected rainwater) may not be fully utilised. Studies have also shown that to maximise contribution of rainwater harvesting to meeting household demands requires plumbing the tank into toilet flushing, laundry or other uses. In many towns, the existing high level rainwater infrastructure as well as established water reticulation systems may provide an opportunity to shift the water service provided from potable to non-potable with minimal disruption to the quality of life or the local economy.

The viability and sustainability of shifting existing water supply infrastructure from delivering potable water to non-potable supplies in small townships should be investigated. The investigation would need to focus on the reliability of rainwater systems which is strongly affected by the prevailing climate, particularly in areas where rainfall variability is high. It would also be critical to determine locations where local industrial emissions or agricultural practices (ie. crop dusting activities) may adversely influence rainwater quality. Appropriate low skill level filtration and disinfection practices may need to be developed to combat potential public health hazards.

### 4.4.3.3 Urban Reuse

Under the '*Urban Reuse*' scenario each household is supplied with two reticulated water products – potable and non-potable – that can be used according to the specific end use application (ie. matching water quality). The source of the non-potable water supply may be stormwater, treated wastewater or a blend (ie. stormwater/effluent or effluent/potable water). In addition to the traditional reticulated potable water supply, the '*Urban Reuse*' service delivery scenario requires a dual (second) water reticulation system with lilac coloured water taps, pipes and plumbing fittings for easy identification in accordance with the WSAA code of practice. Figure 35 shows the concept of the '*Urban Reuse*' approach with two separate supplies of water being imported to the urban centre (township).

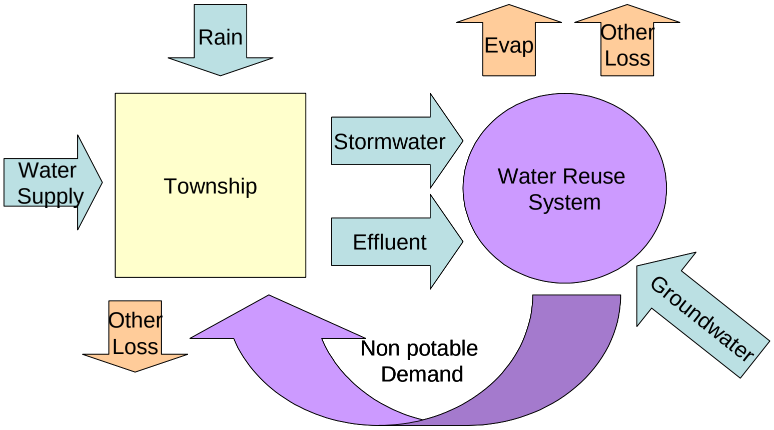


**Figure 35 Alternative Water Harvesting and Reuse Water Infrastructure**

Technically, dual water supply systems are no more difficult to construct, operate and maintain than any other reticulation system. Over the last decade, a number of housing WSUD projects of varying sizes in Australia have incorporated '*Urban Reuse*' infrastructure such as the small 62 allotment development on a 2 hectare site in the Adelaide suburb of New Haven Village commissioned in 1998 (more information is provided in the case study review in Part II). Household wastewater is treated by a local treatment plant located under the main reserve and returned to the dwellings for flushing toilets and irrigation of gardens and reserves. At the other end of the range, the Rouse Hill development commissioned in 1994 (extended in 2001) currently provides 15,000 allotments with dual water supplies where the non-potable supply is used for gardens and toilets. Infrastructure to supply an additional 10,000 allotments with dual water supply is expected to be completed in 2006. There are also a number of similar mid-sized developments around Australia.

These pioneering development sites reveal WSUDD principles to be practical from a technical and operational perspective; but construction and ongoing operation costs are higher cost than traditional supply systems. Most new urban subdivisions now incorporate some water reuse facilities, primarily for irrigation purposes, however the costs of re-plumbing, pumps and storages make '*Urban Reuse*' an extremely costly as a retrofit exercise for large urban centres (Millis 2003). From a social perspective, there should be no major problems, associated with introducing this scenario due to its similarity to current water supply provision and usage. However, an increasing proportion of total investment funds are being devoted to maintenance and rehabilitation of existing water infrastructure systems in Australia (CSIRO 1999). As previously determined, the sustainability of urban centres depends on management and maintenance of semi-permanent infrastructure of society (ie. not just natural resources). The question then becomes can the community afford to sustain the established water infrastructure systems (water, wastewater and stormwater) as well as the capital expenditure and ongoing maintenance costs to introduce an additional non-potable (dual) water supply.

The provision of dual water distribution system in Adelaide could require construction of up to 8,600km of new parallel distribution lines. The very high capital investment of such an undertaking could mean that the non-potable water supply network may not become fully connected and operational for many years, ie. up to 100 years (Doherty *in prep* 2005). For Adelaide, Doherty (*in prep* 2005) estimated the level of expenditure to maintain the established water and wastewater systems to be between $10M and $20M per annum in the near term (ie. up to 2020) gradually increasing to $70M per annum (in current dollars) by the year 2100. The analysis by Doherty was confined to water and wastewater systems owned by the South Australian government (ie managed by SA Water). It does not include projected expenditure to maintain existing stormwater systems or septic tank effluent disposal systems managed by local government, community groups or the private sector. Consequently, the impact of adopting the '*Urban Reuse*' approach must be reviewed from an '*inter-generational equity*' perspective. Any improvement to the present lifestyle should not be at the price of the quality of life for future generations.

While, the costs may be prohibitive for large urban centres, it should be borne in mind that a number of western NSW towns already have a functional dual water supply system. In these towns, older large diameter mains have been retained for reticulating non-potable water for gardens and fire fighting purposes (Polin 1977). A new PVC reticulation system was constructed to deliver potable quality water for household uses only. The viability and sustainability of introducing dual water supply infrastructure for small townships should be investigated more closely. Obviously, retrofitting a non-potable water supply for a small town requires the existence of a suitable water resource that can be developed.

#### 4.4.3.4 Local Reuse

Households continue to be provided with one quality of water through a conventional centralised reticulation system, ie. either the '*Business as Usual*' or the '*Safe Water*' approach. Industrial, commercial, and institutional consumers can represent a concentrated high demand for water within an urban centre compared with residential areas (Mitchell *et al.* 2002a). The presence of several large volume users – especially if they are in the same area – may dictate a geographically limited distribution pipeline. The '*Local Reuse*' scenario involves to the use of dedicated pipelines to supply individual customers with non-potable quality water for end uses that do not require water of potable quality. Alternatives in this category include landscape irrigation of parks, golf courses, and cemeteries, and makeup water for recreational ponds.

The ideal '*Local Reuse*' project would use the greatest amount of non-potable water for needs that require little if any additional treatment, especially those that decrease the potable water demand (ie. to accommodate growth or other industries). The costs vary depending on the individual project being developed, the degree of treatment required, and the proximity to the location where the non-potable water will be used. As the additional infrastructure '*Local Reuse*' infrastructure works alongside conventional water infrastructure already present in urban areas there should be no problems associated with introducing this scenario from a social perspective. This approach also gives locally based institutions the opportunity for more involvement in the delivery of water services.

Many benefits can be realised by adopting local water resource management practices. There are many country towns where the water distribution infrastructure is struggling to meet demand, particularly during peak periods. Greater use of our local sources of water has the potential to relieve pressure on our natural environment and support opportunities for economic development within communities. This type of scheme would serve parks, golf courses, agricultural areas and industry to reduce the demands on potable water during the hot and dry summers. In addition, the introduction of cost reflective pricing as part of COAG water reform has stimulated considerable demand by operations responsible for large areas of grass such as local council, sporting clubs, golf clubs, cemeteries and the like.

Rural towns are being driven to become increasingly water conscious with respect to the cost of maintaining community recreation areas. '*Local Reuse*' projects have been beneficial in small towns as a means of improving their landscape amenity at competitive cost even though the quantity of stormwater runoff and/or effluent available may be small. For example, since the early 1980s, the small South Australian town of Snowtown has successfully harvested stormwater to irrigate community recreational areas (more information is provided in the case study review in Part II). Moore (1990) reported the pay back period for the capital cost of this project was 5 years. Moore also determined the unit cost of the harvested water to be about half the State-wide price of the potable water and speculated that this would be considerably lower than the actual unit cost incurred by SA Water to import water to Snowtown. A range of factors including regional climate, local water demands and the method of reuse determine the effectiveness of a stormwater and wastewater scheme in replacing potable water. Nevertheless, every independent water source which is developed reduces pressure on the State Government reticulated system.

#### 4.4.3.5 Potable Reuse

The '*Potable Reuse*' option is identical to the '*Business as Usual*' scenario except that highly treated wastewater and stormwater are also used as sources for potable water. This option eliminates the need for an extra (dual) reticulation water supply system as required under the '*Urban Reuse*' scenario, however the water treatment processes will be more complex and more energy intensive. The '*Potable Reuse*' scenario also poses a number of technical and social challenges. While it is technically feasible to treat wastewater and stormwater to a potable (drinking) quality level, the '*Potable Reuse*' approach completely reverses one of the major philosophies of current sanitary engineering practice, namely the separation of water supply from wastewater.

The first case history of direct domestic reuse was at Chanute, USA in 1956 (Metzler et al. 1958 in Law 1999). Example 20 describes the most famous case of Windhoek in Namibia. Here, despite initial public protest, public authorities won support for reuse of water in potable water supplies (Polin 1977).

**Example 20 Pioneering Potable Reuse of Wastewater: Windhoek, Namibia**

*The 60,000 plus inhabitants of Windhoek - a city located at the edge of the Kalahari Desert in Namibia - have become used to drinking treated effluent. Since 1968, it has been an intermittent part of the city's drinking supplies. Because of a severe water shortage they drank treated effluent for 4 years between 1969 and 1972. Since that time the plant has been upgraded several times and is still operating to need. The wastewater is treated under a multiple barrier process designed to ensure that no single process is wholly responsible for the removal of any single contaminant.*

*Epidemiological studies carried out in Windhoek showed that 'within the limits of the epidemiological studies done, no adverse effects on health attributable to the consumption of reclaimed water should be established' (Isaacson et. al. 1987 in Law 1997). The water quality at Windhoek is measured against the WHO Guidelines. Water complying with the guidelines is predicted to have no health implications to a person consuming two litres of water per day over a 70 year period (van der Merwe and Menge 1996 in Law 1997). After more than 30 years of supply, there has been no known outbreak of water related disease and public trust has been built up.*

*Source: Law (1997), Clark et. al. (1997), Fleming (1999)*

Potable reuse is a relatively new and somewhat controversial concept that has been successfully demonstrated in other parts of the world, but not yet implemented by any major water authority outside Namibia (Fink 1996). There are now many examples of advanced water reclamation plants that reliably produce treated wastewater effluent of a quality that is equal to or better than that of the local raw water supply or drinking water (Law 1997). Long standing monitoring of potable reuse experiments, similar to that described in Example 21 below, conclude that the potable reuse option was a viable alternative to using water (Law 1998; Fleming 1999; CMHC 2003).

**Example 21 Potable Water Reuse Demonstration Project: Denver, Colorado**

*In the late 1960s, potable reuse was recognised as a potential resource to satisfy the future growing demands of the Denver, Colorado metropolitan area. The Successive Use Project (SUP) which investigated a number of possibilities for developing alternative water supplies for Denver included the operation of a pilot plant in operation from 1970-1979. Based on the results of the SUP, it was concluded that the potable reuse option was a viable alternative to using water from the Trans Mountain diversion. In 1979, plans were developed to initiate construction of a demonstration facility to study the costs and reliability of potable reuse.*

*The Denver Potable Water Demonstration Project began in 1985 with the operation of a potable reuse demonstration plant. The facility was designed to evaluate the feasibility of direct potable reuse of secondary-treated municipal wastewater. Influent to the demonstration plant was from the regional wastewater treatment facility (secondary treatment). The demonstration plant used multiple treatment processes to achieve the required water quality (drinking). Final effluent from the reuse demonstration plant met or exceeded Denver's drinking water standards (physical, microbiological, organic, metals and others) for almost every contaminant. These results indicate that the multiple-barrier used was able to produce a highly reliable process*

*To further test the accuracy of the multiple-barrier system, an organic challenge study was conducted, in which 15 organic compounds were dosed at approximately 100 times the normal levels found in the reuse plant effluent. The results of the challenge study demonstrated that the multiple-barrier process can remove contaminants to non-detectable levels, even when the given organic compounds are present in high concentrations. An accompanying Health Effects Study concluded that no adverse health effects were detected from a lifetime exposure to any of the samples and during a two-generation reproductive sample. The Denver Potable Water Demonstration Plant project concluded in 1992.*

*Sources: CMHC 2003*

Direct potable reuse has not been undertaken in Australia, although it is being investigated by Sydney Water as part of a water services strategy to protect water quality in the Hawkesbury-Nepean River (Clark et. al.1997). Sydney Water has installed an advanced treatment plant that would be suitable for indirect potable reuse at its Quakers Hill Water Factory, in Caboolture (Law, 1998). The technology for advanced treatment is available and epidemiological studies indicate that the risk is comparatively insignificant.

Some suggest planned potable water reuse by blending treated wastewater and stormwater to supplement the potable water supply systems represents the ultimate in the evolution of urban water resources technology (Pigram 1986; Fink 1996, Law 1997; Law 1999; CMHC 2003). A greater reduction in freshwater extractions from the environment would be expected if potable reuse were practiced. Law (1997) showed potable reuse can more than double the savings in freshwater, the estimated figure varying around the country and being dependent upon the local climatic data. For Adelaide, with an annual rainfall of 585mm the effect of the climate on reduction in potable water use for non-potable reuse is estimated to be 35% and for potable reuse 51% (Anderson 1995). It appears that economics and public acceptability are the only barriers to be overcome (Fleming 1999; Marks 2005). This situation is characteristic of '*Potable Reuse*' plans and proposals worldwide. However, the complexity and high level of expertise required to ensure water quality suggests that *'Potable Reuse'* will not be a viable alternative for small communities. An exception may be where the water is imported by major water pipelines from a central treatment facility.

## 4.5 THE PROMISE OF TECHNOLOGY

### *4.5.1 Introducing Innovative Technologies*

Technology innovations are introduced within an organisational context of money, people, institutions and equipment. The question of which solution and hence intervention is appropriate in a particular situation is sometimes one not given enough attention when solution-driven benefactors interact with small communities. Hazeltine & Bull (2003) concluded that to be successful the new technology solution requires the following attributes:

- addressing an identified need;
- being technically sound;
- being suited to prevailing conditions;
- being culturally correct; and
- being introduced in an appropriate way so that it is received favourably.

Thus, organisational factors (systems and people related) as well as technical factors are involved in the introduction of technological change.

International experience is that finding personnel with appropriate training in community organisation and facilitation presents a significant challenge whereas recruiting sufficient numbers of qualified engineers to provide technical support has not (Davis & Iyer 2002). It is also apparent that services requiring high levels of technical and other specialisation may be less appropriate to meeting the long-term needs of small communities. Therefore it is widely accepted that new ideas are an integral part of developing small scale technologies and that a one size fits all approach is not always appropriate. Accordingly, a policy framework that is flexible and adaptive so that different arrangements may be developed to suit to differing regional needs is required. Policy should be strengthened to promote self-sustained and people oriented development with the ultimate goal is the creation of suitable local technology. Development of technology which has low maintenance requirements and utilises available local skills can be exported to rural communities throughout the world.

### *4.5.2 Constructed Wetlands*

Wetlands may be defined as areas within the landscape that are permanently or temporarily covered by fresh, brackish or saline water. Accordingly, wetlands exhibit great diversity in terms of size, depth of water, still or flowing, duration of inundation, hydrologic connection with rivers, water quality, and vegetation. They provide essential breeding and feeding habitats for many kinds of organisms, waterbirds, fish, invertebrates, and plants. Both natural and constructed wetlands are known to remove pollutants from water by a complex range of physical, chemical, and biological processes. These processes include filtering and settling out of sediments and pollutants as the flow rates are slowed, the sterilising effect of sunlight and the uptake of nutrients by many species of wetland plants. In other words, wetlands are natural filters which can improve water quality. However, at the same time, excessive inflow of pollutants will degrade or destroy wetlands.

#### 4.5.2.1 Water Quantity and Quality Control

Stormwater runoff from urban centres is subject to pollution from a wide range of catchment activities. Consequently, in large urban centres stormwater management now has to accommodate both water quantity and quality controls to combat the increased stormwater runoff, velocities and more frequent flood events. The use of constructed wetlands is a relatively common technique to reduce the pollutant load in stormwater runoff from large urban centres (O'Loughlin *et al.* 1992; Fleming 1999). In combination with other stormwater management measures (ie. trash racks, gross pollutant traps, swales) constructed wetlands can also act to slowdown runoff, create local site storage, and reduce flood peaks (Tomlinson *et al*. 1993; Hunter 1997). As a result of the storage within the wetland the peak stormwater outflows are less than the peak inflow. The result is a runoff hydrograph from an urbanised catchment that more closely resembles the hydrograph from the undisturbed catchment (Hunter 1998a).

The potential for wetlands to preserve or improve water quality is becoming widely recognised. Wetlands provide an efficient mechanism for the removal of a wide range of pollutants including suspended solids, nutrients, micro-organisms and heavy metals (Tomlinson 1993; Fleming 1999). Quantitative data on the performance of constructed wetland systems demonstrates they are most efficient if properly designed in terms of size, depth, configuration, biota and residence times (McIntosh 1992; Fleming 1999). The ability of ponds, marshes and wetlands to remove a wide range of pollutants from the water moving through them is an important dimension to the feasibility of using stormwater or sewage effluent as a source of supply (Clark 1992a; Hickinbotham 1997). Outflows from wetlands are usually of a quality suitable for aquifer storage and recovery for irrigation, commercial or industry processing uses (Chaudhary & Pitman 2002). Improved water quality is not the only potential benefit to be obtained from the use of wetlands.

### 4.5.2.2 Recreation Resource for the Community

Constructed wetlands can provide essential drainage functions such as control of flooding and water quality but can also provide a host of additional community benefits. Wetlands add to the diversity of the urban landscape and can provide a focus for recreational activities especially when bicycle paths, walking tracks and picnic areas are incorporated into the buffer surrounds. They can also form the centrepiece of public parklands and provide a source of water for irrigation and other uses (McIntosh 1992). Where wetlands are used to capture urban stormwater runoff, their size requirement can generally fit within the normal 12% allowance for open space in developments (Clark *et. al.*1997). Figure 36 shows how constructed wetlands processes were able to be incorporated into the design of the urban development at Andrews Farm. This 1,300 allotment development is located 30km north of Adelaide.

**Newly Constructed Wetlands(c. 1989)** **Established View of Wetland B (1999)**

**Figure 36 Feature Wetlands at Andrews Farm, South Australia**

At Andrews Farm, the developer helped finance trials to retain stormwater runoff in a three tier system wetlands where it was polished prior to being injected into the aquifer (Hickinbotham 1997). The wetlands at Andrews Farm have now developed into a valuable community asset, important habitat for birds and recreation resource for the community. The Hickinbotham Group also found that in addition to being environmentally desirable localised stormwater management systems were cost effective compared to traditional stormwater systems.

Example 22 below describes how wetland processes and urban drainage have been integrated to create a valuable community resource.

**Example 22 Local Stormwater Wetlands: The Paddocks, Para Hills**

> *The Paddocks is a 46ha community sport and recreation complex at Para Hills, a northern suburb of Adelaide. Before its development, stormwater from a number of drains which converge and discharge at the site presented a flood threat to proposed residential areas nearby. In the early 1970s, the City of Salisbury redesigned the site making use of the stormwater to create a feature of artificial wetlands to control flooding of adjacent urban areas. Since then the area has been progressively developed into an attractive landscape of both wetlands and formal sports fields.*

**Figure 37 Aerial Shot of the Paddocks (Tomlinson *et. al*. 1993)**

*The catchment of The Paddocks wetland is a mature, 60 ha, fully developed residential area. It is subdivided into about 500 building allotments with bitumen roads and concrete footpaths. The catchment is serviced by a fully underground piped stormwater drainage system. The runoff is therefore principally composed of street and roof drainage. Flow and water quality at The Paddocks have been monitored periodically since August 1990. Analysis of the data shows that the wetland provides the expected benefits in flood mitigation: flood peaks generally are reduced by more than 80% and there is a significant improvement in water quality. Levels of suspended solids are reduced by more than 80% after about 5 days residence time and those of total phosphorus by 60% after about 10 days residence time.*

*Source: Tomlinson et. al. 1993*

Over the last 20 years the City of Salisbury has constructed more than 30 wetlands covering an area of 260 hectares for a total investment in excess of $18 million (Chaudhary & Pitman 2002). Surface wetland systems have visible standing water that supports wildlife habitats, particularly fish. Concerns are often raised in relation to surface drainage systems relating to ponds and wetlands. While there are some risks with lagoon systems, the design of wetland systems (shallow flows, low velocities, and sloping banks) often makes them safer than conventional (high flow) drainage systems (McIntosh 1992). Wetland basins are purposely designed to provide more of the characteristics of natural wetlands (Fleming 1999). In fact, because constructed wetlands are designed to be shallow (to imitate natural processes) they make inefficient over season storages.

Evaporation is a function of climate and the surface area of the storage and the losses are higher as a percentage of stored volume from shallow dams and wetlands. Thus, prevailing climate conditions can limit the potential constructed wetlands particularly where evaporation losses can be up to 3,000mm. To reduce evaporation losses many communities build deep and steep-sided open storages which often require fencing to minimise public safety hazards. Alternatively, appropriately selected bank vegetation (ie emergent macrophytes) can act as a barrier to the water edge. Construction of wetlands allows the natural processes to occur, provides the essential drainage functions and also provides a valuable resource for urban communities. Well designed and constructed wetlands imitate natural wetlands, resulting in an efficient biological treatment system. However, the functionality and effectiveness of wetlands depends very much on local conditions including climate, the development of land and its use.

### *4.5.3 Aquifer Storage and Recovery (ASR)*

The idea of storing water in times of plenty (rainy days) for use when it is needed (dry days) is obvious, after all it is the basis of the anthropogenic manipulation of the water cycle. Conventional storage has been in the form of dams which are clearly visible and when full give a sense of security, even though considerable losses of water occur through evaporation and seepage (Armstrong 1992). However, the concept of storing excess surface waters in aquifers (underground) and extracting the stored water when needed is less obvious than traditional storage in dams or tanks.

Advantages of groundwater aquifer storage include the large capacity, low cost, and no loss from evaporation. The land above the stored water can be used for other purposes. Deliberate redirection of surface water into groundwater aquifers for later use to meet peak seasonal or long term demands has become known as '*aquifer storage and recovery*' or ASR (Dillon & Pavelic 1996b; DNR QLD 1998). It is widely practised in some parts of the world including the United Kingdom, United States, Israel and the Netherlands.

#### 4.5.3.1 Methods for Artificial Recharge

There are various methods for storing water in aquifers, collectively known as '*artificial recharge*'. The various methods include; injection wells, pond infiltration/soil aquifer treatment (SAT), induced infiltration (pumping groundwater adjacent streams), and irrigation (all forms can result in unintentional recharge. Figure 38 shows a basic schematic of the commonly adopted artificial groundwater recharge techniques. Artificial recharge ponds (basins) have been used extensively throughout the world including Australia. According to Fox (1999) percolation basins (infiltration ponds) are the most widely accepted low technology method. This method requires the presence of an unconfined aquifer and large areas of land. By comparison, direct injection wells that recharge directly to the saturated zone are expensive; they require more advanced pre-treatment and maintenance technologies (Fox 1999). Therefore, direct injection is not a viable option when low technology solutions are desired.

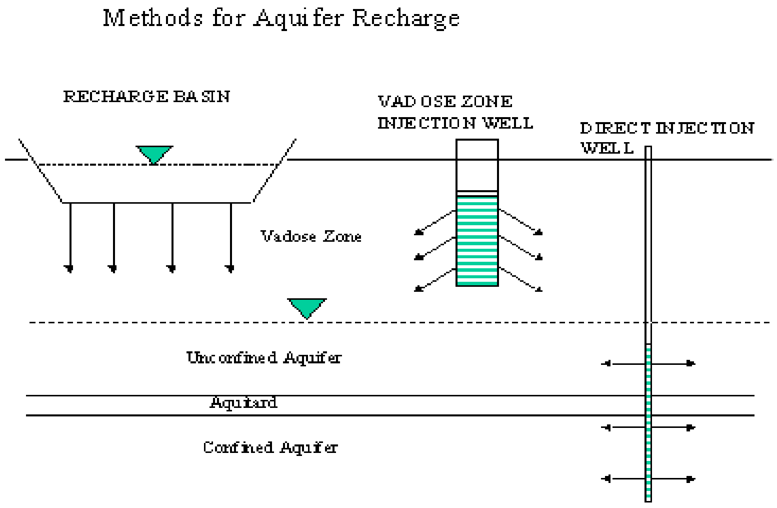


**Figure 38 Commonly Adopted Aquifer Recharge Methods (Fox 1999)**

In urban areas, the high cost of land has provided the motivation for the development of vadose zone injection wells. This recharge method is endowed with some of the advantages of both infiltration ponds and direct injection wells. For example, underlying unsaturated soil layer (vadose zone) may have capacity to remove contaminants from recharged (injected) water as it percolates through the vadose zone and enters the saturated zone. Improvements in water quality are expected but have not been well documented as compared to recharge basins (Fox 1999). Fox also notes that once a vadose zone injection well is clogged, it is very difficult to redevelop. Nevertheless, when land is expensive they can be more economical than either recharge basins or direct injection wells even when systems are designed with a life cycle of only five years (Fox 1999).

Depending on the site, storing water underground may be an appropriate option. ASR is very site specific and the technical advice is required before implementing this option (Fleming 1999; SA Water 1999b). Example 23 below provides a good study on the importance of site conditions for ASR. Estimating recharge rates is critical in any analysis of groundwater systems and the impacts of withdrawing water from them. The measurement of aquifer hydraulic parameters is performed by various types of pumping tests selected on the basis of the site and nature of the data required.

**Example 23 Aquifer Recharge & Storage Investigation: Enfield Cemetery**

*The Enfield Cemetery Trust were interested in harvesting stormwater from a drain which passes through the undeveloped half of the cemetery for on site irrigation. Investigations by the Department of Mines and Energy revealed two possible options for aquifer recharge and storage at the site:*

- *a dry sand bed between 10-20 m depth, overlain with clay, and*
- *fractured rock aquifers below at about 30m.*

*The sand bed was found to be sloping towards the west slightly less than the slope of the land. Any water recharged at the cemetery site would migrate down slope and could eventually cause problems by surfacing near the Main North Road. Field experiments showed that the sand could be recharged but that the water stored would be lost by lateral seepage in the unsaturated sand. An underground storage could be created within the sand layer by constructing a wall of clay around the recharge site to provide the required storage. This was found to be expensive and of no greater benefit than an underground tank or surface storage.*

*A well was drilled to a depth of 117m which yielded a supply of 12l/s with a salinity of 500mg/L. A total of 0.78ML of mains water was recharged by gravity over 9 day period. However, during subsequent pumping the well yielded only aquifer water with little or no contribution from recharged mains water.The investigation and field experiments revealed that conditions at this site prevented aquifer recharge and storage being viable.*

*Source: Armstrong 1992*

Potential problems with ASR systems can be categorised in two groups, those relating to the geology and hydrology of the aquifer and those relating to the quality of the water to be stored in the aquifer (Farmhand 2004). The best technique of artificial recharge depends on local conditions.

#### 4.5.3.2 Benefits of Current ASR Systems

Groundwater aquifers can provide a means of storage and transmission of large volumes of water instead of large transfer pipelines. An unexploited aquifer underlying or near an urban centre is latent water resources infrastructure which has a capacity to store, treat, and distribute water (Dillon 1999). Under natural conditions (pre-development), groundwater systems reach a state of sustainability (equilibrium) where recharge and discharge is balanced overtime. Pumping represents an additional withdrawal from the system which can be sustainable provided the volume extracted is balanced by total amount of natural recharge for the system. The rate at which infiltration takes place depends on the texture and porosity of the soil, which together determine the permeability of the soil. Excess water may be directed purposely into the ground to rebuild or augment groundwater supplies. Thus, estimating recharge rates and the impacts of withdrawing water is critical in any analysis of groundwater systems. At many places in the world, groundwater recharge has been a successful technique for augmenting water resources for more than half a century.

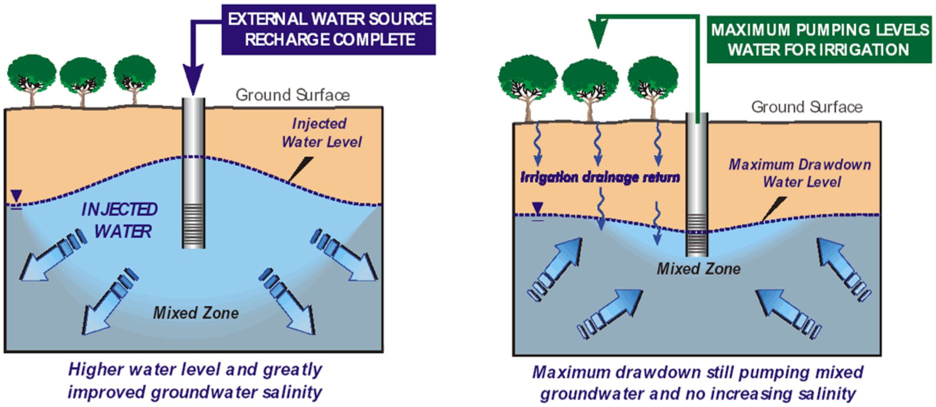
Over fifty years ago, Miles (1952 in Argue 1991) urged that '*serious consideration be given to the possibilities of enhancing the intake into aquifers under the Adelaide Plains by artificial recharge, using the excess runoff water which is now hustled out to sea.*' Miles proposed a '*binary waters*' concept in which the resource was divided according to its use: high quality water (fully treated and filtered if necessary) for domestic consumption, and non-potable water (untreated aquifer water with salinity 1500ppm or better) supplied by bores to manufacturing industries, councils, golf courses, schools for watering large open-space areas and playing fields. However, the 250 page report by Miles failed to attract the attention of decision-makers at an important stage in South Australia's water resource development (Argue 1991). At the time, the focus was on securing water supplies from the River Murray water for Adelaide and other parts of the state (discussed in section 5.5 and Appendix 6). Regrettably, fullest use of Adelaide's local water resources (including brackish reserves) as Miles hoped has not been accomplished.

In fact since the 1990s, a number of ASR projects have been developed in South Australia for new urban developments at Regent Gardens, New Haven Village, Andrews Farm, New Brompton and Parfitt Square (Clark *et. al.*1997). These projects add value to under utilised urban water resources (ie. stormwater, wastewater and brackish groundwater) in a number of ways by blending and storing in times of excess supply until times of peak demand. Following successful trials at Andrews Farm and Regent Gardens, *Guidelines on the Quality of Stormwater and Treated Wastewater for Injection into Aquifers for Storage and Reuse* were published (Sibenalar 1996).

Most Australian ASR projects have been developed to meet non-potable water demands such as irrigation of community sporting facilities and open spaces. In addition, to reducing demand for potable water this approach can enable waters of varying quality to match intended uses. The exception is the potable water supply ASR project for the small holiday hamlet of Clayton in South Australia (more information is provided in the case study review in Part II).

The Clayton potable ASR has been operated within a challenging hydrogeological environment since 1996. Recovered water must be composed of at least 98% of lake water to be of an acceptable salinity for drinking water supply (Gerges *et al.* 2002a). Consequently, preparation to meet summer demand of between 40-70ML requires a significant volume of 200-300ML to be injected into the aquifer. However, the complex aquifer management and specialist expertise required has compelled the Department for Water, Land and Biodiversity Conservation (DWLBC) to operate the system on behalf of the local Alexandrina Council. In August 2005, representatives from the council and the community meet to discuss the future of the Clayton water supply scheme. Based on the information available and the price that customers are willing to pay it was agreed to maintain a safe but non-potable water supply to the community.

The fastest growing type of recharge is the direct injection well as shown in Figure 39. These wells are used to both store and recover water according to supply and demand.



**Aquifer Storage Phase** **Recovery Phase**

**Figure 39 Cross-section of Direct Injection Well System (DWLBC 2005)**

The cost of storage is a function of depth of the bores, the depth of the aquifer and the rates at which water can be transferred into and out of the bores (Clark *et. al.*1997). The viability of an ASR scheme is significantly affected by the life of the injection/recovery wells and their clogging potential. The long-term sustainability of ASR sites requires the management of chemical, physical, and biological clogging in the near and far well zones (Buisine & Oemcke 2002). It remains to be seen if this practice can be extended (ie. scaled up) to assist with delivery of more sustainable water services to small towns in regional Australia.

### 4.5.3.3 Impact of Artificial Recharge on Water Quality

Artificial groundwater recharge can influence local gradients and groundwater flow patterns. For example, an artificial recharge system could displace or cause movement of contaminated groundwater towards a bore that supplies potable water. This may result in the loss of a potable water supply to a community and a contaminated groundwater plume that is more difficult to contain. Since ASR systems can affect the quality of the adjacent groundwater resources, extensive water quality monitoring programs must be implemented.

Geochemical interactions between soils, aquifer materials and recharge waters can dictate final quality of recovered water (Fox 1999). ASR systems are generally designed for high recovery with minimum blending of stored water and native groundwater. However, improvements of water quality with successive operating cycles have been observed at several installations. The various ASR techniques are listed in Table 19 (below) along with their advantage and primary water quality improvement process.

**Table 19 Storing Surface Water in Aquifers (Dillon & Martin 1999)**

| Method | Advantages | Prime Treatment Process |
|---|---|---|
| injection and recovery using one well (ASR) | • can use in saline aquifers<br>• high recovery efficiency<br>• self-cleaning well<br>• small land area needed<br>• cheaper to build | • residence time in storage |
| injection and recovery using different wells | • enlarges ground-water supplies<br>• control treatment in-aquifer by the separation distance<br>• relatively small land area | • passage through aquifer<br>• residence time in storage |
| soil aquifer treatment (SAT) | • makes use of significant treatment capacity of unsaturated zone<br>• suitable for unconfined aquifers or as pre-treatment for injection | • passage through unsaturated zone and aquifer<br>• residence time in storage |
| induced infiltration | • suitable for unconfined aquifers or as pre-treatment for injection | • passage through aquifer<br>• residence time |
| irrigation | • vegetation removes some nutrients<br>• economic benefit from irrigated crop | • passage through unsaturated zone and aquifer<br>• residence time<br>• BUT concentrates salts and nutrients in recharge water |

*Source: Dillon & Martin (1999)*

Since characteristics of injected water can change during storage in the aquifer, a prediction of change and need for additional treatment to meet requirement of intended uses upon recovery must be determined. Research indicates that, in most cases, ASR leads to water quality improvements and does not degrade groundwater quality (AWWA 2001). The ideal soil for soil-aquifer-treatment (SAT) system balances the need for high recharge rates (coarse textured soils) with the need for efficient contaminant removal (ie. fine textured soils). Investigations to characterise chemical, physical, and biological processes that contribute to water quality improvements during ASR is ongoing.

With adequate management and monitoring a SAT system may reduce pre-treatment and post-treatment costs. Experience with ASR technology continues to grow. At one time considered only applicable for recharge of potable quality water, ASR is being expanded to reclaimed water, groundwater and partially treated surface waters (Dillon & Pavelic 1996b; AWWA 2001). A combination of low cost technologies can be used to accomplish groundwater recharge with reclaimed water or other poor quality water sources. For example, stormwater or surface waters can be passed through stilling basins or a sequence of constructed wetlands to reduce the sediment and nutrient loading as pre-treatment to groundwater recharge.

#### 4.5.3.4 The Potential of ASR Systems

In the USA, UK, Netherlands and Israel, aquifer storage and recovery with potable water or its equivalent is practiced. Dillon (1999) suggested artificial recharge of potable water could buffer seasonal peak demands that exceed the capacity of the existing infrastructure as well as a means of providing emergency or drought supplies of drinking water. In other words, the major transfer pipelines can be used in the off-peak season to transport water to recharge a suitable aquifer for subsequent recovery and return to the water distribution system. This approach could also be applied in situations where existing storage capacity within the distribution system is small. Investigation is required to assess the potential for incorporating ASR systems as a means of increasing the life and flexibility of existing water supply infrastructure supporting small towns in regional Australia.

As effluent and stormwater discharge requirements become more stringent, the difference between the quality for discharge to the environment and that for potable reuse will reduce, which in turn will reduce the costs of potable reuse (Law 1997; Fleming 1999). In the long term, the capital cost associated with the implementation of potable reuse is likely to be less than non-potable reuse (Anderson 1995) because the duplication in distribution system is not required. This flexibility presents opportunities for more holistic urban water management, recycling more water and reducing water imports and discharges of polluted water. ASR has been relied on for replenishing drinking water supplies with recycled water in multi-well and soil aquifer treatment systems as the following example demonstrates.

**Example 24 Water Reuse for Aquifer Recharge: Orange County, USA**

*The Orange Country Water District commenced pilot studies in 1965 to determine the feasibility of using treated wastewater as a hydraulic barrier to prevent saltwater encroachment into potable water supply aquifers. Construction of Water Factory 21, a tertiary treatment facility, started in 1972 and injection operations began in 1976. Water Factory 21 reliably produces high quality water. At this site up to 120 GL/yr recycled water has been injected for more than 20 years into an overexploited aquifer used for drinking supplies. Injection creates a groundwater ridge between the coast and the water supply wells to prevent saline intrusion.*

*Passage through the aquifer provides further treatment in addition to tertiary treatment, followed by reverse osmosis or granular activated carbon* *filtration and chlorination. This is a highly regulated scheme and produces water of suitable quality at the recovery wells. It is a widely held view by operators and regulators that direct discharge of recycled water from the water factory to water supply pipelines would not be acceptable to the community at large. The entire treatment operation is expensive, but the cost is justified on the basis of the value of the groundwater which this protects, and the high costs of alternative supplies.*

*Source: US EPA 1992 and Dillon & Martin 1999*

Fox (1999) found that public acceptance of groundwater recharge for indirect potable reuse has been more favourable compared with other forms of proposed potable reuse. Retention in an aquifer may provide the necessary contact with the natural environment to make recovery for potable use more acceptable for consumers (Dillon 1999). If emotional barriers to potable reuse can be overcome, it will provide a substantial opportunity to increase potable water supplies (Polin 1977; WSAA 1998). Alternatives, such as desalinated water, are preferred over potable reuse options (Marks 2005). In Australia, the main obstacle to water harvesting and reuse for potable purposes remains that of public acceptance.

Aquifer storage and recovery has emerged as a means of expanding urban water resources that would otherwise be lost. This underground water banking technique offers the flexibility of storing water from various sources such as surface water, stormwater or wastewater. Recovered water can be used to meet seasonal peak, emergency or long-term demands. The level of water quality treatment depends on the quality of the aquifer, the quality of the source and the quality of the recovered water. Among other things, ASR of potable (mains) water, stormwater, and treated wastewater effluent, can act to increase water supply flexibility, augment water resources, improve the efficiency of use of water infrastructure, and reduce adverse environmental impacts of urban water systems. However, ASR is not a universally applicable method for water supply and can only be applied if certain physical conditions are at hand. Potential problems with ASR systems can be categorised in two groups, those relating to the geology and hydrology of the aquifer and those relating to the quality of the water to be stored in the aquifer (Farmhand 2004). Depending on the site, storing water underground may be an appropriate option.

### 4.5.4 Package Plant Technologies

Although many small towns have sufficient populations to benefit from the economies of scale offered by piped systems, they are too small for conventional (mainstream) urban water utilities (WSP 2003). In addition, many small community water systems in Australia have a difficult time in complying with requirement of the *Australian Drinking Water Guidelines*. Pre-engineered package treatment technology offers an alternative (Polin 1977; NAS 1998). Included among these technologies are filtration systems, disinfection, organics control and inorganic treatment technologies (Clark *et al.* 1994). The treatment processes utilised in '*package technology*' are essentially variations of coagulation and filtration treatment trains capable of treating a few kilolitres per day to many megalitres per day. These units are still '*central*' in that a pipe distribution system is necessary for water to reach the consumers.

#### 4.5.4.1 Application of Package Plants

Various aspects make this type of technology more appropriate for small community operations than conventional treatment plants. The most significant requirements for small water systems are low construction and operating costs, simple operation, adaptability to part-time operations, low maintenance, and no serious residual disposal problems (Clark *et al.* 1994). The major advantages and disadvantages of package technologies are summarised in Table 20.

**Table 20 Advantages and Disadvantages of Package Plants**

| Advantages | Disadvantages |
|---|---|
| • Short construction time<br>• Very compact (small footprint)<br>• Modularity (add to meet growth in demand, an effective way to distribute capital expenditure)<br>• Design for unattended operation | • Difficult to validate claims made by suppliers<br>• Complexity of engineering and process solutions often require ongoing support from supplier (capture of project by supplier) |

Performance data has demonstrated that package plants can meet traditional water treatment goals with regard to controlling microbiological contaminants and turbidity. Where package plants do not meet maximum contaminant levels, Clark *et al.* (1994) found that in general this was caused by failure to run for periods long enough to achieve stable operation (locations with highly transient populations) or lack of operator attention such as not varying chemical dosage to meet changing raw water quality. Highly variable influent water quality requires operator attention and tends to negate the package plant advantages of low cost and automation (Clark *et al.* 1994). While operation and maintenance is simplified by automated features, the operator needs to be well acquainted with water treatment principles and the plant manual, and should have attended a comprehensive training session.

Package plants can differ widely with regard to design criteria, and operating and maintenance conditions. Influent water quality is the most important consideration in determining the suitability of a package plant application (Clark *et al.* 1994). For example, in cases of consistently high levels of turbidity and colour, the package plant capacity should be down rated or a larger model selected. Fail-safe controls are built into many plants to ensure that the finished water does not exceed set turbidity levels. Complete influent water quality records should be examined to establish turbidity levels, seasonal temperature fluctuations, and colour levels and pilot plant tests may be necessary to select a package plant for more innovative designs. It is usually easier to repair and obtain spare parts for simple equipment. The complexity of the package plant usually increases with efficiency and production rate, but so does the need for skilled operators and maintenance people (Hazeltine & Bell 2003). A reasonable guideline is to acquire a machine no more sophisticated than is needed to meet product specifications, with due regard to future changes in those specifications.

#### 4.5.4.2 Technology Verification

There are risks involved with using new or unfamiliar technology, particularly, where new boundaries of technology are being approached. In some cases, the advice of outside consultants may be sought with the overall objective to minimise the level of technical risk borne by the community. Example 25 below provides an overview of the verification program in the United States to provide independent verification of emerging technologies.

**Example 25 Package Technology Verification Program: United States**

*The United States Environmental Protection Authority (US EPA) runs a group known as Environmental Technology Verification (ETV) that supports small communities to ensure compliance with the Safe Drinking Water Act. Support is provided in the form of government funded trials and evaluations to validate the manufacturer's design and claims of packaged technology systems It is a voluntary program designed to allow the performance claims of emerging technologies to be quickly given independent verification, thereby promoting their introduction into the market and minimising risk to the purchaser. While, neither the US EPA nor the ETV endorses a product, the program does provide a means for third party evaluation of systems that would not be cost feasible for many small water authorities, local governments and communities. Since the ETV program is operated at the Federal level, it is automatically valid for all the other states in USA. The ETV program is also actively involved with equivalent approval organisations from Europe and Canada, allowing the verification process to cross international boundaries.*

*Sources: AWA (1999) & Leake (2000)*

Adopting a similar technology verification process within Australia would provide support to water utilities serving small communities by reducing repetitive, and potentially expensive, qualifying and verifying process. It may also minimise risk to the purchaser and facilitate more rapid up-take of new and innovative technologies (wherever generated). Another advantage would be the ability to bring new Australian technologies to the national and international market (AWA 1999). However problems may still arise when the technology is to be used at a significantly different location involving different environmental or operating practices, and a lapse of several years from the time of verification of the original technology may result in some components becoming unobtainable or obsolete.

### *4.5.5 Desalination*

Desalination is achieved by distillation, electrodialysis, and reverse osmosis (the most popular technology for small plants). Reverse osmosis allows people throughout the world to convert undesirable water into water that is virtually free of health or aesthetic contaminants. Pantell (1993) estimated there are more than 7,500 desalination plants in operation worldwide with some 60% located in the Middle East. Desalination of brackish water for domestic and industrial use is employed in some 60 locations around Australia, mainly in small plants associated with isolated mining and tourist developments (AATCE 1998).

### 4.5.5.1 The Process of Reverse Osmosis (RO)

Reverse osmosis is the process whereby one component of a solution is separated from another (in this case salt is separated from the water) by the pressure exerted on semipermeable membranes. Figure 40 illustrates how the reverse osmosis process removes dissolved minerals (including but not limited to salt) from seawater, brackish water, or treated wastewater. Since brackish water has a lower salt concentration the cost of desalting is less than for seawater.

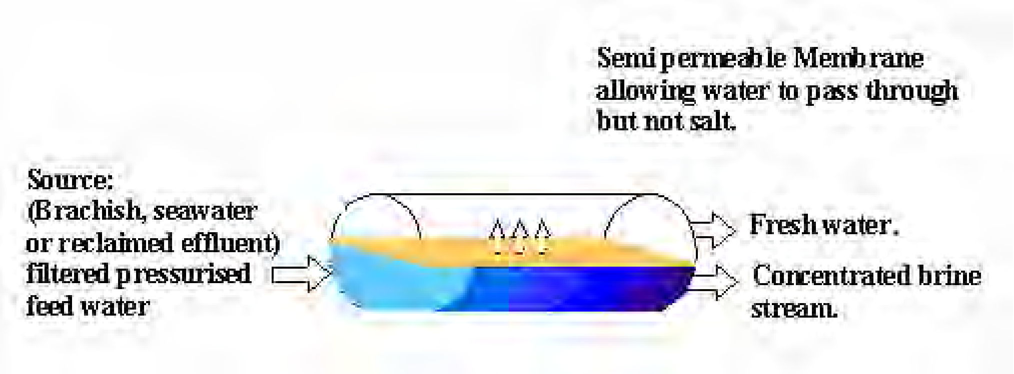


**Figure 40 Schematic of Reverse Osmosis Process**

Membrane-based processes do have associated waste streams. Reverse osmosis produces a continuous liquid waste stream, referred to as '*concentrated brine*', which is low in suspended solids but elevated in total dissolved solids and organics. Desalination requires a place to dispose of the concentrated brine (salt solution). Disposal of the brine from desalination plants needs to be managed carefully to avoid creating environmental problems.

### 4.5.5.2 Reverse Osmosis to Treat Water

Reverse osmosis is the one treatment step capable of presenting a barrier to all contaminants in the production of potable quality water including *Cryptosporidium* and *Giardia* (Law 1999). Based on current knowledge, reverse osmosis will provide an additional 5 to 6 log reduction of pathogen bacteria and protozoa and a 3 to 4 log reduction in pathogenic viruses (Law 1999). It will also remove organic chemicals, heavy metals, and radionuclides and nearly all the dissolved solids, including nitrogen and phosphorous. A possible reverse osmosis water treatment train is shown in Figure 41 below.

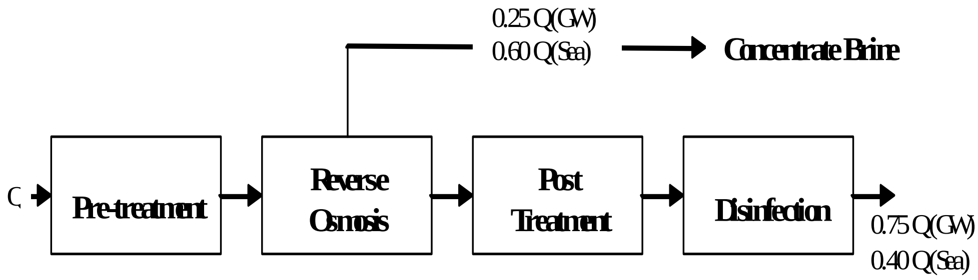


**Figure 41 Possible Reverse Osmosis Water Treatment Train**

Before desalination, source (feed) water should pass through pre-treatment steps (ie. coagulation and filtration) to remove all suspended solids and other particles and reduce fouling of the membranes. Pre-treatment of the source water can extend the life of the membranes by 3 to 5 years (Pantell 1993).

The ratio of product water to feed water (recovery) for desalination plants is typically around 40% for seawater and up to 75% for brackish water. The recovery rate for a desalination plant is also influenced by the particulars of plant operations depending on site specific conditions. Operating the plant on a part-time, rather than full-time basis may be more expensive in the long run because maintenance and capital costs must be paid while the plant is shut down. Scaling is caused by the high salt concentration and can result in reduced plant efficiency (recovery) and corrosion of components. Components must be cleaned to reduce scaling, a condition where salts are deposited on plant surfaces such as pipes, tubing or membranes. Desalination is a high energy consumption process and also has a significant brine output.

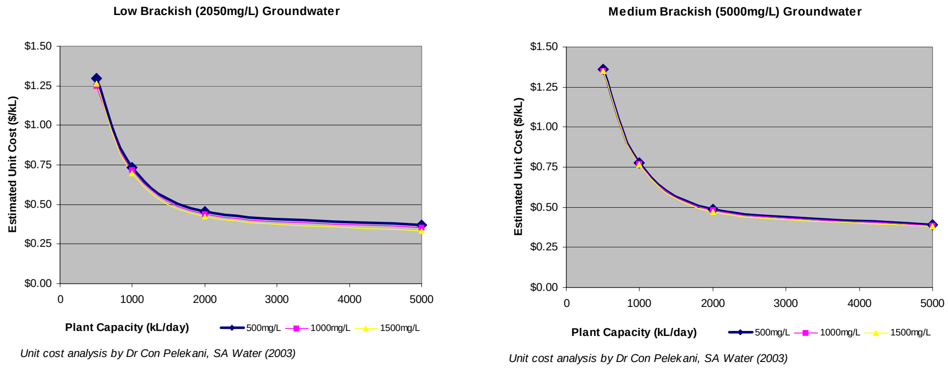
In some cases, to reduce the overall energy consumption and costs the pressurised stream of concentrated brine can be sent through energy recovery units prior to disposal. The concentrated brine can be discharged to the ocean, to mechanical evaporators, to natural evaporation pans or via deep well injection (Law 1999). Metals in feed water are rejected along with the salts by the membranes and are discharged in the brine provided these remain dissolved. The metals present in the brine discharge, though concentrated by the reverse osmosis process, would not normally exceed discharge limits (Pantell 1993).

Desalinated water may be used in its pure form – that is, for make-up water in power plant boilers - or it may be blended with less pure water and used for drinking, irrigation or other uses. Pure desalinated product water is highly acidic and thus corrosive to pipes, consequently post-treatment processes are employed to ensure that product water for drinking meets the health standards (Pantell 1993). Post-treatment commonly includes adjustment for pH, hardness, and alkalinity. Finally, the cost of disinfection by ultra violet (UV) light, chlorine or chloramines is minimised because of the nearly demand-free nature of the reverse osmosis product water and its very high UV transmittance (Law 1999).

#### 4.5.5.3 RO Treatment Costs

In South Australia, brackish groundwater has been desalinated for some time to provide potable water supplies for remote areas including Coober Pedy, Leigh Creek and Roxby Downs. There is one seawater desalination plant along the South Australian coast (commissioned in 1999) which serves the township of Penneshaw (permanent population less than 200) on Kangaroo Island (SA Water 1999d). A proposal for a second seawater treatment plant in South Australia at Cathedral Rocks on Eyre Peninsula where conventional water resources are limited was considered (Kilmore *pers comm*. 2004).

In November 2003, Dr Con Pelekani (water treatment process engineer) from the South Australian Water Corporation carried out a unit cost estimate analysis for treating brackish groundwater and seawater to specified product water salinity levels by blending (shandying) the product water with the source water. The analysis indicated a minimal difference in unit cost for treating low or medium brackish groundwater to various salinity levels 500mg/L, 1000mg/L and 1500mg/L as shown in Figure 42 below. The difference was even less for the seawater analysis as the amount that can be bypassed (for blending) to achieve salinity target was very small (<5%).



*Unit cost analysis by Dr Con Pelekani, SA Water (2003)*

*Unit cost analysis by Dr Con Pelekani, SA Water (2003)*

**Figure 42 Estimated Cost to Produce Water to Specified Salinity Targets**

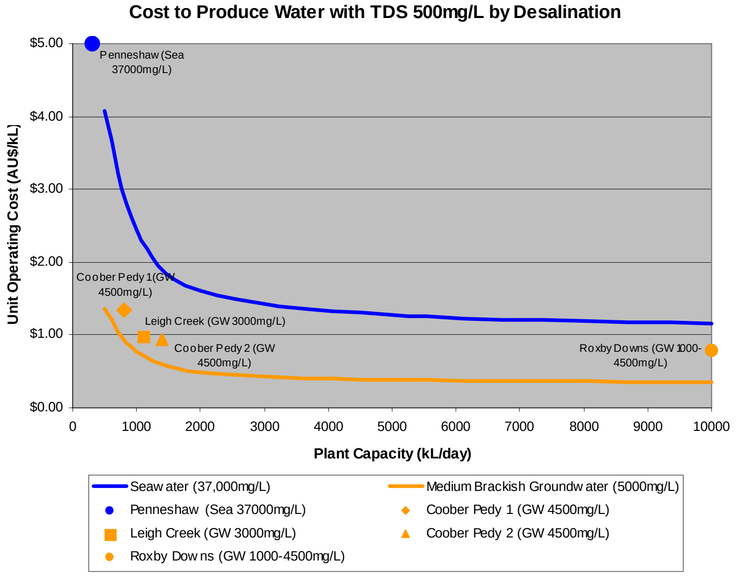
A summary of the cost of producing potable water from operational desalination plants operating in South Australia is provided in Table 21 below. The unit cost is for treatment by the reverse osmosis process and excludes the cost of accessing source water and distribution of product water.

**Table 21 Summary of Reverse Osmosis Plants in South Australia**

| | Plant Capacity (kL/d) | Source | Raw Water TDS (mg/L) | Recovery Rate (%) | Product TDS (mg/L) | Unit Cost ($/kL) |
|---|---|---|---|---|---|---|
| **Penneshaw** (1) | 300 | Sea | 37,000 | 28 | <400 | $5.00 |
| **Coober Pedy** (2) | 600 | Ground | 4,500 | 74 -77 | <100 | $1.34 |
| | 1400 | " | " | " | " | $0.94 |
| **Leigh Creek**(3) | 1100 | Ground | 3,000 | 75 | <150 | $1.00 |
| **Roxby Downs** (4) | 10000 | Ground | 1,000-4,500 | 75 | <150 | $0.79 |
| **Adelaide** (theoretical)(5) | 50,000 | Sea | 37,000 | 80 | <400 | $1.03 |

(1) *Water Proofing Adelaide (2004) & pers comm. Ian Gliddon SA Water (2004)*
(2) *Coober Pedy Council. pers comm. Les Hoad (2000) & Damien Clark (2004). Plant capacity increased November 2001.*
(3) *NRG Flinders, Leigh Creek Operations per comm. Dion Robins (2005)*
(4) *Western Mining Corporation pers comm. Bobby Watson (2004).*
(5) *Water Proofing Adelaide (2004) & pers comm. Natasha Hall, SA Water (2004).*

The costs depend on many local factors including the salinity of the source water, the technology being used, the energy requirements as well as economies of scale. Figure 43 below provides a comparison of the estimated unit cost to produce potable water with a target TDS 500mg/L determined by Pelekani (2003) and the actual operating costs to produce potable water. The existing reverse osmosis plants consistently produce water better than the target TDS 500mg/L.



*(1) Unit cost estimate analysis for groundwater and seawater reverse osmosis desalination plants to treat to specified salinity in product water quality courtesy Dr Con Pelekani, SA Water (2003). Assumptions: Recovery 80% for brackish water & 40% for seawater. RO product water blended with groundwater to achieve 500mg/L salinity target.*
*(2) Penneshaw unit cost data from Water Proofing Adelaide (2004). Operational data courtesy Ian Gliddon SAWater (2004). Raw Water TDS 37,000mg/L. Product Water TDS<400mg/L. Recovery 28%.*
*(3) Coober Pedy data courtesy District Council (2004). Raw Water TDS 4500mg/L. Product Water TDS<100mg/L. Recovery 74-77%. Plant capacity increased November 2001.*
*(4) Roxby Downs unit cost data www.unisa.edu.au (1998). Operational data courtesy Bobby Watson, Western Mining Corporation Olympic Dam (2004). Raw Water TDS 1000mg/L to 4500mg/L. Product Water TDS<150mg/L. Recovery 75%*
*(5) Leigh Creek unit cost data courtesy Dion Robins, NRG Flinders (2005). Raw Water TDS 3000mg/L. Product Water TDS<150mg/L. Recovery 75%.*

**Figure 43 Comparison of Estimated & Operating Unit Cost of RO Plants**

While the cost of the water produced by these plants is higher than that provided through SA Water mains, it remains an attractive proposal for many remote communities or communities where conventional water resources are limited, particularly compared to the real cost of alternatives (ie. taking externalities into account). The desalination process has high energy consumption with per kilolitre energy usage being in the order of three times that required to pump water from the River Murray to Adelaide (GSA 2004). The significant energy requirements of large-scale desalination could result in the need to expand the State’s power generation capability (EWS 1989). Unless the energy requirements can be met by clean renewable sources the associated contribution to green house gas emissions would be significant (GSA 2004). Nevertheless, reverse osmosis can be expected to play an increasing role in water treatment in South Australia, particularly if the energy requirements can be met using sustainable power sources such as wind, hydro or geothermal.

#### 4.5.5.4 Renewable Energy

Renewable energy can reduce dependence on fossil fuels and also provide affordable electricity. A major benefit of renewable energy is not subject to sharp price changes because it comes from sources such as sunshine, flowing water or wind. By comparision, fossil fuels are limited in their supply and their price will increase as they become scarcer. The general principle behind the drive to renewable energy is sustainability.

Rottnest Island in Western Australia is leading the nation in wind energy desalination. The construction of a wind turbine in December 2004 was a definitive milestone in the journey towards a sustainable energy and water supply. Example 26 describes this innovative project.

### Example 26 Wind Power & Water Desalination: Rottnest Island, WA

*Rottnest Island is located 18 kilometres from the mainland west of Perth, Western Australia. The island is 10.5 kilometres long and 4.5 kilometres wide at its broadest point. The surface waters of Rottnest Island consist of a series of saltwater lakes, swamps and several freshwater pools and seeps. It has even been necessary to import additional water by barge from the mainland from time to time. The supply of drinking water in sufficient quantities and at a reasonable cost has always been an issue. Three main sources of water have been developed to meet the annual demand for freshwater on Rottnest Island;*

| | *1995* | *2003* |
|---|---|---|
| • *Rainwater runoff harvested from sealed catchment since 1939,* | *10%* | *10%* |
| • *Underground freshwater borefield recharged by seasonal winter rainfall since 1971, and* | *70%* | *20%* |
| • *Desalination of saline groundwater since 1995* | *20%* | *70%* |

*Groundwater has played a major role as a source of potable water until recently. A reverse osmosis (RO) desalination plant with a capacity of 220kL/day was commissioned in 1995 to augment supplies. The use of desalination as a source of potable water on Rottnest Island is expensive (around $2.40/kL) with costs dominated by the electricity requirements of the plant. At the time, Rottnest Island was totally reliant on liquid petroleum fuels for power generation, at a great and ever-increasing cost.*

*With the depletion of underground freshwater supply, the Rottnest Island Authority produced an Integrated Water and Power Development Plan. The philosophy behind the plan was to deliberately shift from a predominantly rainfall dependant water source to a majority of potable water being supplied through desalination. The capacity of the plant was upgraded to 500kL/day in February 2002 and reduced the reliance on rainfall dependant water supplies from 80% to 30% on Rottnest Island. The project included the construction of a new wind turbine to supplement diesel-generated power in order to make the shift economically and environmentally acceptable.*

*In December 2004, a milestone was reached in the journey towards a sustainable energy and water supply for the island with the construction of the Rottnest Island wind turbine. It has also reduced dependence on fossil fuels by an estimated 40% and to have the potential to effect savings of around $1 million per year in fuel costs. The project received a high commendation in the environment category of the 2005 Premiers Award for Excellence in Public Sector Management.*

*Source: Playford (2000); www.rottnestisland.com/rotto accessed 08/04/05*

## 4.6 TRANSITION CHALLENGES

Almost since the time of European settlement, land and water management practices in Australia have progressively been adapted to suit the environment. Social factors have a definitive say, thus it may take decades before new approaches are adopted and even longer to reap the benefits (Hammond 1998 in Figurese *et al.* 2003). However, recent widespread drought across the country has refocussed the Australian community to their dependence on the limited water resources (Radcliffe 2004). Under the pressure of water shortages, water harvesting and reuse practices offer the potential to increase the total available water supply, particularly, where potable (drinking quality) urban water supplies can be safely substituted with treated wastewater, stormwater or brackish groundwater. Nonetheless, as there is a degree of self perpetuation with the traditional '*business as usual*' approach, the transition from the existing urban water supply infrastructure to any alternative supply system and the introduction of innovative technologies will be problematic.

The key challenges to be actively managed in order to move from the existing '*business as usual*' approach to water services towards more sustainable forms include remaining asset life (financial dimension), community size (technical, institutional and financial dimensions), and community misgivings (social dimension). To ensure sustainability, these need to be managed within the carrying capacity of the local environment.

### *4.6.1 Remaining Asset Life (Established System)*

The sustainability of urban centres and communities depends on management and maintenance of established semi-permanent infrastructure of society as well as natural resources. Infrastructure management and the need to replace existing assets could be seen as an opportunity to restructure water services and eliminate unsustainable water management practices (Clarke *et al.* 1997; Fleming 1999). This philosophy of moving from the established system to an alternative sustainable approach assumes that as the infrastructure '*wears out*' it is replaced with the new system. Firstly, in reality the established system does not fail as one whole system – it tends to fail only in small segments (Doherty *pers comm*. 2005). Secondly, the cost to facilitate the transition would be dependent on how it is to be managed and over what timeframe. The critical question is not so much whether alternative water systems will work reliably, but how they can be integrated in a way that is acceptable to the community into the strategic planning effort.

New water infrastructure systems developed in Australia today must be planned and designed with regard to their long term sustainability. Naturally, it is important to know whether the alternatively configured systems will be successful in terms of achieving desired aspiration for sustainability. Over the last decade, a number of systems to supply new urban development in Australia have been designed to maximise water cycle management opportunities and minimise adverse impacts on the environment. These sites provide full-scale operational models that allow direct comparison over time without the need to compare with '*imaginary*' systems. They can generate information for research on effectiveness of technologies, social, economic and environmental impacts.

### 4.6.2 Community Size

Global sector experience has established that services are better sustained when service delivery is done using approaches that seek to understand and respond to the demands of users of the service (WSP 2003). The processes for developing and managing a small local water supply are the same as the public system but carried out to a different level of service. Small communities are usually more flexible with respect to accepting lower level of service compared with larger urban centres. Small towns with limited potable supplies should be given the opportunity to have lesser standards for non-potable reuse water if it conserves their potable supplies. While small communities are not averse to accepting higher risk (lower standards), health authorities in generally impose conservative standards that do not account for possible less demanding local conditions or local integrated water, wastewater and reuse systems.

### 4.6.3 Managing Community Misgivings

Encouraging community involvement and acceptance is not always easy when introducing new ideas because people are wary of change, particularly, if the specific change is perceived to be detrimental to their interests. International research has identified significant community resistance to the introduction of recycled water systems, in some instances, resulting in the abandonment of such projects (Marks 2005). Several large scale water reuse projects including in Noosa, Australia, San Diego, USA, and Lichi Rijin, The Netherlands, have failed and been abandoned as a direct result of a lack of community confidence (Hurlimann & McKay 2005). In each case, community misgivings could be attributed in part to inadequate communication between the non-potable water supply organisations and their stakeholders. Yet, few authors draw conclusions from their studies with regard to optimal ways of increasing public acceptance. Learning to reconcile different perspectives is an important part of the process of introducing new technologies.

A sceptical community may be reassured if informed of the success that other communities are having with water harvesting and recycling projects similar to that being proposed (Khan & Gerrard 2005). When the community is involved in the planning process there is an increased likelihood of a project being accepted by the community and successfully implemented and sustained. In addition, acceptance of the selected option, which may incorporate lower standards associated with lower capital costs, will be more likely if the community has been engaged early in the development stage. In some circumstances, the community involvement process may be more important than the final detail of the selected scheme because people want to be involved and have an opportunity to complain (Sarkissian *et al.* 1986). It is recommended that planners involved with water harvesting and reuse projects in Australia learn from the experiences of recently implemented projects – both successful and abandoned. The primary goal of a sustainable community is to meet its basic resource needs in ways that can be continued in the future. Understanding that other communities practice water harvesting and reuse as a matter of choice can act as a powerful endorsement.

## 4.7 SUMMARY

There is increasing recognition that present development paths are not sustainable. In Australia, the manner in which water is harvested, treated, distributed and used in urban centres is under constant review. Fortunately, a number of viable strategies exist to meet future urban water demands and safeguard the environment. Initiatives to improve sustainability of urban centres may include a combination of demand management (ie. water efficiency and conservation), water sensitive urban development (ie. policies and alternative practices) and supply augmentation (ie. natural and recycled). All these strategies have strong community support in Australia, with the exception of further development of natural freshwater resources, particularly where they can be shown to be cost effective.

Despite the increase in emphasis placed on future water challenges, a major constraint continues to be how to establish an enabling environment that can accommodate the necessary shift from the present unacceptable state to a more sustainable future. Impediments to increasing the sustainability of water services include the long life of the public infrastructure (including financing), resistance to change (from institutions), time to effect cultural change (ie. businesses and individuals) and the difficulty in predicting the future (ie. impact of climate change). The key challenge will be in transforming established urban water systems, often with an asset life between 50 and 100 years, into more sustainable infrastructure forms while maintaining a high level of services to customers. Opportunities to deliver more sustainable water services will need to be balanced with the retention and use of existing water infrastructure investments.

The introduction of new ways of delivering water services to achieve sustainability requires an advanced understanding of the social and economic climate in which the alternative water systems will be implemented. Given the rainfall variability and wide range of climates across Australia, it is both physically and economically unrealistic to expect a single strategy to deliver the same result for all urban centres. The delivery of sustainable water services to growing urban centres will require selecting a diverse mix of strategies that are best suited to the prevailing conditions. Design solutions should consider the most cost effective approach and seek to maximise the social and environmental benefits.

Innovation and experimentation will remain important elements in the development work to improve the sustainability of water services. In Australia, undervalued (or untapped) water resources near urban centres can include rainwater, treated wastewater, stormwater runoff, seawater and bottled water. Sometimes, the question of which solution is appropriate in a particular situation is not given enough attention when benefactors driven by their own solutions interact with small towns or rural communities. The challenges and opportunities associated with harvesting stormwater and reusing treated effluent for towns in South Australia are examined in detail in the next chapter.

# Chapter 5
# Water Features of South Australia

*"All the water we will ever have is here now"*

Veltrop (1996)

## 5.1 INTRODUCTION

For more than 150 years, water, wastewater, and stormwater services have been provided to the majority of South Australia by government, with a few exceptions. This accomplishment has been a triumph of adaptation and experimentation in the face of disease, engineering trial and error and changing public attitudes (Hammerton 1986). In terms of the health of South Australians, the effect of government provision of urban water infrastructure has been extensive. South Australians of today often take for granted the convenience and reliability of water services. However, without the present urban water infrastructure systems, coupled with security provided by regulation of the River Murray, the population of South Australia would be considerably smaller than it is today (Marohasy 2003).

The level of development of some natural water resources in South Australia is approaching (or has reached) sustainable levels and usage is capped at this level. Physical, hydrological and economic constraints, along with environmental and attitudinal pressures, mean that the option of developing additional natural water resources is becoming less and less relevant. South Australia will be obliged to adopt water conservation measures (ie. reduce demand for selected purposes, modify management of existing systems to enhance availability of water) and develop other non-traditional sources of lower quality water to meet demands. Water harvesting and reuse will become an attractive option for either extending available water supplies to support increased population or in reducing the State’s dependence on the River Murray. This applies to large and small communities.

Demand for water by communities in South Australia is highly dependent on the prevailing climate, physical accessibility, price and local cultural or behavioural water use practices. Within South Australia, the range of local water resources and the security of supply (ie. quantity and quality) can vary considerably between regions. Variations in local environments and patterns of water use can result in different water management approaches and standards of supply between regions. The prosperity of South Australia continues to depend on a secure water supply and this chapter discusses the major features and characteristics which impact sustainable management of the State’s water resources. The primary legislative responsibility for sustainable and equitable management of water rests with the State Government.

## 5.2 LEGISLATIVE FRAMEWORK

### *5.2.1 Response to National Water Reform*

The South Australian Government has made some big changes (summarised in Table 22) over the last ten years as a result of the 1994 COAG water reform (refer Appendix 2).

**Table 22 Summary of the South Australian Water Industry Reforms**

| NATIONAL EVENTS | | CHANGES IN SOUTH AUSTRALIAN WATER INDUSTRY | | |
|---|---|---|---|---|
| | | **Institutional Reform** | **Cost Recovery & Pricing Reform** | **Allocation & Trading** |
| **1992** | **Review of Trade Practices Act (Hilmer Inquiry)** | | Fixed residential water allowances of 136kL introduced (ie not linked to property values) | |
| **1994** | **COAG Water Reform** | Water Resources function separated from EWS | Two part water tariff for all non-commercial customers | |
| **1995** | **National Competition Policy Reform** | SA Water Corporation formed to replace EWS. Required to pay an income tax equivalent to the SA Government | | |
| **1996** | | 15 year contract with United Water to operate Adelaide water and wastewater system<br>Devolution of water resource management to local government *WRA 1996* | SA Water subject to prices oversight under the Government Business Enterprises (Competition) Act SA 1996. Declaration period Nov 1996 to 1999 | |
| **1997** | Third Party Access Inquiry | CSO policy implemented<br>*WRA 1997* provides catchment management boards with management responsibilities and fund raising abilities | SA Government appointed CC to review the water and sewerage prices. Govt did not act on the findings. | 9 out of 10 Irrigation Districts transferred from Govt. to self-management<br>*WRA 1997:* transfer rights and trade in water allocations |
| **1998** | | CSOs explicitly costed | | Interstate water trading pilot introduced |
| **1999** | | 3rd Party Access - Off Peak Transport to Barossa Valley (Contracts 3 – 9 yrs) | Pricing Oversight declaration expired<br>Water Pricing PD | |
| **2000** | | Department of Water Resources created (separated from EPA) | Sewerage Pricing PD | |
| **2001** | COAG deadline extended to 2005 | | | Restrictions on volume of water traded. Rules set by Irrigation Trusts |
| **2002** | | SA Government commenced INRM Reform. DWLBC created (incorporates DWR) | ESCOSA established but water price not regulated | |
| **2003** | | Permanent Water Use Regulation enacted | Phase out of property-based charges for commercial customers by 06/07 | |
| **2004** | **National Water Initiative** | Introduction of new Natural Resources Management Act | SA Government appointed ESCOSA to review water pricing process | |

Notes:
EWS = Engineering and Water Supply Department
SA Water = South Australian Water Corporation
CSOs = Community Service Obligations
*WRA* = Water Resources Act
CC = Competition Commissioner
PD = Public Discussion Paper
DWR = Department for Water Resources
DWLBC = Department of Water, Land and Biodiversity
INRM – Integrated Natural Resource Management

The main change in service delivery was separating the function of water resources management (government responsibility) from service provision (by public or privately operated utilities). This allows the State Government to enable other parties to access and use water for irrigation, mining and other industrial uses, and service rural and urban communities.

The Government of South Australia recently embarked on further significant institutional reforms in natural resource management. The new arrangements provide a single framework (replacing three pieces of legislation) to coordinate and integrate the activities of the wide range of groups involved in natural resource management across the State. The regional, integrated natural resource management boards (combining the current 64 boards) will be broadly based on water catchment areas. This approach recognises the relationship between water catchments and water resource management.

### *5.2.2 Legislation Related to Water Use & Management*

A number of pieces of South Australian legislation have an impact on water resources management. The Acts listed set out responsibilities in relation to water and require government agencies to take appropriate action to fulfil the functions for which they were established. The main Acts (which continues to change) that impact on a local water harvesting or reuse supply project are highlighted below.

**SOUTH AUSTRALIAN LEGISLATION**

Coast Protection Act 1972
Competition Policy Reform (South Australia) Act 1996
**Development Act 1993**
**Development (Sustainable Development) Bill 2005**
Economic Development Act 1993
**Environmental Protection Act 1993**
Essential Services Commission Act 2002
Government Business Enterprises (Competition) Act 1996
Groundwater (Border Agreement) Act 1985
Groundwater (Qualco Sunlands) Control Act 2000
Irrigation Act 1994
Lake Eyre Basin (Intergovernmental Agreement) Act 2001
**Local Government Act 1999**
Local Government Finance Authority Act 1983
Murray-Darling Basin Act 1993
Native Vegetation Act 1991
**Natural Resources Management Act 2004**
Outback Areas Community Development Trust Act 1978
Pastoral Land Management and Conservation Act 1989
Public Corporations Act 1993
**Public and Environmental Health Act 1987**
River Murray Act 2003
River Murray Waters Agreement Supplemental Agreement Act 1963
River Murray Waters (Dartmouth Reservoir) Act 1971
Renmark Irrigation Trust Act 1936
Roxby Downs (Indenture Ratification) Act 1982
**Sewerage Act 1929**
Soil Conservation and Land Care Act 1989
South Australian Health Commission Act 1976
South Australian Local Government Grants Commission Act 1992

South Australian Water Corporation Act 1994
South Eastern Water Conservation and Drainage Act 1992
South Western Suburbs Drainage Act 1959
Upper South East Dryland Salinity and Flood Management Act 2002
**Water Conservation Act 1936**
**Waterworks Act 1932**

Rights to take water exist in a number of degrees, from a basic, unlicensed right of a lawful occupier to take water for stock and domestic or other use, through to the right of a license holder to take a particular volume of water from a prescribed resource (GSA 1999).

## *5.2.3 Water Resource Management in South Australia*

### 5.2.3.1 Management Regions

In South Australia, water resource management is carried out through legislation, which covers allocation and extraction of water resources as well as control of water quality and environmental impacts. Under previous legislation (replaced in 2005 with the integrated natural resource management legislation) a State Water Plan (SWP) was developed. The SWP divides the responsibility for water resource management into regions based on their demographic position, source of supply, population size and concentration, as denoted in Figure 44. This has allowed the devolution of water resources management responsibilities to local communities primarily through the establishment of catchment water management boards and water resources planning committees in any area of the State.

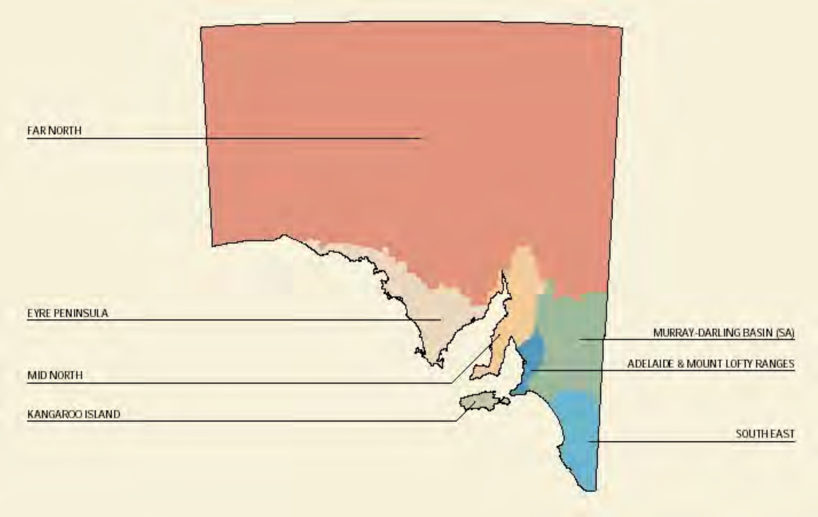


**Figure 44 State Water Resources Management Regions (SWP 2000)**

The variability of South Australia's ecosystems and rainfall patterns necessitates highly localised and adaptive research and development and water management techniques. Each part of South Australia requires a different management approach that is tailored to the particular climate. The SWP allows water to be managed on a regional basis in an integrated and consistent manner across the State. Appendix 7 provides an overview of the water resources for each region.

### 5.2.3.2 Prescribed Watercourse and Well Areas

South Australia has a process to protect water resources that are stressed by the taking of water. This includes the development of water allocation plans for prescribed resources. Water allocation plans for each prescribed water resource detail policies and administrative arrangements to manage water use within sustainable limits. Several water resources have been prescribed under the *Natural Resource Management Act* 2004 (in lieu of repealed *Water Resources Act* 1997), where their level of development and regional significance have warranted a higher level of management than other areas of the State.

| **Prescribed Water Resource**<br>**by Water Resource Management (WRM) Region** | **Ground** | **Surface** |
|---|---|---|
| ***Adelaide & Mount Lofty Ranges WRM Region*** | | |
| • Barossa Valley PWA and Watercourses | ✓ | ✓ |
| • Chapman's Creek Intake Prescribed Watercourse | | ✓ |
| • Dry Creek Prescribed Wells Area (PWA) | ✓ | |
| • Little Para River Prescribed Watercourse | | ✓ |
| • Mc Laren Vale Prescribed Wells Area | ✓ | |
| • Middle Beach Intake Prescribed Watercourse | | ✓ |
| • Northern Adelaide Plains Prescribed Wells Area | ✓ | |
| • Northern Intake Prescribed Watercourse | | ✓ |
| ***Murray-Darling Basin (SA) WRM Region*** | | |
| • Angas Bremer Prescribed Wells Area | ✓ | |
| • Mallee Prescribed Wells Area | ✓ | |
| • Noora Prescribed Wells Area | ✓ | |
| • River Murray Prescribed Watercourse | | ✓ |
| ***South East Water Resource Management Region*** | | |
| • Comaum-Caroline Prescribed Wells Area | ✓ | |
| • Lacepede-Kongorong Prescribed Wells Area | ✓ | |
| • Naracoorte Ranges Prescribed Wells Area | ✓ | |
| • Padthaway Prescribed Wells Area | ✓ | |
| • Tatiara Prescribed Wells Area | ✓ | |
| ***Mid North Water Resource Management Region*** | | |
| • Clare Valley Prescribed Wells and Watercourses | ✓ | ✓ |
| ***Far North Water Resource Management Region*** | | |
| • Curdimurka Prescribed Wells | ✓ | |
| • Muloorina Prescribed Wells | ✓ | |
| ***Eyre Peninsula Water Resource Management Region*** | | |
| • County Musgrave Prescribed Wells Areas | ✓ | |
| • Southern Basins Prescribed Wells Area | ✓ | |
| ***Kangaroo Island Water Resource Management Region*** | | |
| • No prescribed water resources | × | × |

*Source: State Water Plan (2000)*

## 5.3 THE PREVAILING CLIMATE

The climate of a region represents the atmospheric conditions over a long period of time, and generally refers to the normal or mean course of the weather. The weather of a location describes the atmospheric variables for a brief period of time. Climate data is usually expressed in terms of an individual calendar month or season and is determined by averaging over a period long enough to ensure that representative average values for the month or season are obtained. The prevailing climate of a location provides a summary of average conditions as well as information about the natural variability and the likelihood of particular events.

The prevailing climate of a region influences the temporal pattern of water demand. The pattern of rainfall and evaporation also influences the volume and seasonality of water demand. In addition to influencing the water demand, the prevailing climate along with the extent of impervious surface cover (ie. degree of urbanisation) determines the probable volume of stormwater runoff from an urban catchment. For these reasons, understanding the prevailing climate of a location is important when assessing the potential of water harvesting and reuse schemes. The main climatic elements that affect the potential for water harvesting and reuse in any given region are:

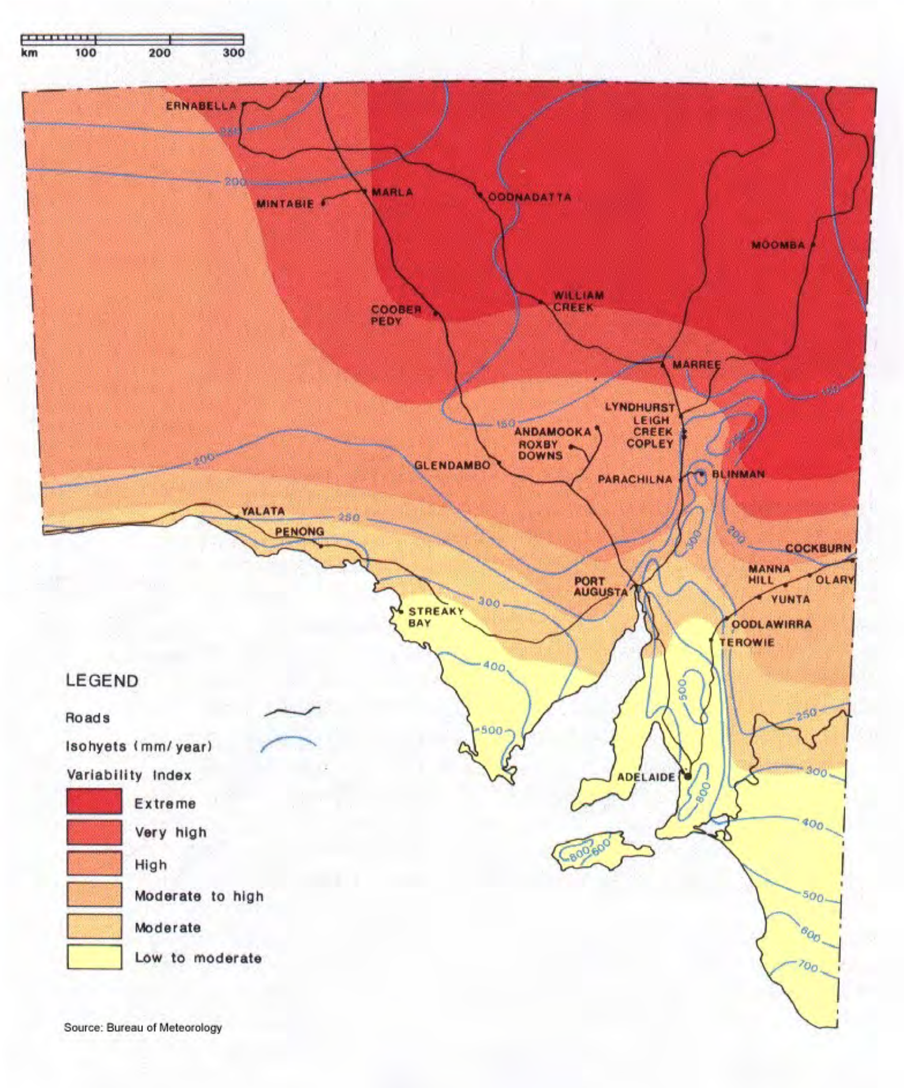
- precipitation (rainfall);
- temperature;
- humidity;
- sunshine hours or net radiation; and
- wind velocity.

All contribute to evaporation

To provide an overview of the features of South Australia’s prevailing climate, the physical factors of rainfall, evaporation, and their variability are discussed below.

### *5.3.1 Rainfall*

South Australia lies between the latitudes 26° and 38° south, corresponding to a region of descending air on the globe (EWS 1987). This, combined with its typically low topographic relief, results in low rainfall. Figure 45 below shows the average annual rainfall and the variability in South Australia. Average annual rainfall of more than 250mm is restricted to the southern third of the State and the southern Flinders Ranges. In these zones the rainfall is relatively reliable and occurs predominantly in the winter months. In the northern two thirds of South Australia, rainfall is highly variable from one year to the next and has a similar chance of occurring in any month of the year. Extreme downpours or extreme heat however are more likely to occur in the Summer months.



Source: Bureau of Meteorology

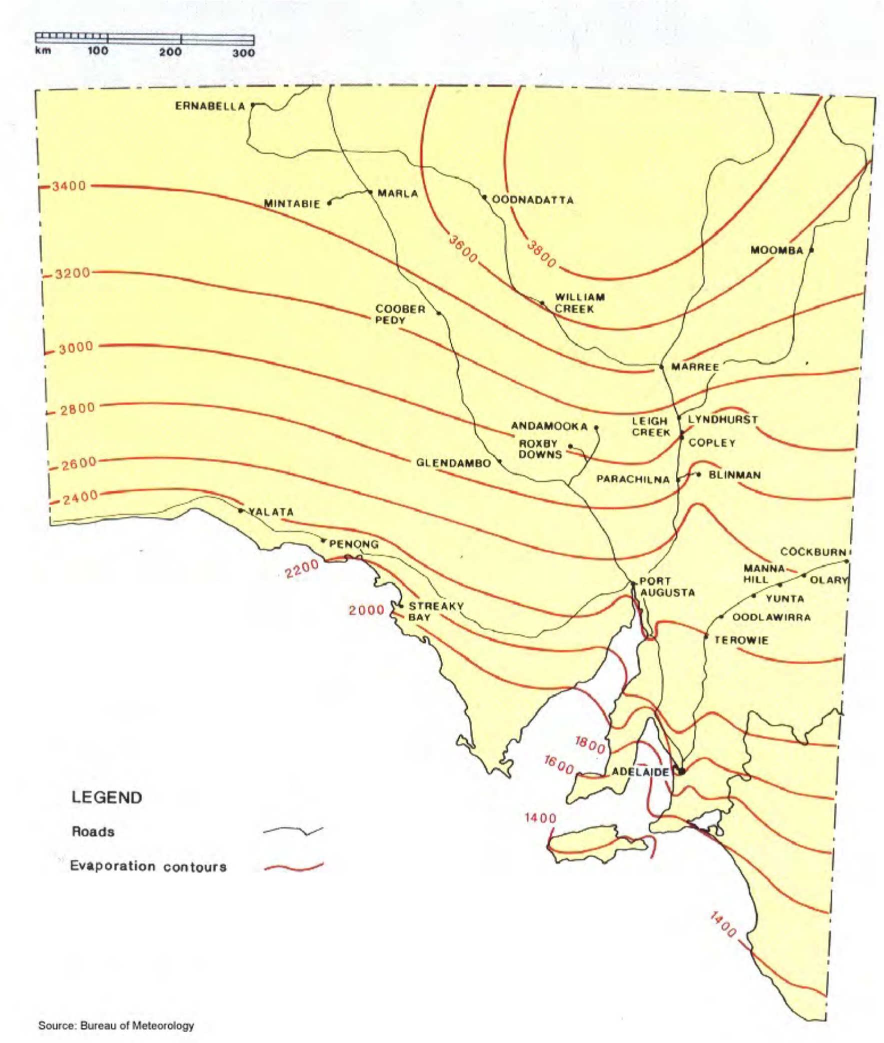
**Figure 45 Average Annual Rainfall in South Australia (BOM)**

Variability is measured by the '*coefficient of variation*' which is a statistical measure of the standard deviation to the mean. In South Australia the coefficient range for rainfall is 0.2 to 0.8 (EWS 1987). In engineering design both the maximum and minimum limits are important. For example, the maximum limit is critical in the design of stormwater drains to avoid flooding. Conversely, minimum rainfall values, the interval between rains and the variability of rain (ie. reliability) are highly important in water supply design.

Average monthly and annual rainfall records for most locations and towns in South Australia are available from the Bureau of Meteorology. Appendix 8 presents the '*average monthly and annual rainfall*' for 220 towns in South Australia (alphabetically listed) based on the work by Mr Kevin Burrows of the Bureau of Meteorology in 1987. It should be noted that due to the high variability in South Australia the actual rainfall can deviate widely from the average monthly and annual figures.

### 5.3.2 Evaporation

While annual average rainfall is variable, the potential evaporation is relatively constant from one year to the next. The potential rate of evaporation is mainly influenced by the wind velocity, atmospheric humidity and solar radiation of a location. Evaporation rates vary daily and seasonally. It is highest in summer periods during the middle of the day and compounded by windy conditions. Wind increases evaporation from a free water surface and surface soil moisture as well as increasing plant transpiration. Figure 46 shows the average annual evaporation for South Australia.



Source: Bureau of Meteorology

**Figure 46 Average Annual Evaporation for South Australia (BOM)**

Average monthly and annual evaporation data are recorded at a limited number of places in South Australia by the Bureau of Meteorology. Appendix 9 presents the '*estimated average monthly and annual evaporation*' for 220 towns in South Australia (alphabetically listed) based on the aforementioned work by Mr Kevin Burrows in 1987.

### 5.3.3 Climate Index for South Australia

There are a number of different ways to describe or classify climates. Towns that are interested in developing local water harvesting and reuse scheme should use climate zones based on rainfall and evaporation rates as these will be most useful. A simple index called a "*Climate Index*" is useful to describe the prevailing climate conditions of townships. It can assist in making broad assessments of stormwater availability (for harvesting and use), as presented below:

$$\text{Climate Index (CI)} = \frac{\text{Average Annual Evaporation (mm)}}{\text{Average Annual Rainfall (mm)}}$$

Figure 47 presents the application of the climate index and identifies four ranges for the state of South Australia. For much of South Australia, the average annual evaporation exceeds the annual average rainfall by a factor of ten.

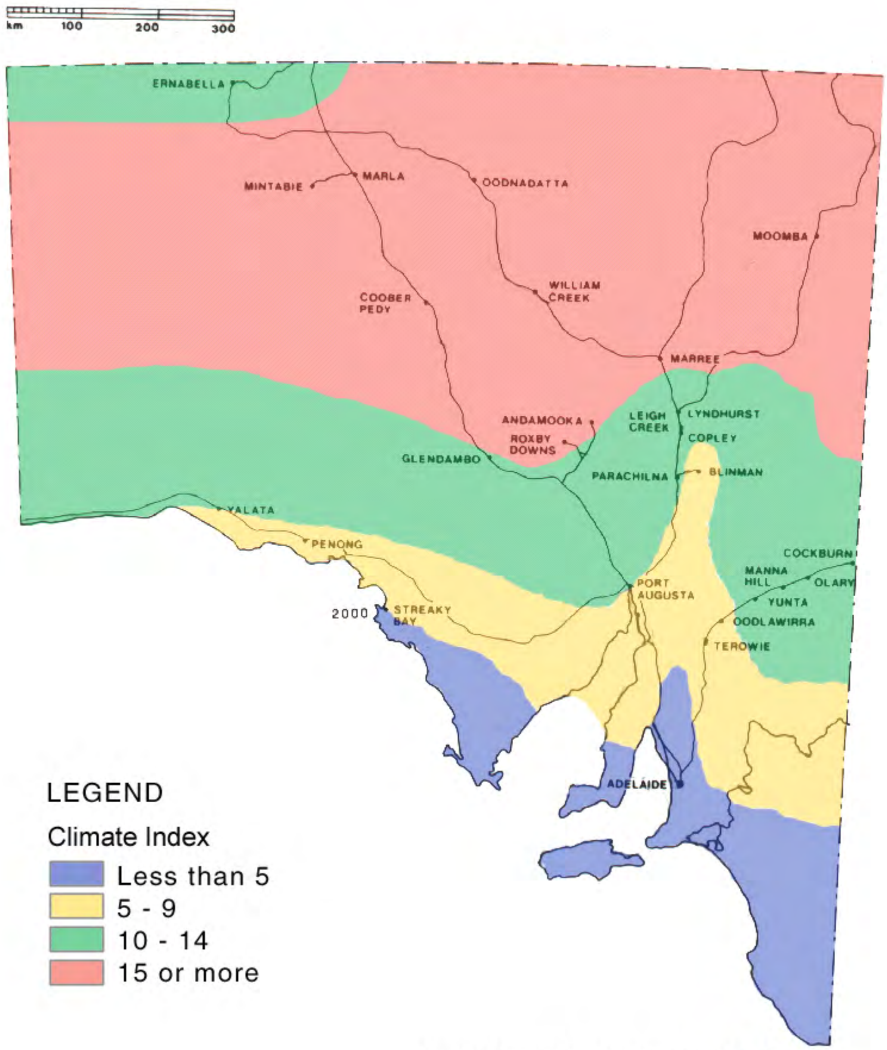


Image Created by Monk (2000) for Rabone

**Figure 47 Climate Index for Areas of South Australia (Rabone 2000)**

Application of the Köppen classification of world climates to Australian climates by the Bureau of Meteorology established two distinct climate zones within South Australia. The two climate zones (based on air temperature and humidity) are described as '*hot dry summer, cold winter*' and '*warm summer, cool winter*'. The climate index range '*less than 5*' in Figure 47 corresponds closely with the Köppen classification '*warm summer, cool winter*' climate. The remaining three climate index ranges shown in Figure 47 being '*5 to 9*', '*10 to 14*' and '*greater than 15*' essentially subdivide the broad Köppen classification '*hot dry summer, cold winter*' climate.

The climate index provides a method of categorising the prevailing climate of a region which assists in assessing the potential for harvesting stormwater. Low values of climate index correspond with a high potential for stormwater to be reliably harvested from impervious surfaces within the town. As the climate index increases (ie. region becomes more arid) the potential for harvesting reliable volumes of stormwater runoff is reduced. Typically, stormwater runoff projects are not viable for areas with a climate index greater than 15, however localised water harvesting by diverting stormwater runoff into depressions at key points in the landscape may still be beneficial. Such water collection depressions, known as limanim, are capable of supporting trees and shrubs without the need for supplementary water, even under the most arid conditions (WA WRC 1986). Figure 48 shows an example of diverted runoff collected in depressions (possibly inadvertently) at Marree which has a climate index of 20.

**Figure 48 Localised water harvesting (limanim) at Marree (January 2003)**

The '*climate index*' value for 220 towns in South Australia (alphabetical listing) is presented in Appendix 10. The '*climate index*' information for the towns by water resource management region (ie. administrative areas discussed in section 5.2.3.1) is contained in Appendix 11. For towns not listed in these appendices the climate index for the region can be approximated from Figure 47.

### *5.3.4 Rainfall Reliability*

The reliability of rainfall has long been an important factor in the history of South Australian settlement and growth. However, it is possible to determine the feasibility of agricultural and pastoral enterprises in a region without detailed records on which to base such assessment. The establishment of the Goyder Line in 1865 described in Example 27 below is perhaps the most notable case in point.

**Example 27 Goyder's Line of Reliable Rainfall for South Australia**

> *By the early 1860's most of the good farming land had already been sold and the government was under pressure to open up the vast more arid lands further north towards the Flinders Ranges. As nothing was known at the time of the rainfall pattern in these drier regions, the Surveyor General George Woodroffe Goyder (1826-1898) was given the task of assessing the feasibility of this northwards expansion. Late in 1865, at the height of a severe drought, Goyder made several trips to the north of the state, making notes as to the type of vegetation and condition of the soils. He finally defined a line on a map (see* Figure 49*) to the south of which rainfall was deemed to be reliable enough for all sorts of agricultural pursuits but the lands to the north of the line were suitable only for grazing.*

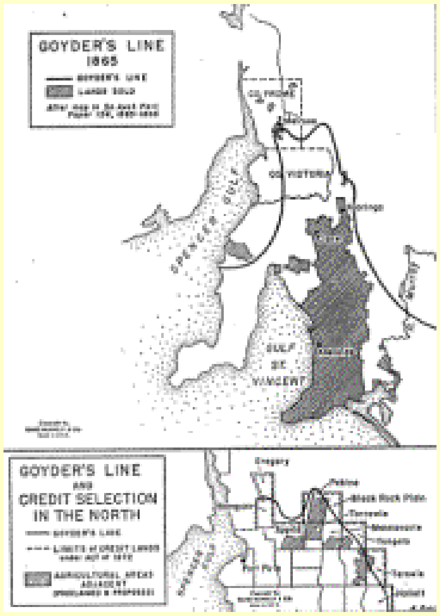


**Figure 49 Goyder's Line of Rainfall c1865 (Vecchio 2002)**

*Source: Vecchio (2002)*

As no detailed rainfall records were then available on which to base his observations, Goyder's line was a bold prediction. With more than a century of rainfall data, Goyder's Line has proved a very accurate comment on the rainfall of South Australia. The placement of Goyder's Line corresponds closely with a climate index of less than 5 (refer Figure 47 above).

In the same way, the reliability of the rainfall for an area can be used to determine the reliability of stormwater generated from the town catchment area. Rainfall reliability is also important in determining the supplementary irrigation needs and balancing storage requirements for any water harvesting or reuse system. To assist in making a quick assessment, the annual rainfall data for 42 towns in South Australia from the 18 year period from 1985 to 2002 (includes 1992 which was a very wet year in the Adelaide & Mount Lofty Ranges) has been analysed. The annual rainfall for each town was arranged in rank order from the lowest to the highest as a percentile for each by climate index range. The average curve for the range of values at each percentile for the four climate index ranges (identified in Figure 47 above) has been plotted in Figure 50.

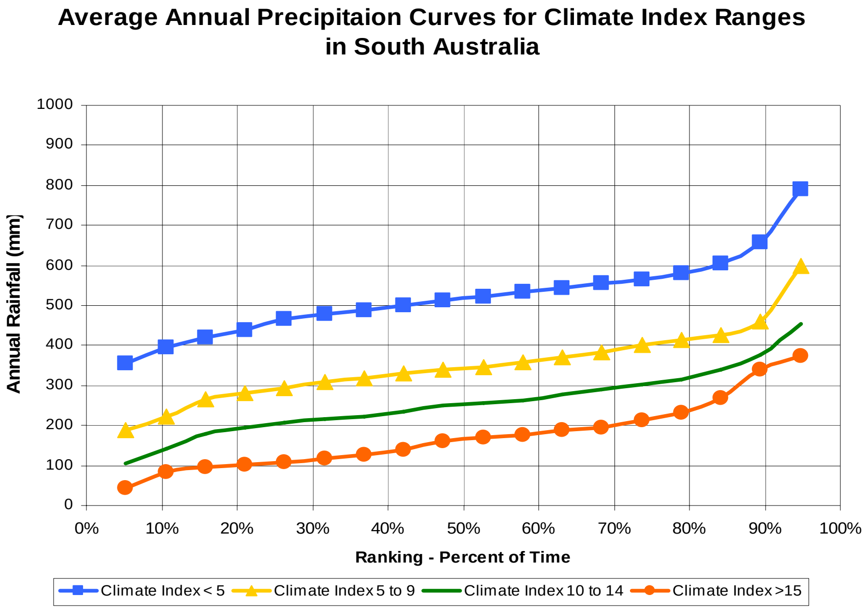


**Figure 50 Average Annual Rainfall Curves for Climate Index Ranges**

The graph shows the percent of time that rainfall of a certain magnitude will not be exceeded for a particular climate index range. The flatter the slope of the curve the more reliable the rainfall is in that region. For example, a town with climate index of 7, the annual rainfall can be expected to be less than 400mm for 75% of the time. The curve also indicates that for 80% of the time the annual rainfall in this town will be between 225mm (10% value) and 460mm (90% value). A similar set of curves is presented later (see section 7.3.3) to assist with quick assessment of expected stormwater runoff from urban and rural catchments in various climate indexes.

## 5.4 INVENTORY OF WATER RESOURCES

The development of a sustainable water resources management strategy for South Australia depends on knowing how much water is available, where it occurs, what quality it is, and how much is currently used. The term water resource refers to water which may be accessed economically and is of appropriate quality for its intended use. In short, it refers to water which can be managed for the benefit of the community (GSA 1995). Though South Australia is recognised as a dry State, it does have ample water for present and future needs, provided careful, flexible and innovative use of the major water resources and infrastructure is adopted (Clark 1987; GSA 1999; Schoenfeldt 2000). Water resources per capita in South Australia are relatively high and adequate volumes of water are available to most of the population (GSA 1999).

Water previously ignored as a potential resource can, with different technology or a shift in community attitudes, be regarded as a resource. To provide an overview of South Australia's water resources, physical factors of rainfall, evaporation, the occurrence of major water resources and their variability are discussed. South Australia's water resources have been divided into the following major resource categories: surface water and groundwater resources, stormwater and treated effluent resources and seawater. Finally, a summary of the quantity and extent of each major water resource's use is presented.

### *5.4.1 Occurrence of Traditional Water Resources*

In South Australia, both surface water and groundwater resources are important. A number of the State's major surface water and groundwater resources extend beyond the State's borders (see Figure 51). South Australia has established partnerships with other states to protect its interest in these resources (Competition Commissioner 1997; GSA 1999).

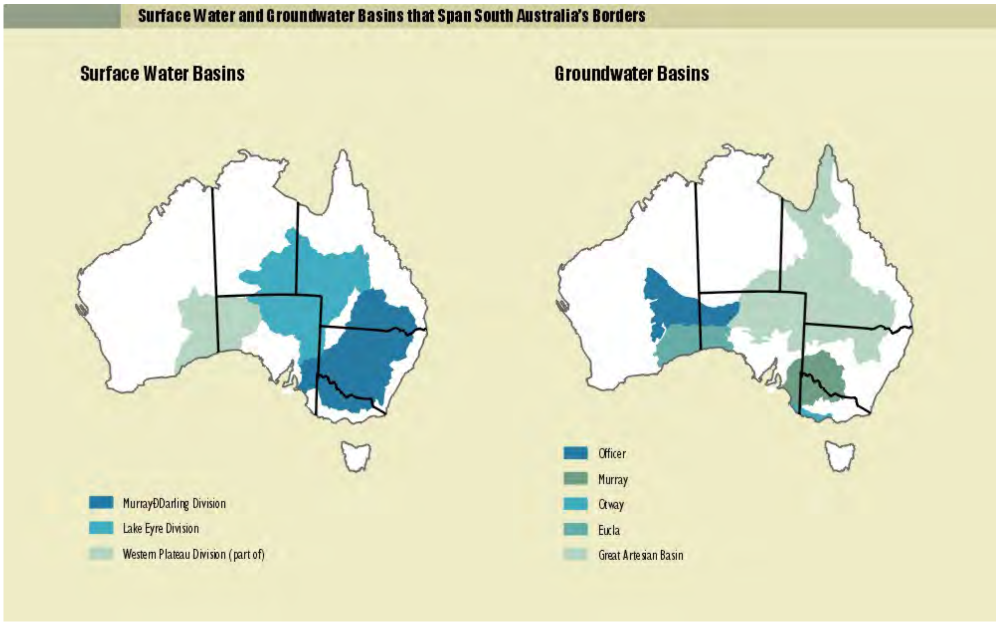


**Figure 51 Major Surface Water & Groundwater Resources (GSA 1999)**

#### 5.4.1.1 Surface Water Resources

Surface water resources in South Australia are distributed unevenly throughout the State and vary from season to season and from year to year. The quality of surface water is highly variable and depends on its location and the season. Most streams, except the River Murray, are intermittent, with most of their flows occurring after steady or heavy rains. Factors that affect the volume of runoff include the prevailing climate, geology, topography intensity of rainfall, its duration and areal extent, and the wetness of the catchment before the rain begins.

The major surface water resources for South Australia are the Murray-Darling and Lake Eyre Basins. In its natural state, the River Murray could not provide for South Australia’s water needs or support the irrigation industries that flourish along its length (Marohasy, 2003). The River Murray environment is highly modified as a consequence of engineering works over the past 100 years to ‘drought proof’ the region (Marohasy, 2003). The River Murray is the most important water resource in South Australia, supplying up to 90% of the State’s urban water consumption in dry years.

Lake Eyre includes the major inland surface water systems of the Coopers Creek and Diamantina-Georgina Rivers. These systems largely consist of turbid, low salinity water, filling water holes and lakes to maintain the internationally significant ecosystem of the Coongie Lakes, sustain the region's cattle grazing industry and provide settlements with water supplies. Discharge into Lake Eyre occurs in wetter years, but more often terminates before reaching it (GSA 1999).

#### 5.4.1.2 Ground Water Resources

Water is found stored in pores, cavities and cracks in the rocks or sediments beneath the ground at various depths. Any formation which can be permeated with water is called an ‘aquifer’, and the water occurring in them is called ‘groundwater’. Aquifers are recharged by surface water, which infiltrates either directly from rainfall or by seepage from creeks and therefore recharge can be quite variable. Factors affecting recharge include rainfall, evaporation, infiltration rate, topography, and interception by vegetation. The occurrence and availability of groundwater resources are determined primarily by geological characteristics.

In comparison to surface water, groundwater resources are more evenly distributed and less variable in terms of quality and availability year round. Flow through an aquifer is generally very slow when compared with the movement of surface water. The long-term storage effect of groundwater guarantees that water is available even in regions with strong temporal variations of rainfall (Kinzelbach & Kunstmann 1999). Consequently, it is of critical importance in large parts of South Australia, especially the arid and semi-arid inland areas where surface water is limited or unreliable.

Figure 52 shows the principal aquifer characteristics and groundwater salinity for South Australia. Fresh to brackish quality groundwater can be found beneath about half the surface area of the State.

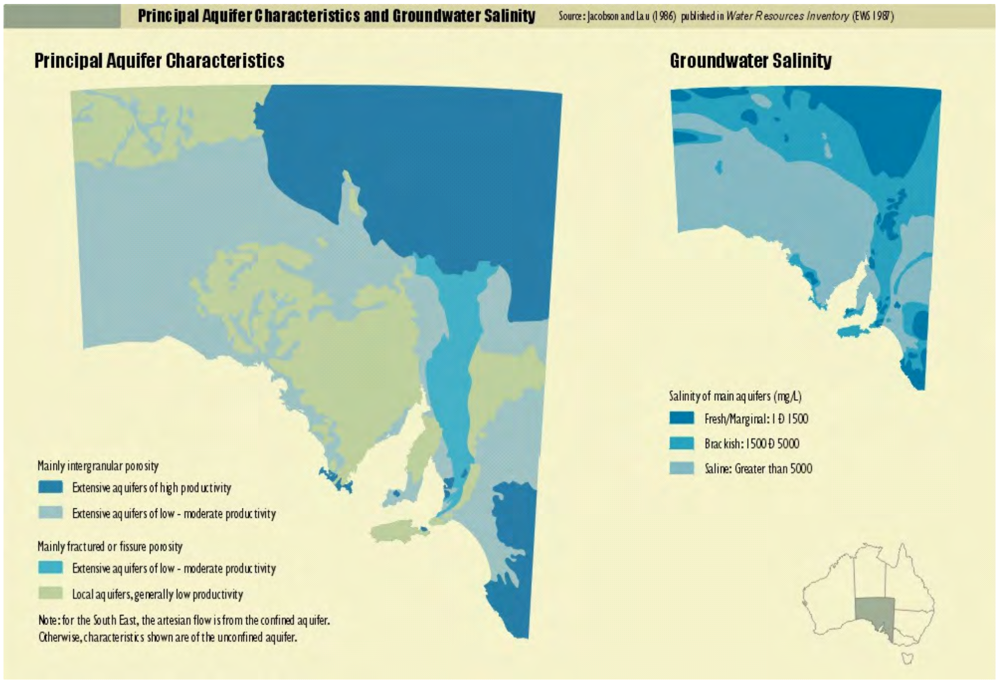


**Figure 52 Principal Aquifer Characteristics and Salinity (GSA 1999)**

The South East has the largest supply of good quality groundwater (part of the Otway Basin), but as with the River Murray, this resource spans state borders (refer to Figure 51). The Great Artesian Basin (GAB) covers most of the eastern half of the arid areas of South Australia, supporting unique ecosystems of national and international significance and the mining, grazing and tourism industries of the region (refer to Figure 51). The deep, confined aquifers of the GAB provide reliable water supplies of good quality and pressure over a wide area and often where there are no reliable alternatives.

### 5.4.2 Occurrence of Non-Traditional Water Resources

South Australia is highly urbanised with around 70% of its population (over 1 million) living in Adelaide and over 85% of its population living in urban centres concentrated within 100 km of the coast far from the arid north. An outcome of urban development is management and disposal of stormwater and sewage effluent, commonly referred to as '*urban wastewaters*'. The volume of urban wastewaters grows in proportion to the size of the urban centre. Treated wastewater effluent and untreated stormwater have historically been discharged into the sea or other major water body.

Natural ecosystems have some capacity to cope with changes in the flow pattern and pollutant load brought about by urbanisation, but high density urban centres produce waste streams that are too concentrated to be assimilated and cause environmental damage. Regardless of the pollutants present, it is possible to treat urban wastewaters to any required standard, thereby adding stormwater and treated effluent to the collection of potential water resources.

### 5.4.2.1 Stormwater

South Australia's urban areas have a significant influence on the quantity and quality of runoff compared to natural (pre-development) catchments. The quantity of water shed from an urban catchment is a function of prevailing climate, the intensity of rainfall, geology, topography, degree of imperviousness, and stormwater drainage practices. During its passage, stormwater collects contaminants from urban surfaces such as roads, roofs, paths and gardens. Consequently, stormwater can be polluted with contaminants, fine particles and dissolved materials (micro-pollutants) as well as litter and vegetation (gross pollutants) and deposits them into rivers and coastal waters without undergoing any treatment. While the use of stormwater can be complicated by the intermittent nature of rainfall and variable quality of runoff, it can be managed using methods developed for conventional surface water resources.

### 5.4.2.2 Treated Effluent

Sewage is a by-product of urban water use. Treated effluent is a reliable source of water in terms of quantity and quality, which are both relatively stable for a given system in contrast to stormwater. Consequently, management of treated effluent resources is different from conventional water resources (surface water and groundwater) because it is continuously generated and when it must be stored or disposed of in some manner it cannot be used immediately.

Tougher standards for discharging effluent into some South Australian waterways has led to improvements in the quality of that water to the point where those standards are on par with or better than the quality of the water required for many industrial, domestic and irrigation purposes. Effluent can be quite salty and so it is generally not appropriately used in areas with salinity problems.

The greatest volumes of effluent are found in large urban centres. However, it is typically located in low lying areas and requires pumping to deliver water where it is needed. The associated distribution and storage costs on top of the treatment costs frequently combine to be more expensive than existing reticulated water supplies. Factors such as pattern of demand, quality required, level of regulation on use and access to economical alternatives limit the viability of water reuse.

### 5.4.2.3 Seawater

Seawater can be used to provide a reliable water supply in places where conventional water resources, ie. surface water and groundwater is limited or unreliable. Seawater can be desalinated to provide potable (drinking water) quality by removing salt through a treatment plant located on the coast. South Australia has a large length of coastline and over 85% of its population is concentrated within 100 km of the coast. The sea can be seen as an abundant resource with a seemingly infinite quantity of water available located close to the vast majority of people.

Example 28 below describes the first location in South Australia where seawater has been developed for use at Penneshaw on Kangaroo Island (SA Water 1999d).

## Example 28 Seawater Desalination: Penneshaw, South Australia

*In July 1998 the South Australian Government approved a $3.5 million project to improve the quality and reliability of water supply for Penneshaw on Kangaroo Island through the construction of an innovative seawater desalination plant. The reverse osmosis plant produces up to 250 kL of freshwater daily. The project included a major new storage facility and other ancillary works to transfer desalinated water into the existing distribution system which serves the town. Construction of the plant is complete and the facility was commissioned in late 1999.*

**Figure 53 Penneshaw Desalination Plant: Site before construction**

**Figure 54 Penneshaw Desalination Plant: Site after construction**

*Source: SA Water 1999c*

A proposal for a second seawater treatment plant in South Australia at Cathedral Rocks on Eyre Peninsula where conventional water resources are limited is under consideration (Kilmore *pers comm*. 2004). However, seawater desalination on any scale is an expensive option to increase total water supply in comparison with other water resources. Nevertheless the option remains attractive, particularly if the energy needs can be met using sustainable power from solar or wind sources (COA 2002).

### 5.4.3 Summary of Water Resource Quantity& Use

South Australia's major water resources in terms of fresh, marginal and brackish water (limited to sustainable yield) and the current level of use are summarised in Table 23. It is interesting to note that the potential of seawater as a resource is not included in the summary for South Australia.

**Table 23 Total Water Quantity Summary for South Australia**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| River Murray surface water (RM) | 700 | 600 |
| Surface water resources (SR) | 220 | 140 |
| Groundwater resources (GW) | 1450 | 465 |
| Stormwater resources (SW) | 125 | 25 |
| Treated effluent (TE) | 115 | 20 |
| Seawater resources (SEA) (1) | Not assessed | <0.1 |
| **State Estimate (rounded)** | **2610** | **1250** |
| | | ≈48% |

Notes:
(1) Seawater desalination plant at Penneshaw

*Source: State Water Plan (2000)*

Despite being a dry State, South Australia, does appear to have ample total water for its present needs with the current total use being less than 50% of the sustainable water use level. Even when taking account of the projected increases in water use, South Australia has water resources available to meet its future demands, although they might not be located in close proximity to need. For example, it appears that there is significant scope to increase the level of groundwater use to meet needs in South Australia. However over 50% (ie. 750GL) of the unused groundwater resource occurs in shallow, unconfined aquifers in the South East. Among other things, the geographical location of this vast water resource makes it difficult to access.

Similarly, in some localised areas the current amount of water used exceeds the available resource. For example, in the Adelaide & Mount Lofty Ranges the current use of local surface water exceeds the sustainable use limit by 15%. In these cases, the resource is either being depleted (used above the sustainable limit) or additional water is being imported from another resource to meet the demand. As a result, a number of surface water and groundwater resources have been included in water resource legislation, which imposes administrative arrangements to manage water extraction from these areas within sustainable limits (GSA 2000). There is limited scope for further development of these prescribed water resources which makes them very valuable.

Appendix 7 provides an overview for each region of the water resources and level of use compared to the estimated sustainable use limit.

There is significant scope to increase the level of use of stormwater (see Table 24) and treated effluent (see Table 25) resources. Currently, only a small fraction (less than 20%) of these '*urban wastewaters*' are used in South Australia. It is clear that a majority of these urban water resources are generated and available in close proximity to urban centes, particularly in Adelaide. Some of these opportunities have been made real in both Adelaide and smaller urban centres throughout the State.

**Table 24 Summary of Stormwater Resources in South Australia**

| Water Resource Management Region | Use Limit GL/y | Use GL/y |
|---|---|---|
| Adelaide & Mt Lofty Ranges | 110 | 21 |
| Murray-Darling Basin (SA) | 4 | <1 |
| South East | 5 | 2 |
| Mid North | 4 | <1 |
| Far North | <1 | <1 |
| Eyre Peninsula | <1 | <1 |
| Kangaroo Island | <1 | 0 |
| State Estimate (rounded) | 125 | <25 |
| *Source: State Water Plan (2000)* | | ≈20% |

**Table 25 Summary of Treated Effluent Resources in South Australia**

| Water Resource Management Region | Use Limit GL/y | Use GL/y |
|---|---|---|
| Adelaide & Mt Lofty Ranges | 79 | 17 |
| Murray-Darling Basin (SA) | 4 | 1 |
| South East | 4 | <1 |
| Mid North | 9 | 1 |
| Far North | 18 | <1 |
| Eyre Peninsula | <1 | <1 |
| Kangaroo Island | <1 | <1 |
| State Estimate (rounded) | 115 | <20 |
| *Source: State Water Plan (2000)* | | ≈18% |

Changing environmental values and technological developments have created major opportunities for the development of these resources for beneficial use and thereby reducing the pollution caused by wastewaters. If the volume of water not currently being used could be harvested cost effectively, South Australia would be in a position to support economic development and population growth. Taking on sustainable new directions in water resources management is one of the necessary steps towards realising this potential (GSA 1995).

## 5.5 WATER INFRASTRUCTURE

The story of the provision of water services in South Australia, including water supply, wastewater, and stormwater services, has been a triumph of adaptation and experimentation, in the face of disease, engineering trial and error and changing public attitudes (Hammerton 1986). Early water technology of South Australia was largely derivative, but it was characterised by skilful adaptation, which was essential for the survival of the first settlements (AATCE 1988). This spirit of adaptation and striving for improvement has persisted and deserves consideration in the planning and development of water harvesting and reuse projects in the country towns of South Australia today.

### *5.5.1 Historical Background*

Settlement in South Australia in 1836 was unusual in that, unlike the other colonies, it was settled by free people and the colony had no financial backing from the British government. The first permanent European settlers came from a green land, with rivers flowing throughout the year with good quality water and with no extreme variations between summer and winter flows. They brought a corresponding sense of water values to Australia, not realising that Australia was a very different land to that with which they were familiar (AATCE 1988). For a time, early water technology, imported largely from the United Kingdom, proved to be inadequate.

The development of natural water resources in South Australia has been characterised by four periods of growth (Hamerton 1986; EWS 1987) summarised below and described in more detail in Appendix 6.

| **Period** | **Summary Description** | ***Appendix Heading*** |
|---|---|---|
| • 1836-1900 | Years of early settlement and agricultural expansion, in which settlers attempted to come to terms with the variable climate. | *Survival of a Colony* |
| • 1901-1945 | A time when regional development made growing demands which where met by the development and management of local water resources and the construction of water reticulation, river regulation, and drainage schemes. | *Watering the State* |
| • 1946-1965 | The post-war period, in which the heavy demand for water made by an increasingly industrialised Adelaide led to the development of often remote water sources. | *Watering the State* |
| • 1966-1990 | A time of transition from unconstrained development of available water resources to careful water resource management. | *Improving Water Quality* |

The provision of water infrastructure by the State government was often used to support regional development in rural and remote South Australia.

### *5.5.2 State Government (Public) Water Supply Infrastructure*

South Australia's major natural water resources are often remote from urban and industrial demand centres (GSA 1999). Consequently, as demands outstripped local resources and as new parts of the State were settled, major pipelines were constructed to transport water to the demand centres. Today, with the exception of a few small or remote communities (ie. comprising about 2% of the State's population), the State government maintains responsibility for provision of reticulated water supplies across the State.

#### 5.5.2.1 Major Water Supply Systems

Two major water supply infrastructure systems– the *River Murray System* and the *Eyre Peninsula System* shown in Figure 55 – provide a reliable water supply to a large majority of urban and rural South Australians. Despite the complex and far reaching major pipeline systems, a number of rural and remote communities rely on groundwater or small local dams. These independent self contained water supply systems are provided by State government, Local government or privately.

Source: Draft State Water Plan (1999)

**Figure 55 Major Water Supply Systems South Australia (SWP 1999)**

Water from the River Murray is supplied around the State through five major pipelines detailed in Table 26 (below). Adelaide is supplied by the Mannum-Adelaide and Murray Bridge-Onkaparinga pipelines. In a normal year, Adelaide derives 60% from the local Adelaide Hills catchment and 40% of its water from the River Murray (CSIRO 2001) and in dry years, the reliance on the Murray water can increase to as much as 90% of needs (GSA 2000; Marohasy, 2003). Two pipelines take water from Morgan to the northern Spencer Gulf industrial towns of Port Pirie, Port Augusta and Whyalla, with a further line north to Woomera. With some 90% of their water coming from the Murray, these towns and their industries would not exist without the pipelines. Two other pipelines, Swan Reach-Stockwell and Tailem Bend-Keith, serve large rural areas of the state. In August 2005, the approval of the Iron Knob to Kimba Pipeline was announced.

**Table 26 Major River Murray Pipelines in South Australia**

| Major Pipelines | Length (km) | In Service | Capacity (ML/day) |
|---|---|---|---|
| **Adelaide & Mount Lofty Ranges** | | | |
| • Mannum-Adelaide | 67 | 1954 | 200 (1) |
| • Murray Bridge-Onkaparinga | 48 | 1973 | 163 |
| **Regional Areas of South Australia** | | | |
| • Morgan-Whyalla (dual pipes) | 360 | 1944 & 1964 | 66 |
| • Swan Reach-Stockwell | 53 | 1969 | 24 |
| • Tailem Bend-Keith | 143 | 1969 | 11.5 |
| • Iron Knob – Kimba (2) | 90 | By Feb 2007 | 6.3 |

*Source: SA Water (1999d)*

(1) *Limited of gravity flow to Summit Storage. 260 ML/day when gravity flow is supplemented by Millbrook Pumping Station*

(2) *This pipeline is an extension of Morgan – Whyalla pipeline announced in 2005. When completed it will connect to the Eyre Peninsula water supply to the River Murray.*

Clearly, a great proportion of South Australia is reliant on water from the River Murray and the water sharing agreement with upstream states which guarantees a minimum flow throughout the year. South Australia's extractions from the River Murray amount to about 5% of flow in the river, made up of 1% for water supply and 4% for irrigation (Mike Smith, DWLBC *pers comm*. 2005).

The Eyre Peninsula has been served by a separate major pipeline system which relies on storage of surface water in the Tod Reservoir, and significant groundwater supplies located near Port Lincoln (SA Water 1999d). While the groundwater basins have been vital in allowing development in the region (supplying up to 70% of reticulated water demand), recent studies show that availability of water is very dependent on the rate of recharge during the previous season (SWP 2000). Consequently, extractions are being managed to best fit the varying resource capabilities and in some cases reduced to below sustainable yield to allow aquifer recovery. However, under a current initiative, a new section of pipeline is being constructed to link the River Murray System with the Eyre Peninsula System between Whyalla and Kimba.

Despite the additional reliance on River Murray by transferring water into the Eyre Peninsula System, South Australia has not over-allocated the water available from this resource. However, demand is fast approaching defined sustainable limits of use. In the near term South Australia will be obliged to adopt water conservation measures (reduce demand for selected purposes, modify management of existing systems to enhance availability of water) and develop and treat other sources of lower quality water. Water harvesting and reuse will become an attractive option for either extending available water supplies to support increased population or to reduce dependence on the River Murray.

### 5.5.2.2 Major Surface Water Storages (Reservoirs)

Highly variable rainfall, long dry summers and heavy dependence on water originating outside South Australia has resulted in a large system of reservoirs to store, regulate and distribute water for urban and rural communities. The main function of the reservoirs is to compensate for fluctuations in natural catchment runoff or in demand for water (ie. provide a buffer during peak usage periods), act as a balancing storage for River Murray water, and to raise the level of water upstream to enable water to be diverted into metropolitan and country water supply systems (ie. service reservoir). The State government operates and maintains 16 large dams as part of the major water systems shown in Table 27.

**Table 27 Major Surface Water Storage (Reservoirs) in South Australia**

| Surface Water Storage | CI | Year in Service | Capacity (ML) | Water Area(1) (ha) | Catchment Area | |
|---|---|---|---|---|---|---|
| | | | | | Natural (km2) | By Diversion (km2) |
| **Adelaide & Mount Lofty Range** | | | | | | |
| Barossa | 3 | 1902 | 4,510 | 62 | 7 | 228 (South Para) |
| Happy Valley | 4 | 1896 | 12,700 | 188 | 63 | 388 (Mt Bold) |
| Hope Valley | 4 | 1872 | 3,500 | 60 | - | 522 (KC & Millbrook) |
| Kangaroo Creek (KC) | 3 | 1969 | 19,000 | 95 | 289 | 233 (Millbrook) & River Murray |
| Little Para | 4 | 1979 | 20,800 | 125 | 83 | River Murray |
| Millbrook | | 1918 | 16,500 | 171 | 38 | 195 River Torrens River Murray |
| Mount Bold | 2 | 1938 | 45,900 | 308 | 388 | River Murray |
| Myponga | 2 | 1962 | 26,000 | 350 | 20 | - |
| South Para | 3 | 1958 | 45,000 | 400 | 228 | River Murray |
| **Reservoirs for Regional Areas** | | | | | | |
| Baroota | 5 | 1920 | 6,100 | 63 | 136 | - |
| Beetaloo | 5 | 1890 | 3,700 | 38 | 48 | - |
| Blue Lake (2) | 2 | c1880 | 36,000 | 61 | - | Groundwater |
| Bundaleer | 5 | 1903 | 6,300 | 80 | 1,567 | - |
| Hindmarsh Valley (3) | 2 | 1917 | 420 | 10 | 9 | Victor Harbor WWTP |
| Middle River | 3 | 1968 | 470 | 11 | 101 | - |
| Tod | 4 | 1922 | 11,300 | 134 | 29 | 159 |
| Warren (4) | 3 | 1916 | 4,770 | 105 | 119 | River Murray |

*Source: SA Water (1999d) & Historical Accounts of Dam Construction*

(1) *At Full Supply Level*
(2) *This is a volcanic crater which contains groundwater ie. not a constructed water storage.*
(3) *Taken out of service in 1993 when Myponga WTP came on line. Recommissioned in 2005 as over summer storage for treated effluent storage from Victor Harbor WWTP.*
(4) *Taken out of service in 1998 when Swan Reach WTP came on line. Barossa Infrastructure Limited (private) uses it as a balancing storage for irrigation system.*

The system of major water storages combines with the major water supply pipelines to secure a reliable water supply system for South Australia. However, more than half of South Australia's major water storages are over 75 years old and in some cases do not meet modern engineering standards. Consequently, the State government has embarked on a significant capital works program to upgrade the safety of these assets.

#### 5.5.2.3 Filtered Water Services

Water quality has undoubtedly been a public issue in South Australia for many decades. The priority of initial water infrastructure was to encourage state development (ie. extensive infrastructure for the capture, extraction and widespread distribution of adequate water supplies). Once the majority of this infrastructure was in place, funding was gradually made available to improve water supply quality. The quality of reticulated water supplied to communities in South Australia varies depending on the primary source of water; River Murray, local surface runoff, or local groundwater. Unfiltered supplies in South Australia, particularly from the River Murray, have always had problems associated with physical appearance, taste and odour (Heyworth *et al.* 1998). By comparison, some groundwater systems, such as Mt Gambier and Pt Lincoln, already comply with Australian Drinking Water Guidelines (ADWG) and do not require filtration.

From about 1975 to 1992, funding was directed to the more cost effective water filtration projects that would benefit the largest proportion of the population (Hudson 1990). At the completion of this program, 85% of South Australians benefited from filtered water (SA Water 1999d). The government's next goal was to extend the delivery of filtered water to residents living outside the metropolitan area. Until 1997, the only area outside Adelaide to receive filtered water was the Iron Triangle from Morgan.

The provision of filtered water services to rural South Australia faced problems including those associated with the distance, the small size of the communities, and lack of good quality local sources of water (Heyworth *et al*. 1998; SA Water 1999d). Nevertheless, by the year 2000, despite the State's dispersed population and poor quality source water, 95% of South Australians were supplied with filtered water which meets or exceeds standards set by the ADWG (SA Water 1999d). This achievement was made possible by the construction of ten regional water filtration plants under a public-private partnership (PPP) agreement. The PPP plants serve 100,000 South Australians, in more than 90 rural communities.

The remaining 5% of the population, predominately located in country areas, receive reticulated water that is generally not sufficiently protected against microbiological contamination. A small proportion of country communities also receive water with some chemical concentrations exceeding ADWG values (SA Water 1996). Where microbiological problems persist in small systems, the guidelines list the options as either improving performance (ie. introducing or upgrading barriers) or declaring the water supply non-potable with appropriate notification of consumers and casual visitors. Many of these systems are likely to require a level of financial expenditure that will be difficult to justify on a purely economic basis.

The water filtration plants that serve metropolitan and country South Australia are listed in Table 28 (below). The water treatment facilities listed above demonstrates that continual improvement of South Australian water quality has been a major commitment of the State government for many years.

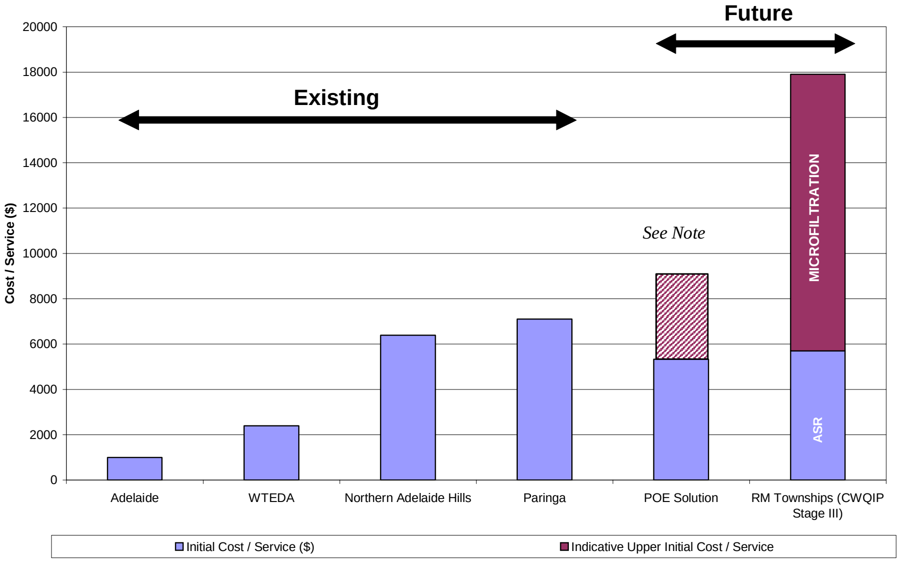
**Table 28 Water Treatment Plants Serving South Australia**

| Water Filtration Plants | In Service | Capacity (ML/day) | Delivery |
|---|---|---|---|
| **Adelaide & Mount Lofty Ranges** | | | |
| • Hope Valley | 1977 | 273 | SAW |
| • Anstey Hill | 1980 | 344 (1) | Design by Consultant/SAW |
| • Barossa | 1982 | 160 | SAW |
| • Little Para (2) | 1984 | 160 | SAW |
| • Happy Valley | 1989 | 850 | SAW |
| • Myponga | 1993 | 50 | D&C Contract |
| • Mt Pleasant | 2001 | 2.5 | Research plant, D&C Contract |
| **Location of Plants Serving Regional South Australia** | | | |
| • Morgan | 1986 | 200 | Design by Consultant/SAW |
| • Middle River | 1998 | 3 | Contract |
| • Penneshaw (3) | 1999 & 2004 | 0.3 | Contract, Upgrade SAW |
| • Summit Storage | 1997 | 71 | WTEDA (4) |
| • Swan Reach | 1998 | 90 | WTEDA |
| • Waikerie | 1998 | 4 | WTEDA |
| • Barmera | 1998 | 5 | WTEDA |
| • Mannum | 1998 | 4 | WTEDA |
| • Berri | 1998 | 8 | WTEDA |
| • Renmark | 1999 | 9 | WTEDA |
| • Tailem Bend | 1999 | 28 | WTEDA |
| • Murray Bridge | 1999 | 38 | WTEDA |
| • Loxton | 1999 | 14.5 | WTEDA |

*Source: SA Water (1999d) & Geoff Kilmore pers. comm. (2005)*

(1) *Limited by supply from Mannum-Adelaide Pipeline*
(2) *Regularly taken off line in summer*
(3) *Seawater desalination plant. To meet specified values new RO plant installed.*
(4) *WTEDA refers to the BOOT water treatment plants constructed by Riverland Water.*

Of the remaining unfiltered public water supply systems, the deficiencies relative to the guidelines are primarily a consequence of the poor quality, limited availability of source waters and prohibitive treatment costs. There are many challenges to successfully improving water quality (ie. introducing or upgrading barriers) in these small water supply systems, however the fundamental impediment is cost. Figure 56 illustrates that the cost of providing conventional centralised water treatment to the remaining unfiltered supplies in South Australia will be two to three times more expensive, on a cost per service basis, than previous schemes (SA Water 2003).



Note: *POE systems have higher operating and maintenance costs than a community filtration facility. If the NPV of these additional costs is taken into account, the equivalent cost/service for a POE system is around $9 000/service.*

*WTEDA is refers to the Water Treatment Plants constructed by Riverland Water under contract*
*CWQIP is the country water quality improvement program*

*SA Water (2003)*

**Figure 56 Cost of Community Future Filtration Plants (SA Water 2003)**

The task for SA Water (ie. a State government enterprise), in conjunction with the South Australian Department of Health, will be to determine an appropriate future management strategy for these systems (SA Water 2003). As the existing public water infrastructure enters the era of asset replacement an opportunity to embrace new ideas about the ideal form for water infrastructure and service delivery may be presented.

### 5.5.2.4 Non-Potable Water Supplies

Many South Australian townships do not conform to health and aesthetic drinking water standards and their water supplies are declared as ‘non-potable’ (ie. not for drinking) in accordance with the ADWG (SA Water 2005). In these circumstances, signs at the town entrance, at public facilities, and accommodation establishments are used to notify consumers and visitors, however such measures may not prevent water from being consumed by visitors. Poor water quality and quantity diminishes the capacity of a community (or town) to develop related services for its residents, tourists, and industry.

Table 29 lists the small State government water supply systems (ie. serving less than 1,000 people), and miscellaneous off-takes from major pipelines, that have been declared ‘non-potable’ as at August 2005.

**Table 29 Towns with Government Provided Non-Potable Water Supply**

| Town | Water Management Region | Climate Index | Services (No.) |
|---|---|---|---|
| Blinman | Far North | 8 | 21 |
| Cockburn | Far North | 11 | 26 |
| Dutchman Spring | Mid North | 8 | 4 |
| Coonatto (Hammond) | Mid North | 10 | 23 |
| Mannahill | Far North | 10 | 11 |
| Marree | Far North | 20 | 83 |
| Marla | Far North | 20 | 47 |
| Olary | Far North | 10 | 10 |
| Oodla Wirra | Mid North | 8 | 10 |
| Oodnadatta | Far North | 21 | 74 |
| Saltia Creek | Mid North | 9 | 8 |
| South Creek | Mid North | 7 | 28 |
| Terowie | Murray-Darling Basin (SA) | 7 | 24 |
| Woolundunga | Mid North | 9 | 29 |
| Woolshed Flat | Mid North | 9 | 8 |
| Willowie | Mid North | 8 | 10 |
| Yunta | Far North | 9 | 51 |

*Source: SA Water, Vince Sweet pers. comm. (August 2005)*

All the towns with declared non-potable supplies have a declining permanent population of less than 200 people and are located in the Mid North and Far North regions of South Australia with a climate index of 7 or greater (ie. highly variable rainfall). For instance, during the 1880s the settlements Cockburn, Olary, Oodla Wirra, Terowie, and Yunta emerged to service steam trains along the railway. Subsequent changes in railway infrastructure (ie. standard gauge) have resulted in a decline in the population and function (EWS 1991a). The existing railway towns generally depend on rainwater tank collection and surface catchment dams to provide water for the town population. When this supply is deficient, water is carted from Peterborough (ie. between 80 and 235km) to supplement the supply (EWS 1991a). For these and other communities in similar circumstances the options are limited, however extensive water conservation education (ie. in-house water saving appliances and practices) and long-term demand management programs coupled with appropriate pricing structures will be necessary to contain the cost of providing water for essential purposes.

### 5.5.3 Non-State Government Water Supply Systems

In addition to the major water supply pipelines and independent country water supply systems provided by the State government, there are also a number of small non-state government and private water supply systems operated by local councils and boards (SA Water 1999). For example, the Roxby Downs Council and Coober Pedy Council operate and maintain the community reticulated water supply services. Such water supply systems were usually established in areas where the State government agency was unwilling to provide a service (Clark *et al*.1997). Typically, the high cost of water from these non-state government and private water supply schemes means that most property owners only use this water for domestic use (ie. an alternative water source is used for landscape irrigation, pastures and stock where these exist).

The processes for developing and managing a small local water supply are the same as the public system but carried out to a different level of service. However, the record of past small water supply companies in South Australia has not always been good. Many collapsed and some had to be taken over by the State government at considerable expense (Clark *et. al*.1997). Several companies have endured however, and have provided a reliable level of service. It should also be noted that many utilities supply just one town while others such as the Alexandrina Council manage water supply to multiple towns. Part II contains information on the operation of several non-government water supply services for a number of South Australian towns.

## 5.6 WASTEWATER INFRASTRUCTURE

The average South Australian family flushes nearly 40kL of water down the toilet every year. SA Water provides conventional wastewater systems to metropolitan and country areas that serve around 80% of the State's population (SA Water 2000). The majority of country towns rely on septic tank effluent disposal schemes (STEDS) managed by Local government and some towns are not provided with community wastewater services. In South Australia, STEDS provide approximately 10% of all public wastewater services (LGA 2003). Less than 25 country towns in South Australia have conventional sewerage services with a sewage treatment plant.

The conventional method of effluent disposal from large urban centres (ie. Adelaide) has been by dilution in natural bodies of water. More than 75% of urban wastewater produced State-wide continues to be disposed of to the ocean or other water courses or evaporation. Under the pressure of changing environmental values and technological developments, this untapped resource represents one of the largest potential sources of '*new water'* in South Australia. Throughout the State, communities are planning new or expanded water reuse schemes for beneficial use and in so doing can reduce the pollution load of wastewater on natural water bodies.

### *5.6.1 Adelaide Metropolitan Wastewater Services*

#### 5.6.1.1 Historical Background

Wastewater is an inevitable product of human settlements, necessitating treatment, frequently of a complex nature, in the interest of public health and the environment (AATCE 1988). Adelaide's first night soil removal firm appeared in 1848, twelve years after settlement of South Australia (Hammerton 1986). The first sewerage drains were laid in the city in 1865-66 and carried sewage and stormwater to the River Torrens (Argue 1991). The urban development within the Torrens catchment contributed to a growing pollution problem that impacted on the mortality of the early settlers. By the 1870s, people came to agree that public health was government business, and the government should provide deep drainage for Adelaide (Hammerton 1986).

Argue (1991) considers the fortuitous visit by Mr William Clark, a British engineer, to Adelaide in 1877 as one of the most important events in the colony's brief history. To avoid the problems experienced in Britain, Clark recommended that sewage and stormwater be handled in separate systems. He also devised a sewerage network of deep drains to collect and convey sewage to a sewage farm at Hindmarsh with effluent from the farm discharged via a long channel to the sea (Argue 1991). From January 1881, all sewerage that had previously run into the Torrens was taken by main sewer to the first sewerage farm at Islington.

The history of the provision of water infrastructure and services in South Australia is described in more detail in Appendix 6.

#### 5.6.1.2 Metropolitan Major Wastewater Systems & Treatment Plants

Adelaide was the first capital city in Australia to have a waterborne sewerage system (EWS 1992). By 1965, nearly 100% of Adelaide was served by sewerage whereas no other Australian city had more than 75% of its population served by sewerage (Hammerton 1986). The sewerage system serving the city operates essentially by gravity flow with pumping kept to a minimum. The physical features of Adelaide and its environs mean that the population could be served by four major sewerage systems and wastewater treatment plants (see Table 30).

**Table 30 Metropolitan Wastewater Treatment Plants (WWTP)**

| Treatment Plant | Equivalent Population Served | Plant flow (ML/d) | Constructed / Upgraded (Year) | Effluent Reuse (%) |
|---|---|---|---|---|
| Bolivar | 1 300 000 | 130 | 1964 & 1969 | 25% |
| Glenelg | 200 000 | 55 | 1932,42,65 & 75 | 10% |
| Christies Beach | 135 000 | 27 | 1971 & 1981 | 20% |
| Port Adelaide (1) | 125 000 | 35 | 1935 & 1954 | 0% |

(1) In 2005, the Bolivar High Salinity plant replaced the Port Adelaide WWTP.

*SA Water (1999d) & effluent reuse information courtesy of Grant Lewis (2004)*

In just over 150 years, Adelaide's population has grown to 1,000,000 and produces a large volume of treated effluent each day. In addition, to sewage from households, the wastewater system also collects '*trade waste*' generated by industry, business, and manufacturing processes. Trade waste can contain high levels of grease, dissolved solids (a measure of salinity), heavy metals or heavy organic loads. Treated effluent from the major WWTPs can be used for irrigation and industrial purposes, subject to limitations imposed by public health considerations and the presence of dissolved salts and other minerals (EWS 1992).

Today, the metropolitan plants treat some 90% of the total wastewater generated in South Australia (SA Water 1999d). Reusing the treated effluent means less water leaves the treatment facilities to end up in ocean outfalls or river systems. The water authority in conjunction with other government departments and private organisations, have tried to promote the use of treated effluent wherever practicable, particularly for irrigation. Thus, South Australia has a strategic interest in the reuse of wastewater.

#### 5.6.1.3 Long Tradition of Treated Effluent Reuse

South Australia can claim a longstanding practice of treated wastewater effluent reuse. As early as 1933, effluent from the Glenelg WWTP was used for lawn and shrub watering at the facility itself (Phillips 1977). Since 1958, the use has been extended by distribution schemes capable of supplying up to 90% of the dry weather flow from the works (Strom 1985). Effluent from Glenelg WWTP is still used in the following areas: three 18-hole and one 9-hole golf courses and a golf driving range, two caravan parks, a bowling green, tennis courts and several sporting fields, the surrounds of the Adelaide airport, and public parks along the Glenelg foreshore and the Patawalonga foreshore.

South Australia has a number of more recent water reuse irrigation projects. Treated effluent from the Bolivar and Christies Beach WWTPs is available for agricultural and horticultural purposes through the privately owned geographically limited Bolivar-Virginia and Christies Beach-Willunga pipelines schemes. The viability of these infrastructure projects was dependent on the presence of several large volume water users with stressed and/or limited local water resources close to the respective treatment plant. The viability of the Bolivar project was reliant on substantial financial contribution from the Federal and State governments, ie. construction of the DAFF facility to achieve Class A effluent (Grant Lewis *pers. comm*. 2004). The Christies Beach scheme that supplies Class B effluent to its customers under individual contracts was financially viable in its own right. No financial support from the State was needed.

At the other end of the spectrum are the '*pioneering*' dual reticulated water supply systems to serve residential areas. Two such initiatives have recently implemented in Adelaide. Firstly, in 1998 the 62 allotments in the New Haven Village development were provided with both a potable and a non-potable water service, however since August 2002 both reticulation systems have supplied potable water to the households (see case study in Part II). The second reticulated dual water supply initiative is the 3,400 allotment development at Mawson Lakes. In 2005, the non-potable water supply system was commissioned.

**Figure 57 Mawson Lakes - Dual Water Supply to Households (Marles 2005)**

At a practical level, these ‘pioneering’ dual reticulation sites demonstrate that dual water supply systems are functional, however they have a different risk profile from traditional supply systems and considerably higher capital and operating costs (Rabone 2005). At the present time in Adelaide, developers that undertake to provide a dual water supply system to allotments can not be competitive with traditional developments. Critical analysis of these full-scale operational models - especially institutional, technological, social, financial, and environmental dimensions - compared with traditional approaches, will advance the design of sustainable urban water services for Adelaide into the future. From these projects a great deal can be learned and applied to advance the attaining of increased sustainability in the provision of water services water in South Australia.

#### 5.6.1.4 Policy for Effluent Reuse from Major WWTP

SA Water has a long term goal of achieving 50% reuse of wastewater in South Australia (SA Water 2000). Accordingly, SA Water has adopted a policy of reusing treated effluent, wherever this is practical, to minimise discharge of nutrients and other contaminants from wastewater treatment plants into receiving waters, rather than upgrade plants for biological nutrient reduction and continued discharge to receiving waters (Sickerdick & Desmier 2000). In 2002, SA Water’s Environmental Policy, included a target of achieving 30% effluent reuse by 2005. Large-scale water reuse initiatives that take treated effluent from the major metropolitan WWTP would play a significant role. However, the time taken from inception to commissioning of the water reuse schemes has been much longer than planned.

Figure 58 shows a clear increase from 7.6% in 1995/96 to nearly 20% in 2004/05 in the level of water reuse from the major metropolitan WWTPs. The marked increase in level of effluent reuse from 1999/2000 coincides with the commissioning of two large treated effluent schemes in 1999, being the Willunga Basin Pipeline taking effluent from Christies Beach WWTP and Virginia Pipeline Scheme taking effluent from Bolivar WWTP (Sickerdick & Desmier 2000). Both of these schemes will result in an increase in the production of high value irrigated produce which will lead to an increase in export earnings for South Australia. While the goal of 30% reuse was not achieved by 2005, SA Water continues to aim for 30% reuse of treated effluent by 2008 (revised date). A significant level of investment will be required to achieve this.

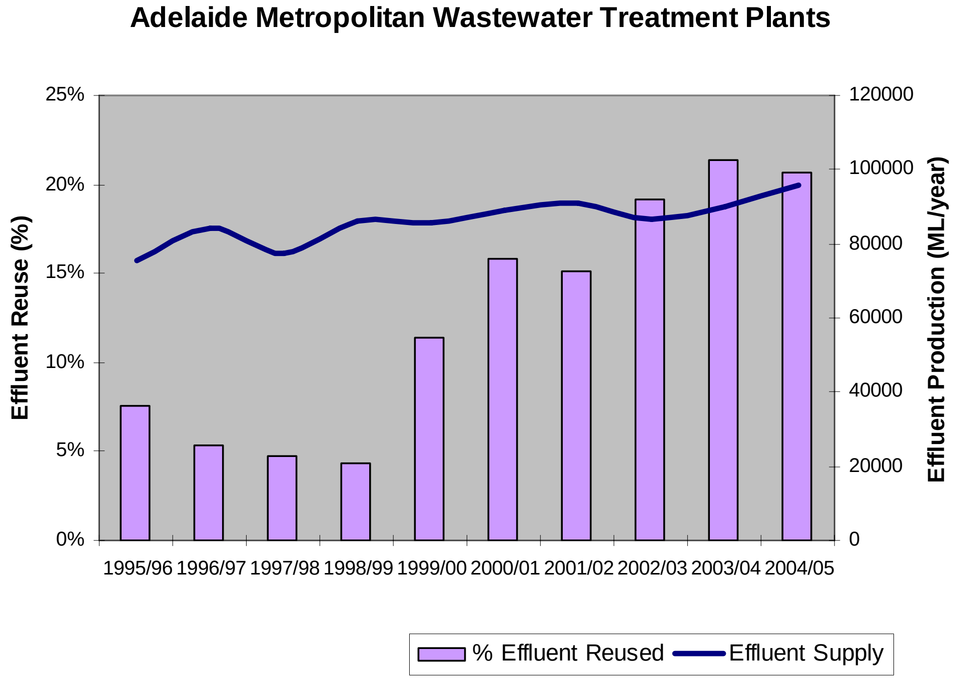


**Figure 58 Adelaide's Effluent Production & Reuse (SA Water 2003)**

Adelaide's annual effluent production is relatively stable, making effluent a reliable source of water in terms of timing (see Figure 58). However under the prevailing conditions in Adelaide, demand for irrigation water is seasonal and only required some of the time (ie. when it is not raining). The provision of adequate storage will become the critical design problem to achieving an ultimate 'idealistic' goal of zero discharge of treated effluent into the Gulf of St Vincent. While it may not be possible to eliminate all effluent discharges it would be worthwhile spending the time to work out how much of the effluent produced and treated can be recovered.

Treatment of wastewater to the extent where it would be entirely suitable for reuse as potable water in Adelaide remains a long way off. Such an approach poses a number of challenges from both the technical (ie. unknowns associated with treatment processes) and social perspectives (ie. health risk and aesthetics) which is likely to prevent it from being accepted by the community and public institutions in the near future (Rabone 2005). Such treatment remains a strategy that may be developed by Adelaide in the longer term.

### *5.6.2 Country Wastewater Services*

As with the provision of water supply infrastructure, funding was directed predominantly to the most cost effective projects. Towns with the largest populations, existing public health issues associated with individual septics or located within the water catchments, attracted more funding (Sickerdick *pers comm.* 2004). The Government's goal was to progressively extend the service to residents living outside the metropolitan area.

### 5.6.2.1 Conventional Sewerage Systems

In general, South Australian country towns have not been provided with conventional sewerage schemes. The first country town in South Australia to be served by conventional wastewater system was the original coalfield town of Leigh Creek in 1946. The State government has since provided conventional sewerage and wastewater treatment to the towns listed in Table 31.

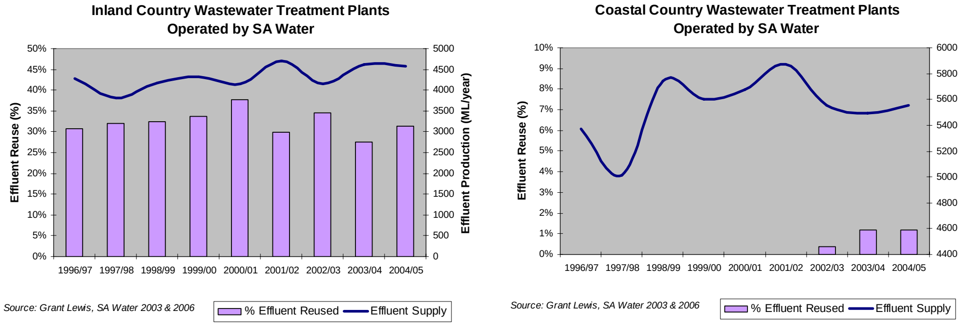
**Table 31 State Government Country Wastewater Treatment Plants**

| Treatment Plant | Clim. Index | Pop. served | Plant flow (ML/d) | Const. | Mains (km) | Effluent Reuse (%) |
|---|---|---|---|---|---|---|
| Aldinga | 3 | 3 500 | 1.2 | 1997 | - | 100% |
| Angaston | 4 | 1 900 | 0.30 | 1962 | 24.5 | 50% |
| Bird-in-Hand | - | 3 660 | 0.80 | 1965 | - | <5% |
| Finger Point (1) | 2 | 23 800 | 6.00 | 1989 | 294 | 0% |
| Gumeracha | - | 630 | 0.10 | 1965 | 10 | 100% |
| Hahndorf | - | 3 200 | 0.78 | 1977 | 42 | 0% |
| Heathfield | - | 6 000 | 1.05 | 1981 | 107 | 0% |
| Mannum | 7 | 1 600 | 0.39 | 1968 | 33 | 100% |
| Millicent | - | 5 360 | 2.23 | 1968 | 56 | 40% |
| Mount Burr | 2 | 510 | 0.13 | 1963 | 6.5 | 0% |
| Murray Bridge | 5 | 12 500 | 2.8 | 1970 | 134 | 100% |
| Myponga | 2 | 190 | 0.06 | 1963 | 6 | 100% |
| Nangwarry | - | 740 | 0.19 | 1963 | 7.5 | 0% |
| Naracoorte | 3 | 5 600 | 1.00 | 1961 | 66 | 0% |
| Port Augusta East (1) (2) | 11 | 8 000 | 2.46 | 1981 | 61.5 | 0% |
| Port Augusta West | 11 | 3 600 | 0.57 | 1977 | 47 | 50% |
| Port Lincoln (1) | 3 | 11 500 | 2.30 | 1994 | 157.5 | <10% |
| Port Pirie (1) | 7 | 16 000 | 3.61 | 1971 | 153 | 0% |
| Victor Harbor | 3 | 6 400 | 1.70 | 1972 | 177 | 10% |
| Whyalla (1) | 7 | 27 000 | 4.60 | 1966 | - | 0% |

(1) Coastal Country Wastewater Treatment Plants.
(2) Some reuse occurs

*SA Water (1999d) & effluent reuse information courtesy of Grant Lewis (2003 & 2006)*

The majority of these systems were designed and constructed when it was common practice for treated effluent to be discharged into the ocean, other adjacent natural water courses or to low lying areas for evaporation. Under the pressure of changing environmental values, a number of planned new or expanded water reuse schemes are being considered that will reduce the pollution load of wastewater on natural water bodies. Figure 59 shows the level of reuse achieved to from inland and coastal wastewater systems operated by SA Water.


Inland Country Wastewater Treatment Plants Operated by SA Water

Coastal Country Wastewater Treatment Plants Operated by SA Water

Source: Grant Lewis, SA Water 2003 & 2006

Source: Grant Lewis, SA Water 2003 & 2006

**Figure 59 Country South Australia Effluent Reuse (SA Water 2006)**

The average level of treated effluent reuse for regional inland communities is around 35% and has been steady for several years. By comparison, over the same period, significant amounts of treated effluent continue to be discharged to the marine environment for the coastal plants. This is because the salinity levels in the treated effluent make the water more difficult to reuse (Grant Lewis *pers. comm.* 2006). For example, hyper saline groundwater infiltration into the Port Pirie wastewater system prevents reuse without a desalination process. Upon the commissioning of the project to reuse effluent treated at the Whyalla WWTP in 2006, the level of effluent reuse from coastal plants should increase to 7% initially and then up to 12% when all available water is taken (Grant Lewis *pers. comm.* 2006).

In addition to those communities served by SA Water systems, Table 32 sets out the handful of country towns served by conventional sewerage systems where the infrastructure has been provided by local government or private enterprises. The level of reuse for these towns is a reflection of the need to optimise water use in arid regions. The design of the wastewater system included storage and reticulation for irrigation of recreation facilities and parklands.

**Table 32 Other Country Wastewater Treatment Plants**

| Treatment Plant | Climate Index | Equiv. Pop. Served | Plant flow (ML/d) | Const. | Mains (km) | Effluent Reuse (%) |
|---|---|---|---|---|---|---|
| Coober Pedy (1) | 19 | 2 000 | 0.25 | 1994 | - | 100% |
| Leigh Creek (2) | 14 | 1 500 | - | 1981 | - | 100% |
| Roxby Downs | 17 | 4 000 | - | 1986 | - | 100% |
| Woomera | 16 | 2 500 | 0.3 | 1947 | - | 100% |

(1) Limited conventional wastewater system to serve main commercial areas.
(2) Data refers to the existing township of Leigh Creek South not original township.

While there are a number of small communities throughout the State who have conventional wastewater services provided by other bodies, the vast majority of the population not serviced by SA Water are dependent on individual systems or linked to community septic tank effluent schemes (STEDS) operated by local government. STEDS differ from the conventional wastewater systems in that they are designed to accept septic tank effluent rather than raw sewage.

### 5.6.2.2 Septic Tanks Effluent Disposal Systems (STEDS)

Due to funding limitations, the pace of providing conventional sewerage systems to South Australian towns was slow. The provision of STEDS in South Australia has been a partnership between the State Government and Local Government in a cost sharing arrangement to speed up the delivery of sewerage services (LGA 2003; Palmer *et al.* 1999). Around 130,000 South Australian residents (or approximately 10% of the population) have their wastewater treated and their local environment and public health protected by STEDS (Lightbody & Endley 2002). Figure 60 shows the location of STEDS in operation within South Australia. The number constructed since 1962 exceeds a hundred in total.

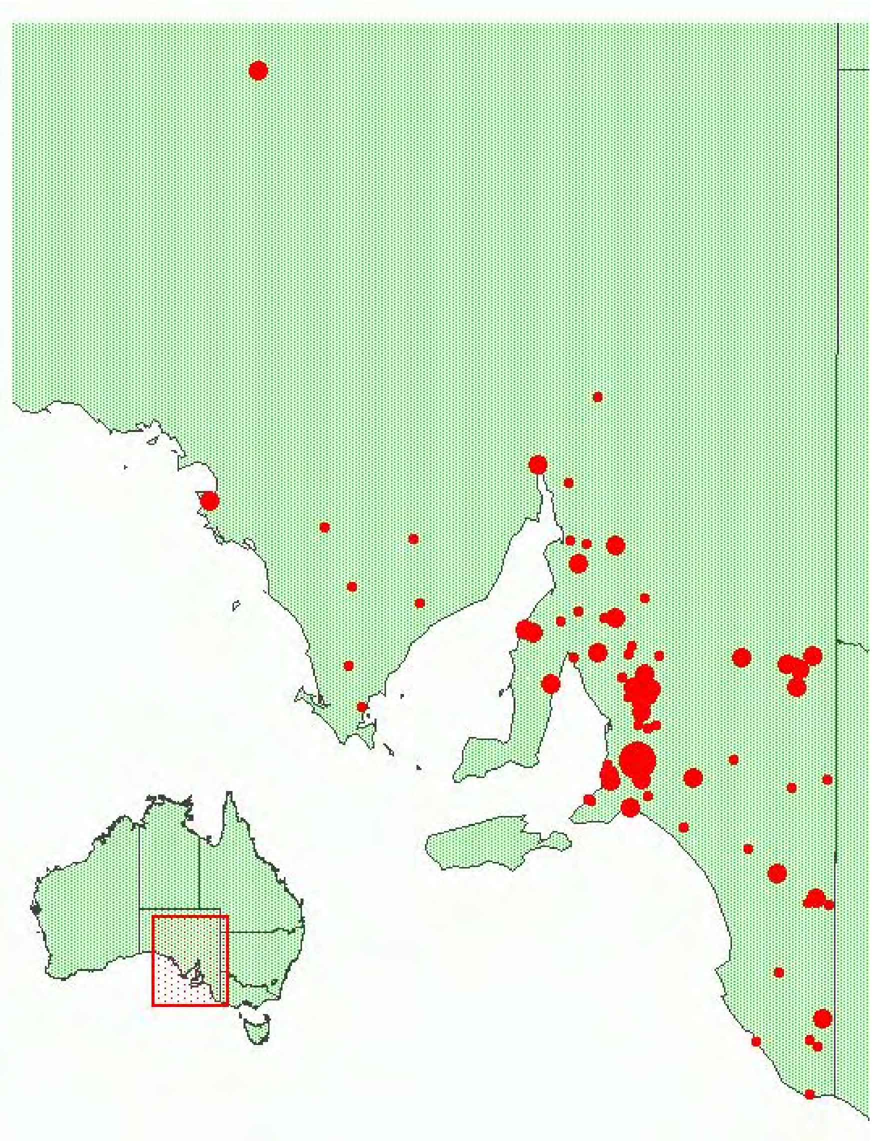


**Figure 60 Location of STEDS in South Australia (Neil Palmer *et al.* 1999)**

There is considerable public health, environmental, economic and community benefits from STEDS. A further 30 towns and communities (ie. around 68,000 people) currently meet the trigger criteria for connection to similar communal wastewater services (Lightbody & Endley 2002). There remains a substantial funding requirement to satisfy the expectations and demand for new STEDS, and also the replacement and upgrading of existing schemes.

Reuse is carried out at an increasing number of STEDS in South Australia. Even though the quantity of effluent is small, the use of this water reduces the demands on potable water during the hot and dry summers. Some South Australian towns that have practised reuse of treated effluent for irrigation for more than 30 years are listed in Table 33. More recent schemes have risen to over $5,000 per connection due to effluent reuse (Palmer *et al.* 1999).

**Table 33 Longstanding STEDS Reuse Sites in South Australia**

| Township | WRM Region | Climate Index | STEDS Const. | Reuse Purpose | Remarks |
|---|---|---|---|---|---|
| Barmera | Murray-Darling Basin | 9 | 1965 | Golf Course | Plus river water |
| Berri | Murray-Darling Basin | 8 | 1967 | Golf Course | Plus river water |
| Cleve | Eyre Peninsula | 5 | 1969 | Oval | Plus mains |
| Lameroo | Murray-Darling Basin | 5 | 1975 | Golf Course | Plus stormwater |
| Pinnaroo | Murray-Darling Basin | 6 | 1967 | Golf Course | - |
| Port Elliot | Adelaide & Mt Lofty | 3 | 1968 | Oval | Plus mains |

*Source: Phillips (1977) & Atlas of Water Reuse (EPA 1998)*

Traditionally, the total annual flow in STEDS was not collected and this has made it difficult to establish the total level of effluent reuse. For South Australia, more than 50% of the 18ML of STEDS effluent treated each day is estimated to be reused in agriculture and irrigation of sports fields, town commons and wood lots (Lightbody & Endley 2002). The proportion is expected to increase as all new schemes developed under the STEDS program include dedicated reuse facilities wherever feasible and investment in upgrading of existing STEDS often includes reuse facilities for environmental reasons (Lightbody & Endley 2002).

## 5.7 STORMWATER SYSTEMS

All runoff involves water flowing across the ground. Land use and activities within catchments affect the quantity and quality of water running off the land surface. In any urban development, a system of channels and pipes must be designed to carry any reasonable stormwater away to avoid flooding. Drainage lines in the catchment may be creek lines or parts of the engineered drainage system. The usual practice for the design of stormwater disposal includes a minor system to remove nuisance water from regular rainfall events and a major system to deal with major floods.

Stormwater infrastructure is constructed principally to prevent flood damage in developed areas. Urbanisation has a major impact on the quantity and quality of stormwater runoff generated in a catchment, and results in large volumes of wastewater discharged to waterways and coastal waters and, to a lesser extent, on land (Mitchell *et al.* 2002a). Stormwater runoff from urban areas produces a considerable amount of water pollution (Cordery 1976). The major difficulty in treatment of stormwater is the huge discharges which occur for very short periods of time with long periods between flows.

Natural catchments have become effectively camouflaged by urban development. Urban runoff management in its broadest and most comprehensive form involves controlling both the quantity and quality of the runoff (Hunter 1998a). Ownership and maintenance of most of South Australia's stormwater drainage systems is fragmented, with local councils and state government organisations having varying responsibilities. This can inhibit a catchment-based management strategy for urban water (O'Loughlin *et al.* 1992; Clark *et al*. 1997).

### *5.7.1 Flood Protection for Metropolitan Adelaide*

#### 5.7.1.1 Historical Development

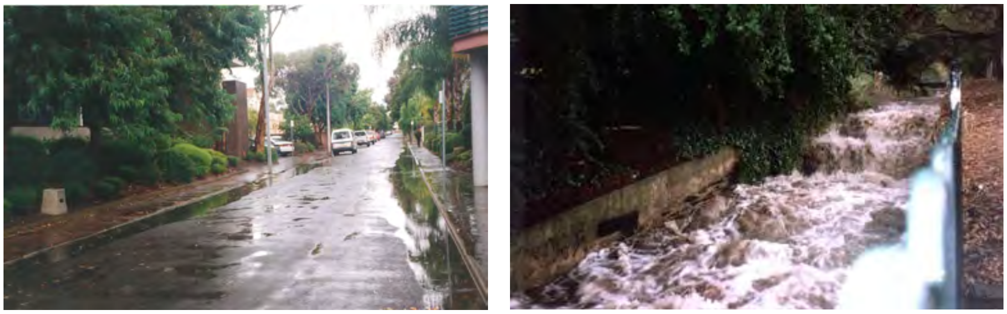
Stormwater infrastructure in South Australia has been continuously developed since settlement. Early accounts of the history of Adelaide mention that at times, the bullock drays travelled on the footways, while pedestrians walked in the boggy carriageways (Hammerton 1986; Argue 1991). In 1865-66, the first drains laid in the city were common drains that carried both sewage and stormwater to the River Torrens (Argue 1991). Shortly after this, based on the advice of a visiting British engineer Mr William Clark in 1877, the colony decided to handle sewage and stormwater in separate systems (Argue 1991). The legacy of this strategic policy direction continues.

Urban development within the Torrens catchment impacted on early settlers in the form of flooding and pollution. By the early 1900s, the potential for flooding of properties - mainly market gardens - beside the Torrens and Sturt Rivers caused concern (Argue 1991). In 1911, a comprehensive scheme for floodwaters control was proposed, however only limited works from this were completed to contain streams and convey their water directly to the sea. Discussion of the remaining elements continued but no further significant action was taken until the great flood of 1931. In September 1931, a 21 square kilometre area of the western suburbs along the River Torrens was inundated. Ironically, this event came within a period (1930-34) of particularly severe summer water restrictions during which the public was required to conserve water (Argue 1991).

An Act was passed and a program of works - the *Metropolitan Floodwaters Scheme* - was undertaken between 1935 and 1940 (Argue 1991). The effect of these works was to collect stormwater runoff and convey it rapidly to the Patawalonga Creek near Glenelg to be discharged to sea (Argue 1991). With the completion of the Metropolitan Floodwaters Scheme, there was little concern over stormwater, except in the south western suburbs of Adelaide which were still growing in the 1940s and 1950s. The resulting South-Western Suburbs Stormwater Drainage Scheme, centred on the upgrading of the main channel of the Sturt River which was completed in 1974 (Argue 1991). Throughout the 1960s and 1970s, extensions to the network of formal drainage channels established under the schemes continued.

The usual practice for design of stormwater disposal includes a minor system to remove nuisance water from regular rainfall events and a major system to deal with major floods. The minor system, using kerbing, side entry pits and underground pipes, is to ensure the roads and sidewalks do not get covered with water. The major system is to manage a 1 in 100 year event without flooding property. In urban situations, the underground stormwater drains may drain areas other than the natural surface catchment. This is because pipes can go through watersheds. The local government authority is responsible for drainage and should have plans of all drainage systems which identify the catchment boundaries in urban systems.

In general, stormwater runoff from urban areas passes along well-ordered roadside channels and drains causing little or no inconvenience (Argue 1991). However, stormwater runoff from suburban streets can combine and flow in large volumes and such speeds as to be dangerous. Figure 61 shows stormwater running along Jaffrey Street during a heavy rain event and the corresponding flows in a nearby stormwater channel that takes this water to the coast.



**Runoff in Jaffrey St, Parkside** **Stormwater Channel, Goodwood**

**Figure 61 Stormwater Runoff from Suburban Streets (Rabone 2000)**

It was not until the 1970s that the consequences of the 'remove stormwater as quickly and completely as possible' philosophy became apparent (Clark *et. al*. 1997). Rubbish, sediment and faecal bacteria was washed into the Torrens Lake, Patawalonga and West Lakes after each storm (Argue 1991). Within the next decade, the Patawalonga was declared unsafe for swimming and/or fishing and similar notices appeared on other recreational waterways. It was generally not appreciated by individuals that materials washed into drains become contaminants of the water environments that are so highly valued. A number of local councils have drain stencilling programs to highlight the connection between streets and the natural environment (COA 2002). In areas of growth and new development, new stormwater systems should be designed to incorporate beneficial use from the outset wherever possible.

#### 5.7.1.2 Ongoing Challenges

Increased flows in older stormwater networks have increased the frequency of overflows and localised flooding. Much of the existing stormwater drainage system is under capacity, requiring very substantial expenditure requirement to meet expected future growth needs and ensure sustainability of our natural water bodies. Future stormwater management measures should be designed to achieve multiple objectives including cost effectivness, consistent and socially acceptable levels of flood protection for urban development, improved quality of stormwater, and maximising opportunities for stormwater to supplement potable water for amenity and recreational purposes.

The *Metropolitan Adelaide Stormwater – Options for Management* (ECA 1991) report broadly estimated (order of magnitude only) that the cost of implementing a strategy of multi-objective stormwater management in metropolitan Adelaide would be in excess of $1 billion over a thirty year period. Of this, nearly 60% would be spent on trunk and street drainage (generally required, whether or not a new strategy is implemented), 10% on water quality works such as downstream retention basins and 5% on works for groundwater recharge and mains water substitution (ECA 1991). The challenges with stormwater infrastructure are related more to asset generation rather than asset replacement as with water supply systems (Clark 1992b). The South Australian community will ultimately fund the required investment through taxation instruments (ie. levy schemes) and lifestyle changes.

In South Australia, stormwater management has largely been the responsibility of local government but the administrative boundaries almost never coincide with catchment boundaries. Figure 62 shows the apparent '*mismatch*' of major surface water catchment areas and the local government areas for the Adelaide metropolitan area.

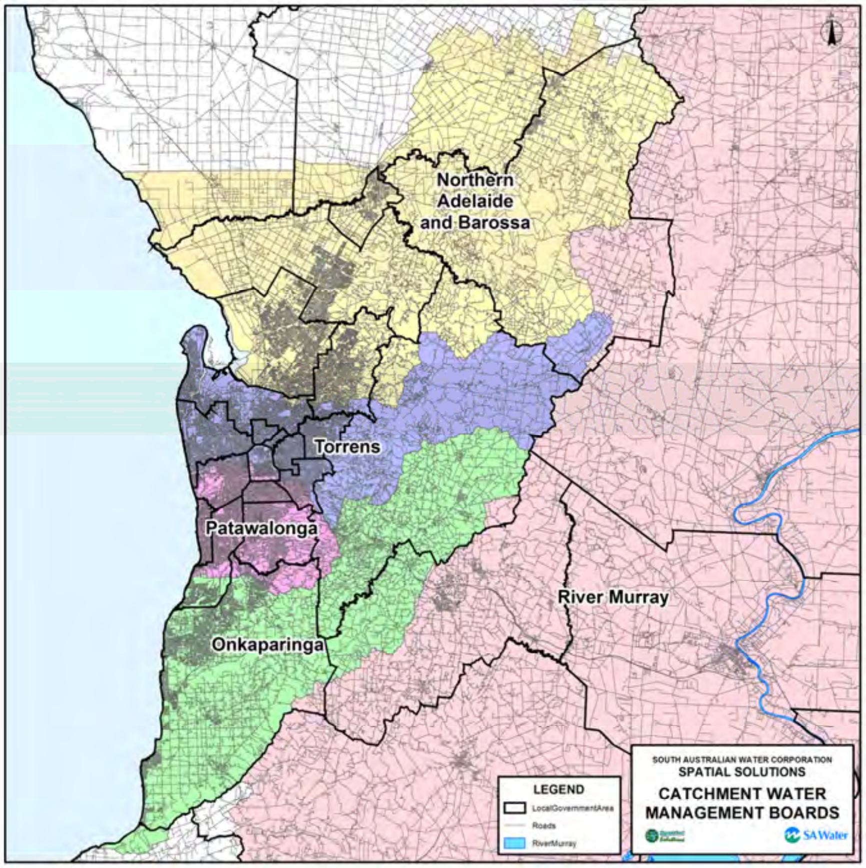


**Figure 62 Surface Water Catchment Areas of Adelaide (SA Water 2006)**

Local governments did not necessarily have responsibility for the whole catchment and until recently did not have responsibility for the quality of stormwater leaving their area. For example, flood producing runoff from upper parts of the catchment may arise from areas that are administratively independent from those which are flooded. Local stormwater systems can be handled by municipal councils, but without a regional approach encompassing major catchments, downstream local government areas cannot provide adequate stormwater management (O'Loughlin *et al.* 1992). At common law, the local council can be held liable for damage caused by stormwater.

To cope with the complexities of water management, *Catchment Water Management Boards* (CWMB) were formed in the late 1990s to emphasise comprehensive long range planning and coordination between local government, state government agencies, community groups, and individuals on a regional or local level (GSA 1999). The State government is in the process of reforming the current institutional arrangements. Under the new arrangements, CWMB's will be replaced by *Integrated Natural Resource Management Boards* (INRMB), based largely on water catchment areas. This approach recognises the relationship between catchment activities and water resource management and will be integral to protect, manage and enhance a catchment and associated waterways to support the economic development and designated uses of the resource. Local government will remain actively involved in urban stormwater management and in floodplain management.

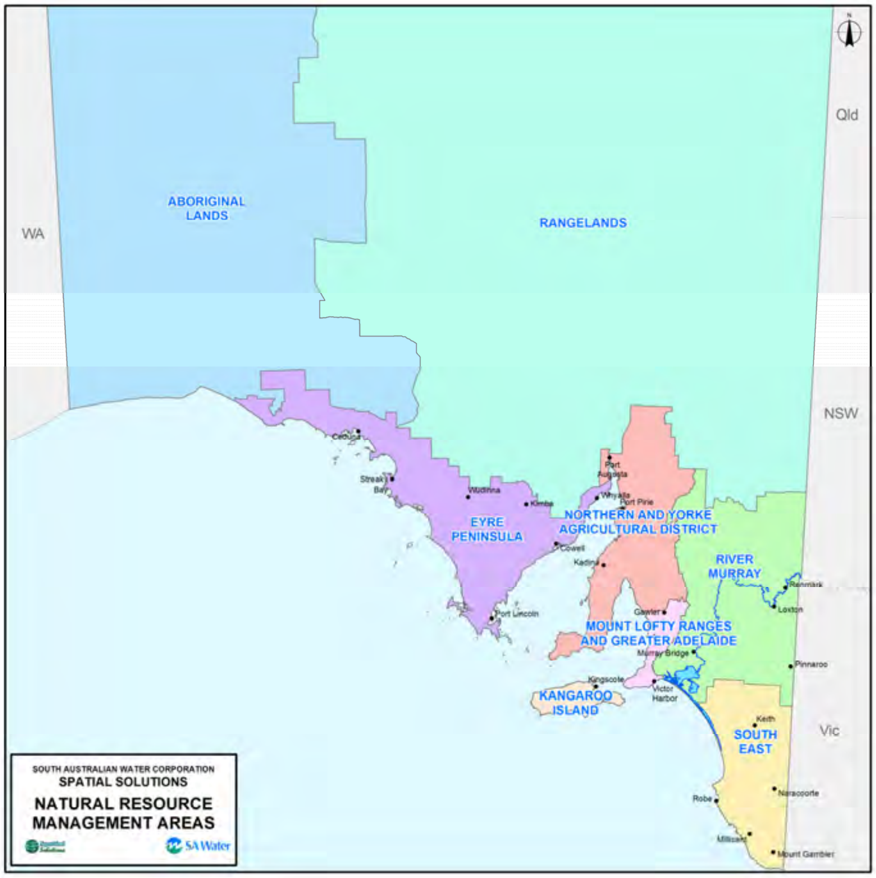


**Figure 63 New Natural Resource Management Boards (SA Water 2006)**

In South Australia, stormwater harvesting and reuse will become an increasingly attractive option for either extending available water supplies to support increased population or to reduce dependence on the River Murray. Little is known about the quality or volume of stormwater flows from towns and cities or the percentage that is used for beneficial purposes (COA 2001). Gerges et al. (2002) reported that only about 3% of the stormwater runoff generated in Adelaide is harvested for beneficial use. Stormwater harvesting seeks to use runoff for purposes for which its quality permits, such as irrigation or industrial purposes. One of Adelaide's most recent stormwater reuse projects, completed in 2002, is the 1.1ML per year Parafield Airport non-potable water supply project described in Example 29.

**Example 29 Stormwater Reuse Project: Parafield Airport, Adelaide**

*This project originated from a discussion in 1999 between the City of Salisbury and GH Mitchell & Sons, the largest wool processing company in Australia. The company's process involves the use of 1.1ML/year of mains water to wash the wool, which in turn produces large quantities of effluent. The costs of freshwater and sewerage disposal were high enough to encourage the company to consider alternative, cheaper locations elsewhere, potentially resulting in the loss of around 700 jobs in Adelaide. Extensive site trials demonstrated that the wastewater could be treated through natural wetlands.*

*The project involves diverting stormwater from existing drains to a system of constantly flowing, bird-proofed reed bed ponds on Parafield Airport land, where it would be treated and supplied direct to users. The Parafield drain was the last remaining stormwater catchment in the City of Salisbury without treatment to filter and cleanse stormwater prior to discharge to the marine environment. Stormwater in the main Parafield drain is diverted via a weir to a 50ML capture basin and then pumped to a similar size holding basin from where it gravitates to a 2ha reed bed system. Nutrients are reduced by 90% and the treated water will have a salinity of <250mg/L (compared to the typical salinity from the River Murray of >400mg/L). The system is designed to provide an average of 10 days residence time to ensure optimal treatment.*

*Surplus water is injected into aquifers for extraction during dry periods. Two ASR bores will ensure a continuous supply to Mitchell throughout the year. The volume to be recharged is 500Ml/year and will meet the Environment Protection Authority requirements. A proposed second stage of the scheme will expand the yield from 1.1 to 2.1ML/year by adding other catchments.*

*Source: Chaudhary & Pitman (2002)*

Reuse requires storage facilities for the water because runoff is sporadic while the demand for water may be continuous or at different times to the rainfall. The price of recycled water is greatly influenced by the subsidies received from other government sources and the return sought by the Council on its capital investment. The Council has opted for a payback period of 10 years or more on its schemes to ensure that the recycled water is always competitively priced compared to the mains water (Chaudhary & Pitman 2002). The value of water is well recognised in South Australian towns where water conservation strategies are widely promoted.

### *5.7.2 Managing Stormwater Runoff in Country Regions*

In general, the same '*dispose of as quickly and completely as possible*' philosophy has been adopted for stormwater works in country towns in South Australia. The principle issues in stormwater management vary from one town to another depending on climate, soil, topography and the urban water environment. Because metals and other pollutants tend to stick to sediment particles, it is important to prevent the wash off of contaminated sediments by runoff. Regular programs of street and footpath vacuuming, especially areas such as shopping centres and streets with deciduous trees in autumn are an integral part of good stormwater management (COA 2002). In many cases, strategies for coping with the water quantity and quality problems of stormwater runoff are hindered by financial, legal and organisation problems.

Rural towns are being driven to become increasingly water conscious with respect to the cost of maintaining community recreation areas. For over 20 years, stormwater harvesting and reuse projects have been beneficial in small towns as a means of improving their landscape amenity at competitive cost even though the quantity of stormwater runoff and/or effluent available may be small. Established stormwater management and wastewater infrastructure are incorporated into the water harvesting and reuse system. The urban development (ie. town area) leads to greater and more frequent stormwater runoff, particularly from summer rainfall that can be a useful resource, if captured. The efficiency of harvesting runoff can be increased by adopting technologies developed for larger urban centres, ie. paved areas, lined or pipe channels to take water to a single point for storage, albeit at a smaller scale. The process of capturing flows also reduces the impacts of discharging excess runoff on surrounding natural environment (ie. vegetation and water bodies).

Schemes are being implemented or proposed for the stormwater or effluent within many communities for irrigation of public and recreational areas. However, relatively little is known on regional about the volume of stormwater flows from towns and the level of reuse in regional areas. The annual volume of stormwater reused in regional South Australia is around 25%, ie less than 4GL per year out of around 15GL per year (based on the information in Table 24). Councils are becoming increasingly aware of potential economic savings through the replacement of reticulated potable water with a recycled supply for such applications. Currently, in South Australia water harvesting and reuse opportunities are receiving considerable interest.

## 5.8 TRENDS AND PATTERNS OF URBAN WATER USE

### *5.8.1 Breakdown of Total Water Use*

The breakdown of the total water use for South Australia is estimated to be 80% for irrigation, 15% urban and industrial and 5% rural towns and mining (GSA 2004). This breakdown of total water use is illustrated in Figure 64 below.

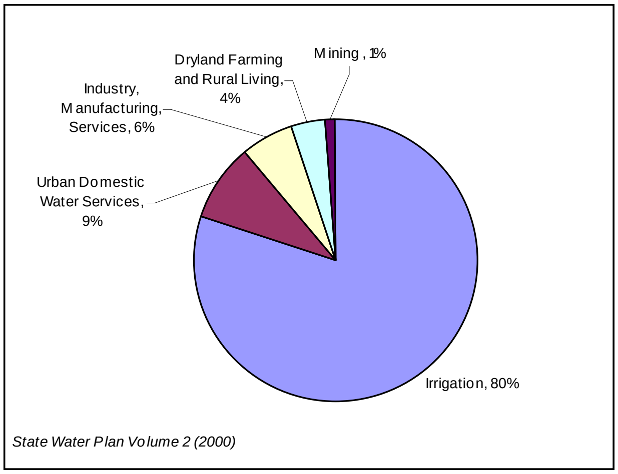


**Figure 64 Water Use in South Australia**

Figure 64 does not include an allocation for water required to meet the environmental needs, the level of this is a subject of ongoing national debate, but will most likely be sourced from within the current irrigation allocation. Accepting that water use by the irrigated agriculture sector presents significant potential for realising water savings that can be reallocated to other uses, the focus of this investigation is the potential for more efficient use within the second largest water use sector, that of water services to urban areas. Specifically, how local conditions, lifestyle and water use behaviour affect the potential of local water harvesting and reuse for towns in South Australia.

### *5.8.2 Urban Water Use from Public Reticulated Supplies*

Urban water supply includes water used to meet domestic (residential), industrial, commercial and institutional demands. It also includes water used to irrigate gardens, landscaped areas, sports fields, parks and open spaces. Reticulated water systems have provided a safe and reliable water supply to most South Australians at an affordable price, largely as a result of the Government’s uniform price policy. However, the prices charged do not reflect the true cost of service provision to rural or remote areas (Hudson 1990; SA Water 1999). As increasing demands are made for additional water resources, their local availability and quality is often a limiting factor, resulting in a relative increase in capital cost and associated treatment. As a result, water authorities can no longer absorb these expenses and they have progressively been passed on as higher water charges to consumers.

The demand for water in Adelaide grew around 4% a year until 1978. Since that time, the average water use per household has decreased due to factors such as user pays pricing, dual flush toilets, higher density dwellings and a general increase in the community’s awareness (GSA 2004). However, total consumption continues to rise due to population growth. Figure 65 below shows the historial annual water consumption by SA Water customers (ie. 98% population) as well as the number of customers being supplied for each financial year since 1977/78.

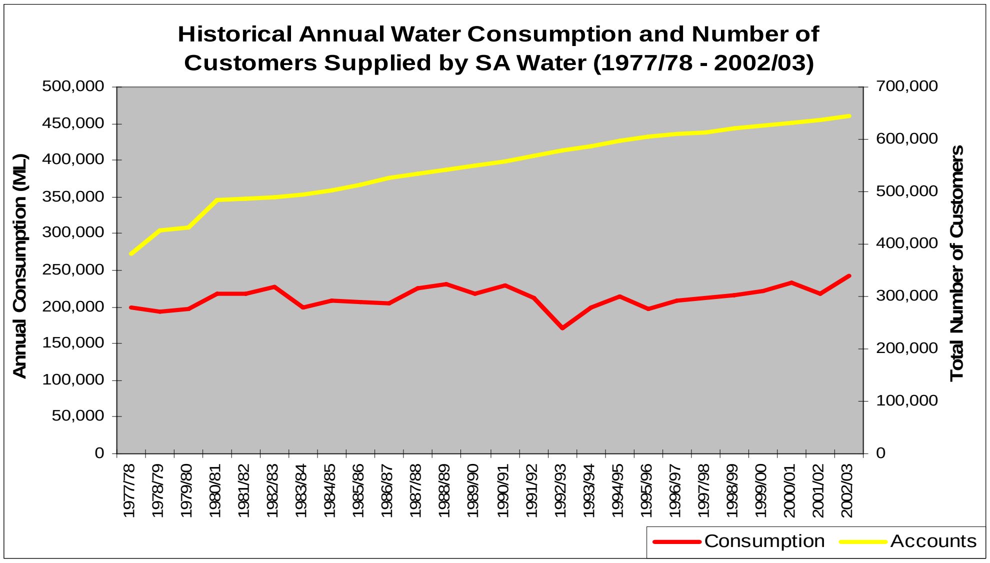
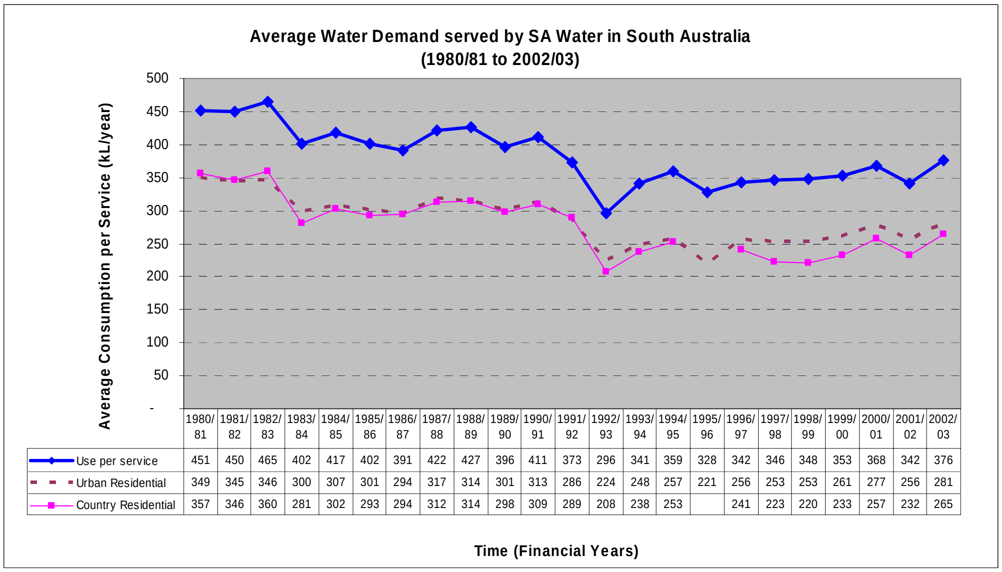


**Figure 65 Total Annual Water Use by SA Water Customers**

There has been a 22% increase (less than 1% per annum) in the total annual water demand by urban water customers over the 26 year period compared to the 69% growth (approx. 2.5% per annum) in the number of properties supplied over the same period. Figure 66 shows the average annual water use as well as residential water use for metropolitan and country water businesses.



| | 1980/ 81 | 1981/ 82 | 1982/ 83 | 1983/ 84 | 1984/ 85 | 1985/ 86 | 1986/ 87 | 1987/ 88 | 1988/ 89 | 1989/ 90 | 1990/ 91 | 1991/ 92 | 1992/ 93 | 1993/ 94 | 1994/ 95 | 1995/ 96 | 1996/ 97 | 1997/ 98 | 1998/ 99 | 1999/ 00 | 2000/ 01 | 2001/ 02 | 2002/ 03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use per service | 451 | 450 | 465 | 402 | 417 | 402 | 391 | 422 | 427 | 396 | 411 | 373 | 296 | 341 | 359 | 328 | 342 | 346 | 348 | 353 | 368 | 342 | 376 |
| Urban Residential | 349 | 345 | 346 | 300 | 307 | 301 | 294 | 317 | 314 | 301 | 313 | 286 | 224 | 248 | 257 | 221 | 256 | 253 | 253 | 261 | 277 | 256 | 281 |
| Country Residential | 357 | 346 | 360 | 281 | 302 | 293 | 294 | 312 | 314 | 298 | 309 | 289 | 208 | 238 | 253 | | 241 | 223 | 220 | 233 | 257 | 232 | 265 |

**Figure 66 Average Annual Water Use per Service, 1977/78 to 2002/03**

Figure 66 shows a decreasing trend in the average annual consumption per service (all customer classifications) from 450 kL per service with the average consumption over the last 10 years stabilising at around 350 kL per service between 1980/81 to 2002/03. It is believed that this 100 kL drop in average consumption per service has resulted from the introduction of a user pays pricing policy. The introduction of two part tariff over the year period from 1991/92 to 1996/97 resulted in further reductions of 14%, 15% and 17% in the average water consumption per service, metropolitan residential and country residential customers respectively (Rabone 2004b). Despite this achievement, there is a concern that total water consumption is now trending upwards.

### 5.8.2.1 Country Residential Water Use Component

Post tariff reform, the average water consumption per service and for metropolitan residential customers has remained stable up to 2001/02, while over the same period the average annual consumption per service for country residential customers continued to drop by 7% (Rabone 2004b). When plotting the urban and country residential water consumption data for SA Water customers (refer to Figure 66), it was noticed that a close correlation exists between the two sets of data. As part of further investigation Figure 67 was constructed and the correlation constant ($R^2$) was found to be high at 0.965.

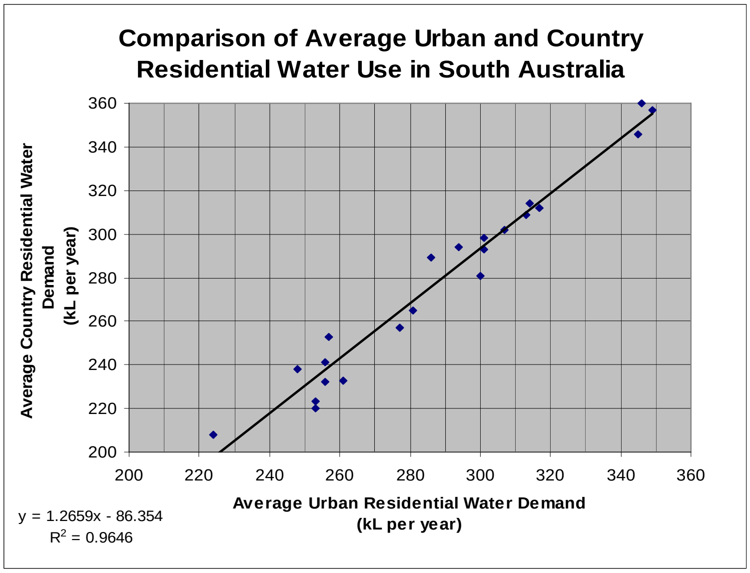


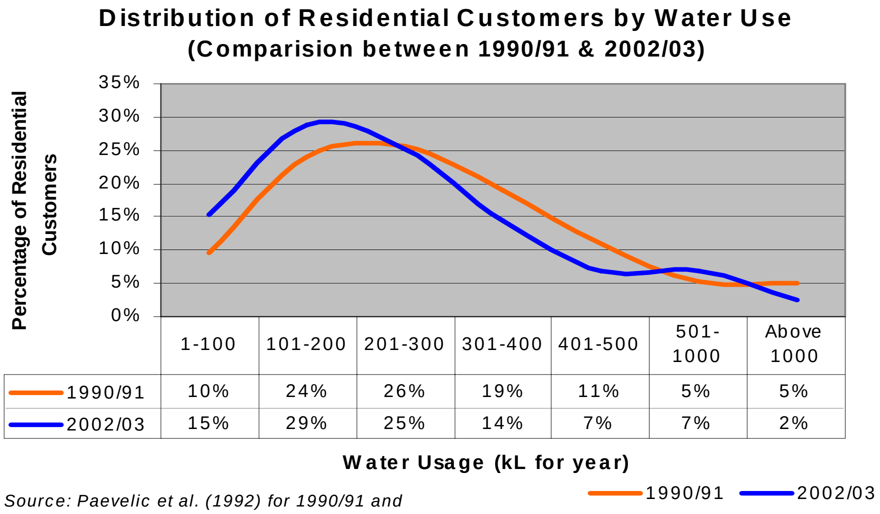
**Figure 67 Residential Water Use for South Australia & Country Areas**

This implies that the general domestic water consumption pattern is the same between urban and rural users (and dependent upon weather conditions).

### 5.8.2.2 Distribution of Residential Customers

It is fundamental that price reflects the cost of providing water to urban centres to create the conditions to bring about optimum use and encourage adoption of measures to maximise efficiency in water use. Reform of water pricing towards pay-for-use was initiated in the early 1980s by the State Government (SA Water 1999). In response to the COAG water reform, there have been further major structural changes in water pricing policy since the early 1990s. Using the pricing structure, excess water use is discouraged through increased rates and water conservation becomes voluntary. The expected outcome of the pricing structure reform is that low water users will be rewarded by lower bills, high water users will face higher bills if they maintain their consumption levels, and median water users will face a moderate increase if their consumption is unchanged.

Information concerning residential mains water use (up to 1,000kL) was obtained from SA Water for the 2002/03 year (based on 499,455 properties) and compared with information published in Pavelic *et al*. (1992) for the 1990/91 year (based on 448,000 properties). Figure 68 gives the breakdown of the annual residential consumption and their relative significance compared with total residential water use.



| | 1-100 | 101-200 | 201-300 | 301-400 | 401-500 | 501-1000 | Above 1000 |
|---|---|---|---|---|---|---|---|
| 1990/91 | 10% | 24% | 26% | 19% | 11% | 5% | 5% |
| 2002/03 | 15% | 29% | 25% | 14% | 7% | 7% | 2% |

*Source: Paevelic et al. (1992) for 1990/91 and*
*K. Sichler, SA Water pers. comm. 2004 for 2002/03*

**Figure 68 Distribution of Residential Customers by Water Use**

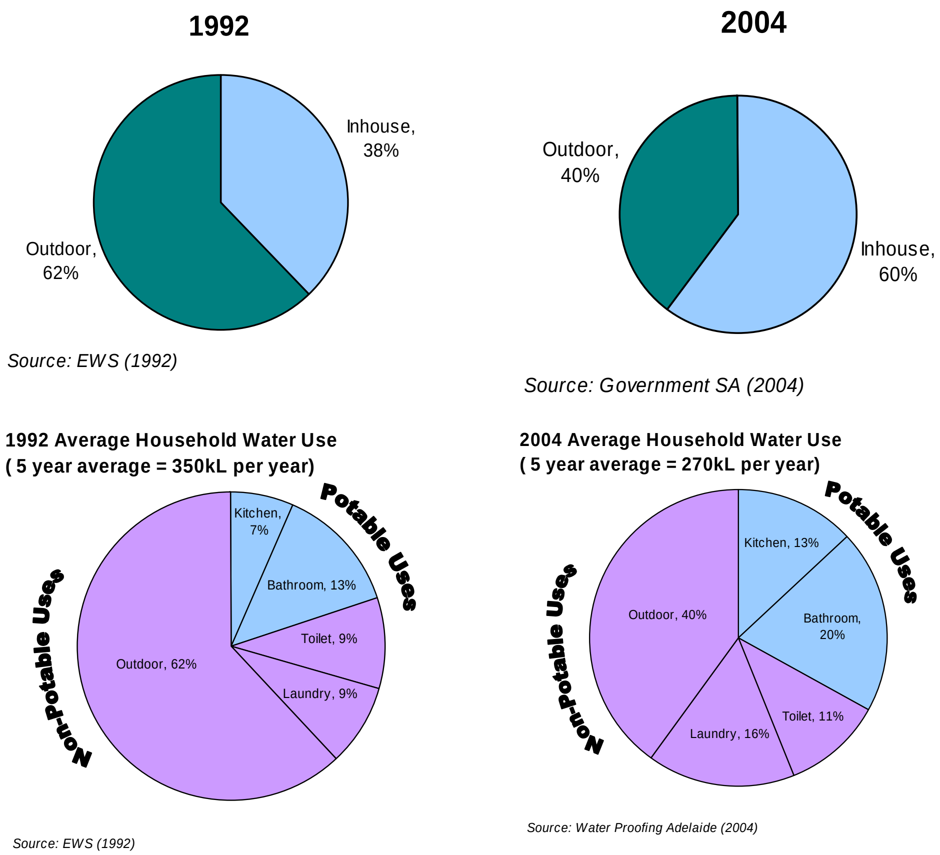
Pricing reform has had a significant impact on average residential consumption and contributed to changing the way South Australian households use water (Rabone 2004b). The comparison of the distribution curve for 1990/91 and 2002/03 suggests there has been a movement towards decreased water use (ie. increased peaks in the low water use groups). There is a level of uncertainty associated with the distribution for any given year particularly with respect to the influence of weather conditions on discretionary water use (Rabone 2004b). The uncertainty associated with weather conditions might be reduced by adopting a distribution based on a rolling average if the information is available.

### 5.8.2.3 Location of Residential Water Use

On the basis of the typical water use location within households, a distinction can be made between that used for indoor purposes and water used outdoors for garden and allotment uses. It is also possible to identify two distinct types of water quality requirements according to the end use. Potable (drinking) quality water is needed for bathroom, laundry and kitchen purposes. However, the remainder of the household demand as well as outdoor demand does not require potable quality water. As residential customers use water more efficiently, patterns of water use will change and historic consumption information may no longer be reliable for long-term planning purposes.

For example, in Adelaide, water use by residential customer’s accounts for nearly 60% of total water consumption (GSA 2004) making domestic water use a significant component of total urban water consumption. Over the last decade, the average household water usage pattern in Adelaide has changed as shown in

Figure 69. More than 40% of the drinking quality water supplied is still used for lower quality purposes, such as garden watering and toilet flushing.



*Source: EWS (1992)*

*Source: Government SA (2004)*

*Source: EWS (1992)*

*Source: Water Proofing Adelaide (2004)*

**Figure 69 Average Household Water Use in Adelaide in 1992 & 2004**

Understanding residential water use trends is essential for urban water utility to effectively plan for the present and future needs of its domestic and other customers. This will become more important as new or alternative water delivery options are introduced. In South Australia, a number of initiatives have been recently implemented to place water services on a more environmentally responsible and sustainable basis. Pioneering projects, such as New Haven Village, offer an essential proving ground for generating political support and public acceptance of new approaches.

New Haven Village is a 65 home housing development on a 2 hectare site approximately 20 kilometres from the Adelaide central business district. The housing estate features engineering innovations which radically change the way water and waste water is managed within a development. The purpose of the development was to demonstrate and evaluate ideas for urban water harvesting and reuse which might be applied in larger scale developments. Information concerning residential mains water use (up to 1,000kL) at New Haven Village (indoor only) was obtained from SA Water for the 2003/04 year (based on 64 properties) and compared with information for the entire metropolitan area (indoor and outdoor).

Figure 70 gives the breakdown of the annual residential consumption of potable and their relative significance compared with total residential water use.

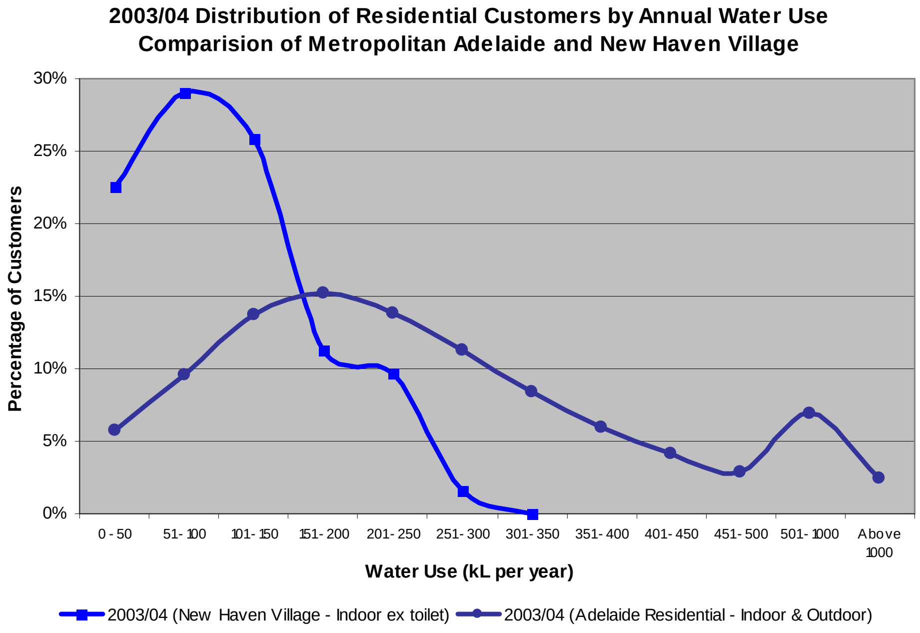


**Figure 70 New Haven Village – Distribution of Customers by Water Use**

The impact of changing the location of potable water use within a household is apparent from the distribution of residental customers by water use. Pioneering projects can be used to generate information vital for urban water supply research on aspects such as effectiveness of treatment and technologies, economic and environmental impacts. Such research will be valuable to refine guidelines and standards relating to urban water supply practices most suited to South Australian conditions.

### *5.8.3 Breakdown of Urban Water Use By Customer Classification*

The maximum potential for water reuse within a given township can be assessed by examining consumer meter data. An appreciation of the nature of water use within a given township can be obtained by subdividing it into the various customer classification based principally on land use as set out in Table 34 below.

Table 34 shows there is a significant variation between communities in the quantity of water used for recreational areas and public institutions. It has been assumed that users classified as recreational or public institutions have the potential to replace potable water with a non-potable source of water. The users include public sporting facilities, council areas such as parks and gardens and schools.

## Table 34 Average Water Use by Customer Type as a Percentage of Demand

| Town | | | Consumption by Customer Classification | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **CI** | **Period of Record** | **Com** | **Ind** | **PI** | **Rec** | **Resi** | **Supply by Measure** |
| Bordertown | 3 | 88/89-02/03 | 5% | 5% | 8% | 3% | 66% | 13% |
| Clare | 3 | 88/89-02/03 | 7% | 9% | 9% | 6% | 69% | 0% |
| Cleve | 5 | 88/89-02/03 | 3% | 9% | 13% | 7% | 67% | 0% |
| Cowell | 7 | 88/89-02/03 | 3% | 12% | 8% | 13% | 62% | 2% |
| Cummins | 4 | 88/89-02/03 | 4% | 11% | 17% | 4% | 61% | 3% |
| Geranium | 5 | 88/89-02/03 | 5% | 4% | 16% | 1% | 66% | 9% |
| Hawker | 9 | 88/89-02/03 | 5% | 4% | 16% | 0% | 53% | 22% |
| Jamestown | 5 | 88/89-02/03 | 3% | 4% | 14% | 6% | 73% | 0% |
| Karoonda | 6 | 91/92-02/03 | 5% | 5% | 19% | 4% | 61% | 6% |
| Keith | 4 | 88/89-02/03 | 5% | 19% | 10% | 4% | 59% | 3% |
| Kingscote | 3 | 88/89-02/03 | 6% | 6% | 7% | 5% | 73% | 3% |
| Lameroo | 5 | 88/89-02/03 | 4% | 3% | 11% | 3% | 75% | 3% |
| Lock | 5 | 88/89-02/03 | 5% | 2% | 34% | 11% | 48% | 0% |
| Lucindale | 2 | 88/89-02/03 | 4% | 10% | 21% | 4% | 61% | 0% |
| Maitland | 4 | 88/89-02/03 | 4% | 6% | 18% | 3% | 69% | 0% |
| Marree | 20 | 88/89-02/03 | 4% | 15% | 12% | 2% | 51% | 16% |
| Minnipa | 7 | 88/89-02/03 | 4% | 12% | 4% | 25% | 51% | 4% |
| Mt Pleasant | 3 | 98/99-02/03 | 7% | 3% | 11% | 6% | 70% | 3% |
| Oodnadatta (1) | 21 | 93/94-02/03 | 6% | 12% | 38% | 2% | 38% | 4% |
| Orroroo | 7 | 88/89-02/03 | 2% | 10% | 17% | 11% | 56% | 5% |
| Penneshaw | 3 | 88/89-02/03 | 7% | 7% | 6% | 8% | 68% | 4% |
| Penola | 2 | 88/89-02/03 | 5% | 9% | 7% | 3% | 75% | 1% |
| Peterborough | 7 | 88/89-02/03 | 2% | 6% | 9% | 8% | 73% | 2% |
| Pinnaroo | 6 | 88/89-02/03 | 4% | 8% | 12% | 2% | 72% | 3% |
| Port Augusta | 11 | 88/89-02/03 | 3% | 8% | 12% | 9% | 66% | 2% |
| " Stirling Nth | 11 | 88/89-02/03 | 1% | 9% | 8% | 1% | 79% | 1% |
| Quorn | 8 | 88/89-02/03 | 2% | 8% | 6% | 6% | 68% | 9% |
| Renmark (2) | 8 | 91/92-02/03 | 5% | 4% | 7% | 1% | 82% | 1% |
| Snowtown | 5 | 88/89-02/03 | 2% | 9% | 25% | 0% | 63% | 1% |
| Streaky Bay | 5 | 91/92-02/03 | 4% | 8% | 12% | 13% | 62% | 0% |
| Wallaroo | 6 | 88/89-02/03 | 3% | 14% | 4% | 10% | 68% | 2% |
| Whyalla | 9 | 91/92-02/03 | 4% | 5% | 10% | 8% | 71% | 1% |
| MAXIMUM | | | 7% | 19% | 38% | 25% | 82% | 22% |
| MINIMUM | | | 1% | 2% | 4% | 0% | 38% | 0% |
| **AVERAGE** | | | **4%** | **8%** | **13%** | **6%** | **65%** | **4%** |
| STDEV | | | 1.4 | 3.8 | 7.7 | 5.0 | 9.5 | 5.0 |

*Notes:*

*(1) Non-potable supply only*

*(2) Second non-potable supply available from CITB*

*Source: SA Water – Water Consumption Statistics*

| | |
|---|---|
| *CI* | *Climate Index* |
| *Com* | *Commercial properties* |
| *Ind* | *Industrial properties* |
| *PI* | *Public Institution* |
| *Rec* | *Recreational properties* |
| *Resi* | *Residential properties* |

### *5.8.4 Annual Water Use per Service by Town*

A comparison of the average water use per service for the given town with the state wide average is provided in Table 35.

**Table 35 Water Consumption per Service for Towns in South Australia**

| Town | Water Management Regions | CI | Period of Record | Annual Water Use per Service | | | |
|---|---|---|---|---|---|---|---|
| | | | | Max (kL) | Min (kL) | Ave (kL) | State Ave. |
| State-wide | NA | NA | 91/92-02/03 | 427 | 296 | 350 | - |
| Bordertown | South East | 3 | 91/92-02/03 | 554 | 294 | 333 | 95% |
| Clare | Mid North | 3 | 91/92-02/03 | 393 | 229 | 317 | 90% |
| Cleve | Eyre Peninsula | 5 | 91/92-02/03 | 463 | 227 | 323 | 92% |
| Cowell | Eyre Peninsula | 7 | 91/92-02/03 | 477 | 230 | 341 | 97% |
| Cummins | Eyre Peninsula | 4 | 91/92-02/03 | 350 | 180 | 270 | 77% |
| Geranium | M-D Basin | 5 | 91/92-02/03 | 418 | 198 | 274 | 78% |
| Hawker | Mid North | 9 | 91/92-02/03 | 340 | 202 | 246 | 70% |
| Jamestown | Mid North | 5 | 91/92-02/03 | 362 | 206 | 311 | 89% |
| Karoonda | M-D Basin | 6 | 92/93-02/03 | 362 | 210 | 303 | 86% |
| Keith | South East | 4 | 91/92-02/03 | 456 | 262 | 291 | 83% |
| Kingscote | Kangaroo Island | 3 | 91/92-02/03 | 293 | 214 | 247 | 70% |
| Lameroo | M-D Basin | 5 | 91/92-02/03 | 411 | 213 | 282 | 81% |
| Lock | Eyre Peninsula | 5 | 91/92-02/03 | 392 | 209 | 311 | 89% |
| Lucindale | South East | 2 | 91/92-02/03 | 297 | 152 | 242 | 69% |
| Maitland | Mid North | 4 | 91/92-02/03 | 316 | 187 | 261 | 74% |
| Marree | Far North | 20 | 91/92-02/03 | 341 | 148 | 285 | 81% |
| Minnipa | Eyre Peninsula | 7 | 91/92-02/03 | 407 | 210 | 264 | 75% |
| Mt Pleasant | Mid North | 3 | 98/99-02/03 | 282 | 226 | 257 | 73% |
| Oodnadatta | Far North | 21 | 91/92-02/03 | 681 | 423 | 545 | 156% |
| Orroroo | Mid North | 7 | 91/92-02/03 | 382 | 237 | 320 | 91% |
| Penneshaw | Kangaroo Island | 3 | 91/92-02/03 | 280 | 180 | 230 | 66% |
| Penola | South East | 2 | 91/92-02/03 | 231 | 146 | 170 | 49% |
| Peterborough | Mid North | 7 | 91/92-02/03 | 314 | 184 | 231 | 66% |
| Pinnaroo | M-D Basin | 6 | 91/92-02/03 | 430 | 263 | 333 | 95% |
| Port Augusta | Mid North | 11 | 91/92-02/03 | 606 | 358 | 434 | 124% |
| “ (Stirling Nth) | Mid North | 11 | 93/94-02/03 | 584 | 414 | 484 | 138% |
| Quorn | Mid North | 8 | 91/92-02/03 | 306 | 211 | 268 | 76% |
| Renmark | M-D Basin | 8 | 92/93-02/03 | 460 | 303 | 376 | 107% |
| Snowtown | Mid North | 5 | 91/92-02/03 | 370 | 194 | 270 | 77% |
| Streaky Bay | Eyre Peninsula | 5 | 92/93-02/03 | 325 | 180 | 289 | 82% |
| Wallaroo | Mid North | 6 | 91/92-02/03 | 281 | 174 | 211 | 60% |
| Whyalla | Mid North | 9 | 92/93-02/03 | 446 | 282 | 337 | 96% |

*Source: SA Water – Water Consumption Statistics*

There is considerable variation in the quantity of water used per service between South Australian townships depending upon service provided, cultural preferences and the prevailing climate. For example, at Oodnadatta, the town with the highest climate index, the average use per service is 545kL or 156% higher than the average state usage. This is a reflection of the household size, level of visitors rather than garden watering. This water is used for all indoor purposes except toilet flushing. At Penola the average water use was 50% or 176kL per service, which closely approximates the indoor water use. This is a reflection of the milder climate and local access to groundwater for garden watering.

In addition to the water supply systems provided by the State government, there are also a number of small non-state government and private water supply systems operated by local councils and boards (SA Water 1999). A comparison of the average water use per service for the given town served with a non-state government scheme with the state wide average is provided in Table 36.

**Table 36 Water Use Per Service for Non-State Water Supply Schemes**

| Town | Water Management Regions | CI | Period of Record | Annual Water Use per Service Ave (kL) | State Ave. |
|---|---|---|---|---|---|
| State-wide | NA | NA | 91/92-02/03 | 350 | - |
| Andamooka | Far North | 15 | 01/02-05/06 | <100 | <30% |
| Clayton (1) | Murray-Darling Basin | 4 | NA | NA | NA% |
| Coober Pedy | Far North | 19 | 97/98-02/03 | 185 | 53% |
| Leigh Creek | Far North | 14 | 00/01-05/06 | 1297 | 370% |
| New Haven Village (2) | Adelaide & Mt Lofty Ranges | 4 | 99/00-03/04 | 150 | 43% |
| Roxby Downs | Far North | 17 | 00/01-03/04 | 545 | 156% |

Notes.

(1) Council (water supply operator) unable to make this information available.

(2) Households are supplied with dual water supply. SA Water has records of indoor potable water use (excluding toilet flushing). Council unable to provide non-potable water use records (no meters). Assumed 40kL for toilet flushing. All house lots.

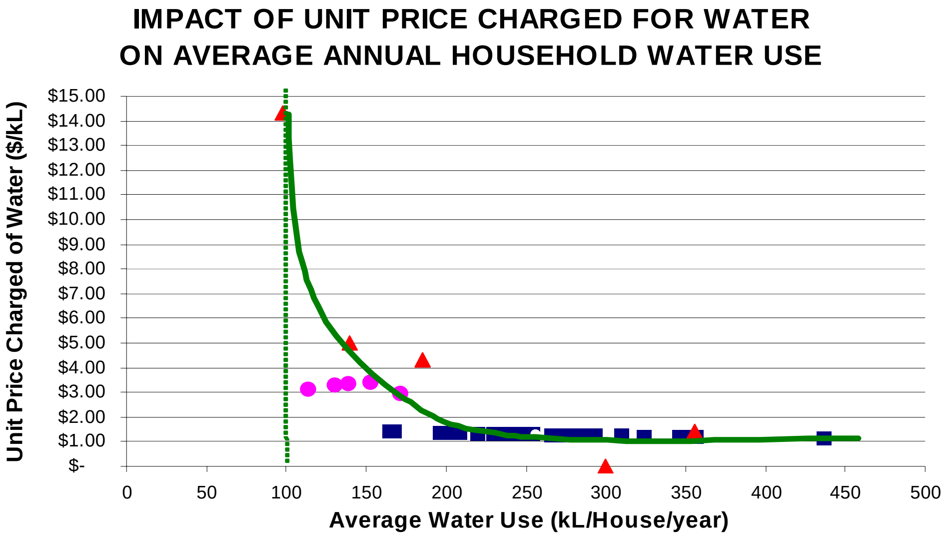
*Sources: Operational data provided by the individual system operators (refer Part II).*

The first observation is the wide variation of average annual water use per service ranging from less than 30% up to more than 300% in comparison to the state average. The towns of Andamooka and Coober Pedy are located in a region with a climate index of more than 15 (harsh environment). Water is expensive in both townships and consequently there is limited outdoor (ie. residential gardens). However, at Leigh Creek and Roxby Downs, also with high climate index, reticulated water is used by service industries and for gardening purposes on residential allotments (ie. traditional looking suburbs). Water is supplied free to residents of Leigh Creek, and is supplied to residents of Roxby Downs at a price comparable to state-wide price although with a different tariff structure.

### 5.8.5 *Impact of Unit Price of Average Annual Water Use*

Water pricing reform is one measure that can be designed to encourage efficient use of water resources. This is because the price of water provides the clearest message to customers and allows them to achieve an appropriate balance between the benefits and costs of usage of water services (WSAA 1998 and SA Water

1999). The extent to which customers adjust their consumption of water in response to price changes is termed the price elasticity. For South Australia, the internal water use component is not considered elastic (ie essential uses) and is typically of the order of 175kL per household. Figure 71 is a plot of the average annual water use per household for 43 South Australian towns against the unit price charged for water. The plot is constructed with water use information for 33 towns receiving reticulated water provided by the State government at the state-wide price, 4 communities supplied by the State government at roughly double the state-wide price, and several towns supplied by local authorities. The unit rate that has been plotted was calculated based on the individual tariff structure in place by dividing the total water bill by the average annual water use.



Notes of Construction:
1. Based on kL/house/year records for 43 towns, including 4 non-State schemes & 5 state schemes where the price charged is higher than state wide price.
2. Unit price charged was calculated as Access Charge + Usage Charge divided by the average water use.

*Source: SA Water - Water Consumption Records & Individual Operators for the Non-State systems*

**Figure 71 Impact of Average Unit Price & Average Annual Water Use**

As expected, there is clearly a lower limit to the average annual household water use for essential indoor uses. Currently, outdoor water use appears to be curtailed when the unit rate of water approaches $3.00kL, ie. the price has a regulating affect. Conversely, it is widely accepted that water use in households tends to increase once the unit rate for reticulated water is reduced as experienced by the Coober Pedy case study. In Coober Pedy, the local council is responsible for operation and maintenance of the town’s reticulated water supply. The historical annual demand trend for water between July 1986 and June 2003 is shown in Figure 72. The number of services doubled over this period while the annual demand tripled. After the introduction of a two-part tariff with an access charge and a lower presiding unit rate in 2000/01 a clear increase in the annual demand for water can be observed.

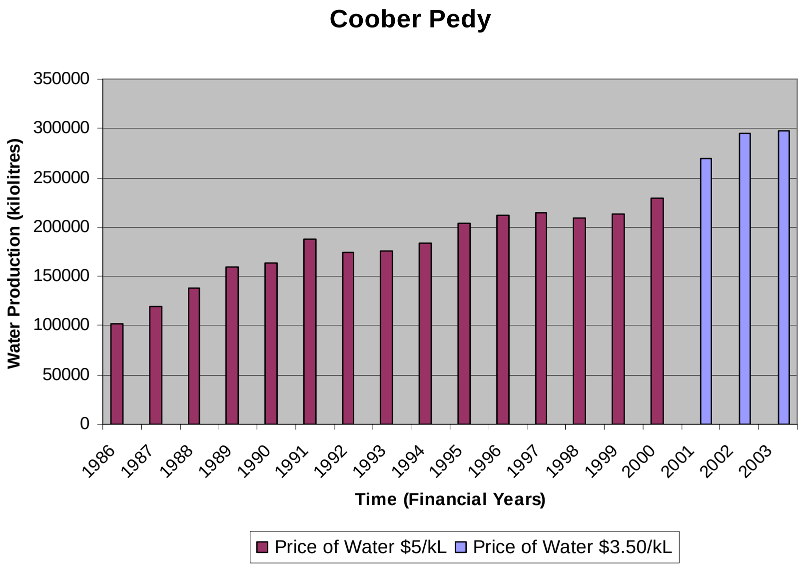
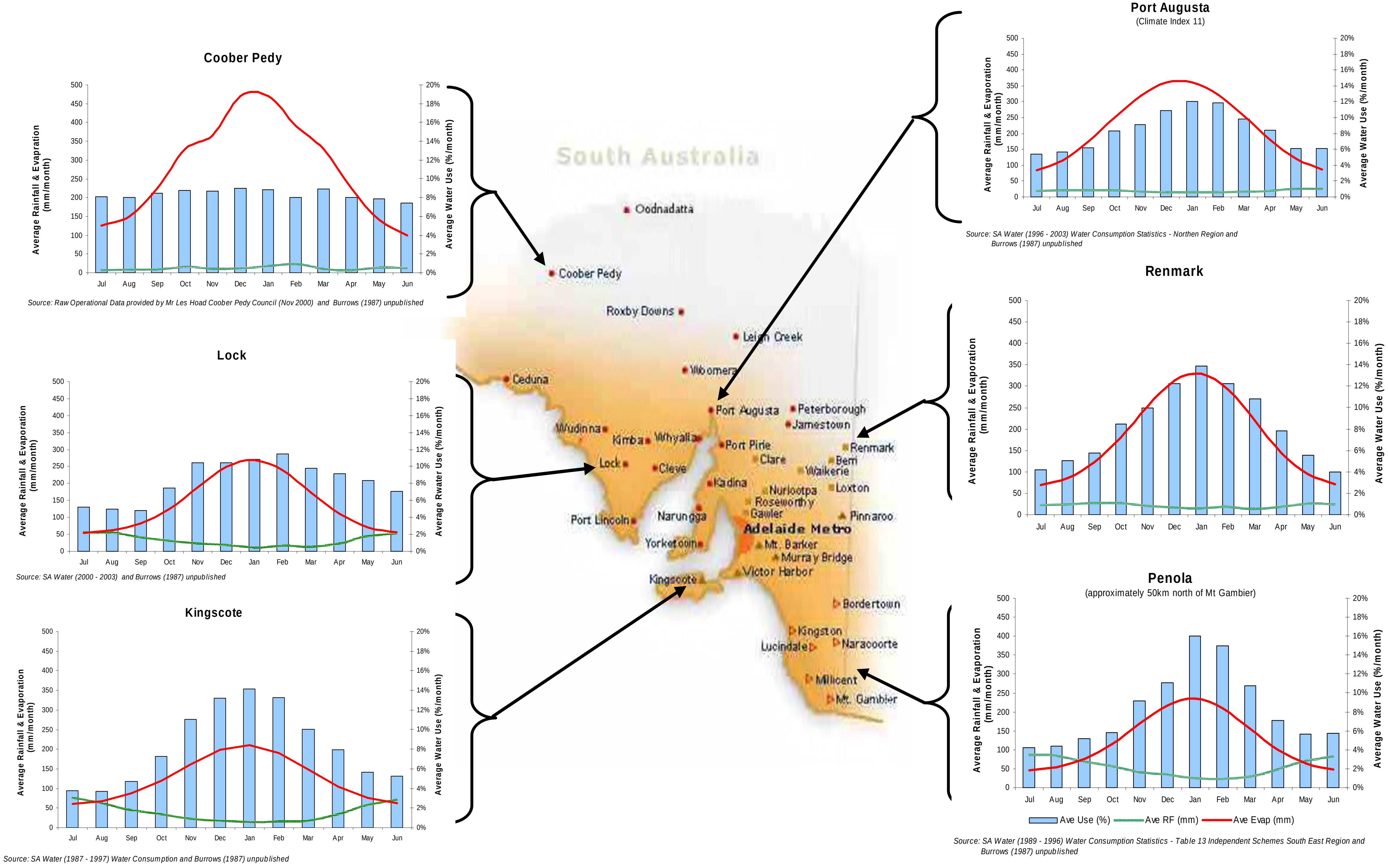


**Figure 72 Coober Pedy - Historical Annual Water Demand**

The average annual water use per service (including commercial) was 135kL in 1986/87 and nearly 185kL in 2003/04 (both these points are included in Figure 71 above). In 1986/87, the price of reticulated water was $5.00 per kilolitre on a pay for use basis (ie. no access or minimum charge). In 2000/01, the Council converted the water price structure to a two part tariff which consisted of an access charge and water use charges. To discourage excessive water use, the variable water use component was subjected to a three block inclining tariff being; $3.00 per kilolitre for the first 50kL, $3.50 per kilolitre up to 300kL, and $4.10 per kilolitre above 300kL.

### *5.8.6 Monthly Water Use Patterns*

There is considerable variation in the monthly water use pattern between various townships within South Australia depending upon the region they area located in. The prevailing climate influences the temporal pattern of people's water demand. The pattern of rainfall and evaporation also influences the volume and seasonality of water demand. The pattern for outdoor (non-essential) use is seasonal, depends on the size and type of garden and influenced by the prevailing climate. Water required for gardening varies considerably between towns according to rainfall and evaporation. To illustrate the influence of prevailing climatic conditions the average monthly water demand and climate indicators (rainfall and evaporation) for a number of towns in South Australia are compared in Figure 73. With the exception of Coober Pedy, this comparison shows a seasonal rise in urban water demand in response to an increase in outdoor water use for towns to maintain lawns and gardens during summer. The effect is more pronounced in locations where the pattern of rainfall is more seasonal (ie. reliable rainfall occurs during the winter months with little rainfall during summer) such as Penola and Kingscote. The constant demand for water exhibited by the township of Coober Pedy is more a reflection of the high water price (more than 3 times that of other townships) that acts to curtail outdoor water use rather than the prevailing climate



Source: Raw Operational Data provided by Mr Les Hoad Coober Pedy Council (Nov 2000) and Burrows (1987) unpublished

Source: SA Water (2000 - 2003) and Burrows (1987) unpublished

Source: SA Water (1987 - 1997) Water Consumption and Burrows (1987) unpublished

Source: SA Water (1996 - 2003) Water Consumption Statistics - Northen Region and Burrows (1987) unpublished

Source: SA Water (1989 - 1996) Water Consumption Statistics - Table 13 Independent Schemes South East Region and Burrows (1987) unpublished

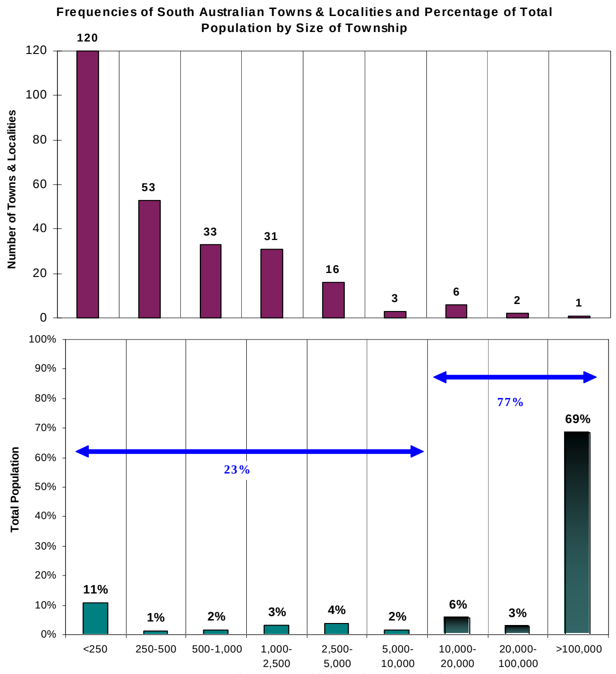
**Figure 73 Water Demand and Average Monthly Climate Indicators**

## 5.9 OTHER CONSTRAINTS IN SOUTH AUSTRALIA

Reticulated water systems have provided a safe and reliable water supply to most South Australians at an affordable price, largely as a result of the Government's uniform price policy. However, the prices charged do not reflect the true cost of service provision to rural or remote areas (Hudson 1990; SA Water 1999). For rural South Australia, additional problems in the provision of water services include those associated with distance and the small size of the communities.

### *5.9.1 Geographic and Demographic Statistics*

The geographic distribution of the customer base impacts on operational cost and capital efficiency of a water utility. In excess of 75% of the South Australian population live in nine urban centres of more than 10,000 people. At the other end of the scale, around 10% of the State's population live in 120 small towns and communities of less than 250 people. The number of communities and percent of the total population by size based on the 2001 Census is presented in Figure 74.



*Total of 265 towns in analysis.*
*Population Data from ABS CENSUS 2001*

**Figure 74 Summary of the Frequency of Towns by Population Size**

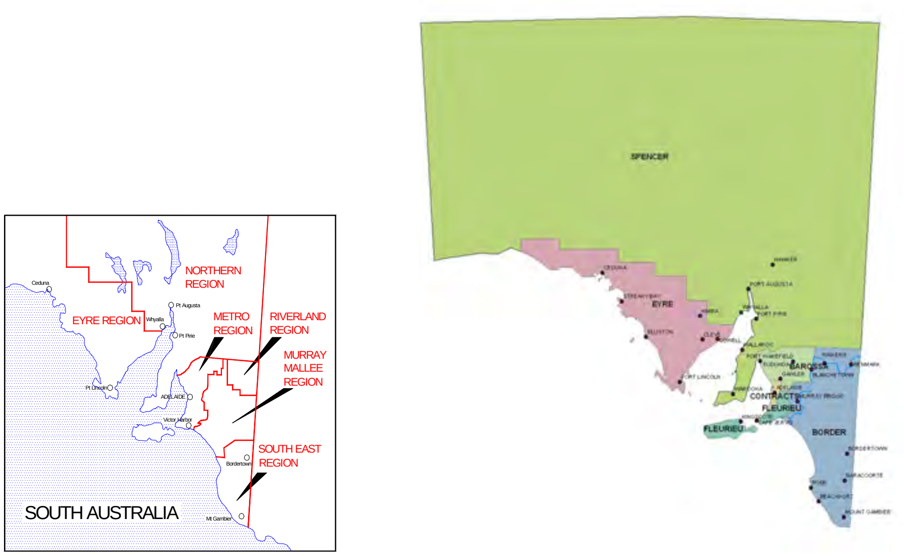
Under the accepted urban water system size definition (discussed in section 3.2.3.1), South Australia has one '*major urban*', three '*non major urban*', six '*small*' and more than 100 even smaller systems. Despite these challenges, with the exception of a few communities, the South Australian Water Corporation, a State owned government business, has the responsibility for the management of reticulated water supplies across the State.

### 5.9.2 State-wide Water Pricing Policy

People pay for the right to access the service and for the delivered product itself. A variety of costs are incurred by the supplier and the wider community in the provision of water and wastewater services. These costs are dominated by the capital costs of the systems, including depreciation and the need for the assets to make a return comparable to other public investments. There are also non-capital operating related costs (pumping, treatment, chemicals etc) that vary with the volume of water delivered. Both capital and operating costs vary across the State according to such factors as terrain, the compactness of the customer base, the distance of the customers from major water sources or storages, the designed peak capacity of the system, the quality of raw water to be treated, and the condition and service life of the asset being used (SA Water 1999).

A feature of water pricing in South Australia is that it is consistent state-wide for services provided by the State government (SA Water 1999). This policy is applied in spite of significant differences in operating environments that can have an impact on the cost of the service. The uniform water price operating throughout most of the State acts to mitigate the effect of a full cost recovery policy on the rural and regional areas. For example, a residential user in Adelaide pays the same total bill for the same amount of water as a consumer in Mount Gambier or Port Lincoln supplied by a State government system. Under a state-wide pricing approach, some cross subsidisation between metropolitan and regional systems is inevitable. This means that the costs reflected in the price paid are not necessarily the costs of any one particular system.

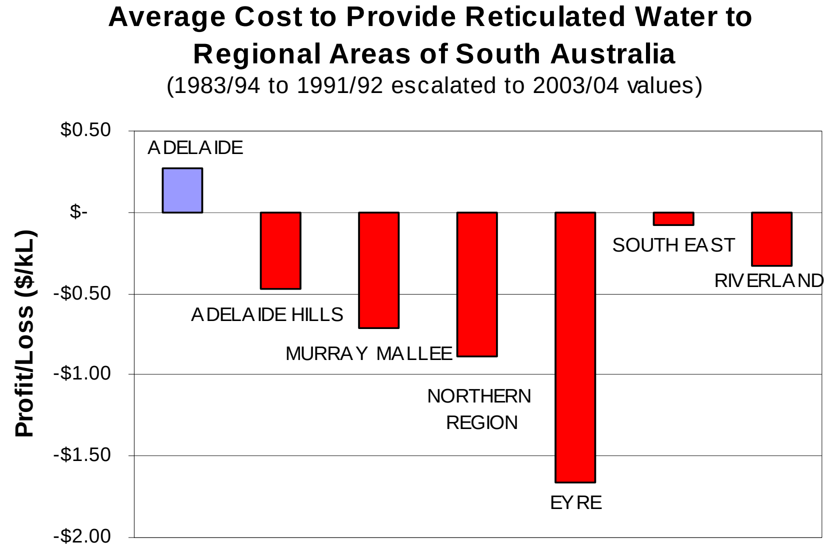
Figure 75 shows the geographic operating regions for SA Water, the State owned government water business. Since the 1980s, there have been discrete geographic operating regions within the water agency, however the boundaries that existed prior to 1996 and those that existed between 1996 and 2005 are different. The boundaries have recently been redefined in the current strategic plan initiative.



**Prior to 1996** **1996 to 2005**

**Figure 75 SA Water's Operating Regions (Homes 1998; SA Water 2005)**

Because of geographical and demographic differences, costs differ across systems and indeed within systems (SA Water 1999). While based on data last published in 1991/92, Figure 76 illustrates that the average cost of providing water to regional operating areas of South Australia varies widely.



*Source:*
*EWS Water Statistics Reports for 1983/84 - 1987/88 and 1986/87-1991/92*

*Construction:*
*Published anuual cost and revenue per kL for the 9 year period 1983/84 to 1991/92 has been escalated by CPI to 2003/2004 values and then averaged for profit and loss comparision.*

*Notes:*
1. *Cost and revenue data by region not published after 1991/92*
2. *CSOs not explicitly costed until 1995/96.*
3. *Water bill based on improved property values until 1991/92.*
4. *Current boundaries for water supply regions have changed.*
5. *Water services provided to most regional areas at the same price as Adelaide under the statewide pricing policy.*

**Figure 76 Indicative Costs to Provide Reticulated Water to Regional Areas**

Similar variations in true costs between operating regions are still likely to be true in 2005/06. However, the cost performance by operating region of the government business is no longer explicitly published. The most reliable indicators of performance are trends over time for each operating region because confounding factors, or differences in cost drivers, are held constant. Regularly changing boundaries (and names) of the geographic operating regions in South Australia adds to the difficultly in comparing performance data over time.

A key requirement of the national water reform agenda is ensuring that the cross subsidies are transparent (ESCOSA 2004). Today, in accordance with National Competition Policy, the State government pays a community service obligation (CSO) to SA Water for providing these services to country areas of the state. Consequently, where systems of water supply subsidies exist water harvesting and reuse projects can be economically disadvantaged.

### *5.9.3 Community Service Obligations*

Governments often require their government business enterprises (GBEs) to produce specific goods or services, to maintain a specific pricing structure, to provide concessions to particular users, or to utilise specific inputs or level of inputs. Where operating costs are higher than revenues, based on standard prices set by government, and the government deems that the service should continue, the financial gap is termed a community service obligation (CSO). There has been a tradition in Australia of governments imposing special requirements on GBEs to provide a range of social benefits and meet government policies. Many of these CSOs have been in place for decades. Where governments have taken a policy decision to not seek full cost recovery, and therefore the income received is not sufficient for viability, a CSO payment is made from the government to the utility. For such utilities, the revenue can be significant.

In 1997, the South Australian government implemented a policy on community service obligations (CSOs) in accordance with the National Competition Policy. Under the state CSO policy, SA Water receives supplementary payments from the government to provide services at less than the commercial price. The CSO payment compensates for the application of state-wide price within the higher cost country systems. These country services require extensive networks to provide water to a small customer base which results in costs that are higher than can be recovered under the state-wide price set by the South Australian government. Table 37 below sets out the revenue SA Water received from the South Australian government for each financial year, since the CSO policy was implemented.

**Table 37 Level of Funding for Community Service Obligations**

| **Business (1)** | **1995/96** | **1996/97** | **1997/98** | **1998/99** | **1999/00** | **2000/01** | **2001/02** | **2002/03** |
|---|---|---|---|---|---|---|---|---|
| Metro Water | - | 0.3% | 1% | 0% | 1% | 1% | 1% | 1% |
| Metro Sewer | - | 0.3% | 1% | 1% | 3% | 2% | 4% | 3% |
| Country Water | - | 45% | 42% | 45% | 44% | 43% | 44% | 41% |
| Country Sewer | - | 31% | 29% | 31% | 31% | 31% | 30% | 28% |
| Other | - | 0.0% | 0% | 4% | 3% | 4% | 3% | 2% |
| **Total** | (2) | **14%** | **13%** | **14%** | **14%** | **14%** | **14%** | **13%** |

*Source: SA Water Annual Reports 1996 to 2003.*

(1) *SA Water has two major business undertaking related to provision water supply and sewerage services in South Australia.*

(2) *CSO not explicitly costed until 1996/97.*

Typically, the CSO payment SA Water receives from the State government is equivalent to 14% of the total annual revenue, with nearly 80% being for the provision of services to country. The level of CSO funding is less than 5% for the metropolitan business but ranges between 30% and 45% for the country business. Despite annual reporting on the breakdown of revenue sources, including the level CSO received by SA Water, the true costs of providing reticulated water services to individual towns are not clearly defined or readily available at the moment.

Under the current CSO policy these payments are not contestable, and consequently, do not provide an incentive for SA Water to seek efficiencies in its country operations. The identification of CSOs is very important when introducing competition into a market previously dominated by a GBE monopoly where cross subsidisation (within the government business enterprise) has covered wide ranging activities including those which benefit particular groups, eg low incomes, sectors of industry, or people in remote or isolated areas (GSA 1996).

Clark (1999) suggested requirements for an efficient contestability structure (in addition to an industry regulator) should include:

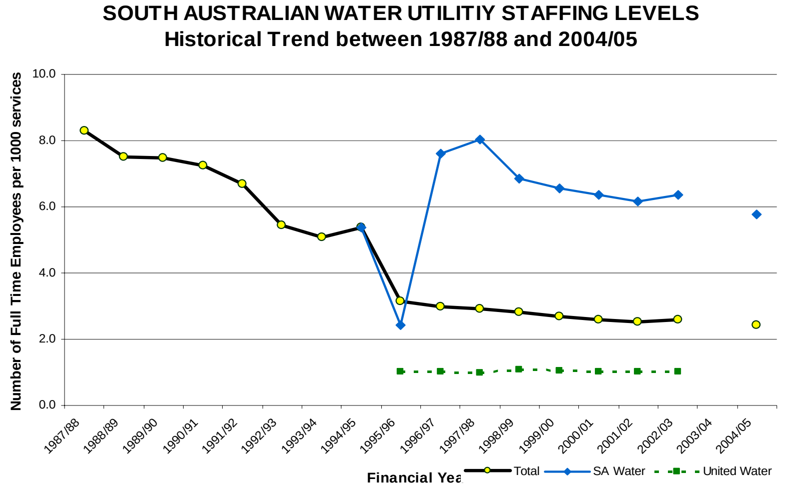
- identification of CSO values down to small system size. Data and methods are available for calculating CSOs down to individual customer levels;
- standardisation of the formulae used to calculate CSOs in order to avoid '*moving*' CSO estimates before and during the '*contest*' negotiations;
- a widely advertised CSO contest with sufficient reward for winning, ie. operate and maintain for a period; and
- a long term plan for the whole system which recognises the extended timeframe of the transition process and that aging infrastructure may not be replaced in its existing form.

In principle, all sections of the community should be charged efficient, commercial prices. The cost of providing an alternative water supply should be compared with the marginal cost of supplying additional water to that town. For example, if the true cost of water supplied to Whyalla from the River Murray is 2 to 3 times the current maximum charge rate, then there is significant economic justification, apart from the environmental benefits, to develop stormwater and effluent resources in Whyalla (Telfer 1997). Future reviews may consider the benefits of prices based on the cost structures of individual water supply systems. This could reduce or eliminate cross-subsidies and promote efficient resource utilisation (Competition Commissioner 1997).

### *5.9.4 Staffing Levels*

In recent decades, the size of the public sector in South Australia has significantly reduced due to increased contracting (outsourcing) of services. The private sector involvement in the provision of infrastructure through BOOT schemes has increased. These changes are driven by a world wide trend for the reduction in size of government funded entities and increased sophistication of the private sector. Increased emphasis is now placed on asset management, procurement practices and sustainable development. In 2000/2001, the ‘*non major*’ urban utilities in Australia collectively employed 3,359 full time equivalents (FTEs), spanning a range of 0.7 to 12.9 FTES per 1,000 properties (AWA 2002a). A business that outsources a relatively large number of functions would of course be expected to show lower normalised figures for the number of employees. Thus, employee numbers themselves are not readily comparable across utilities without taking into account outsource expenditures (AWA 2002a). This is also true for the water industry in South Australia.

Figure 77 shows the historical trend of the full time equivalents (FTEs) in the government business managing water services for 98% of South Australia's population.



Notes:
1. Between 1987/88 to 1995/96 in-house construction workforce phased out and replaced by increased use of contractors.
2. In January 1996, United Water commenced management of the of the Adelaide metropolitan systems under contract

*Source: EWS & SA Water Annual Reports 1987/88-2002/03, SA Water (2005) Towards 2010 Visonary Workshop Outcomes, Craig Nihill, United Water (October 2004)*

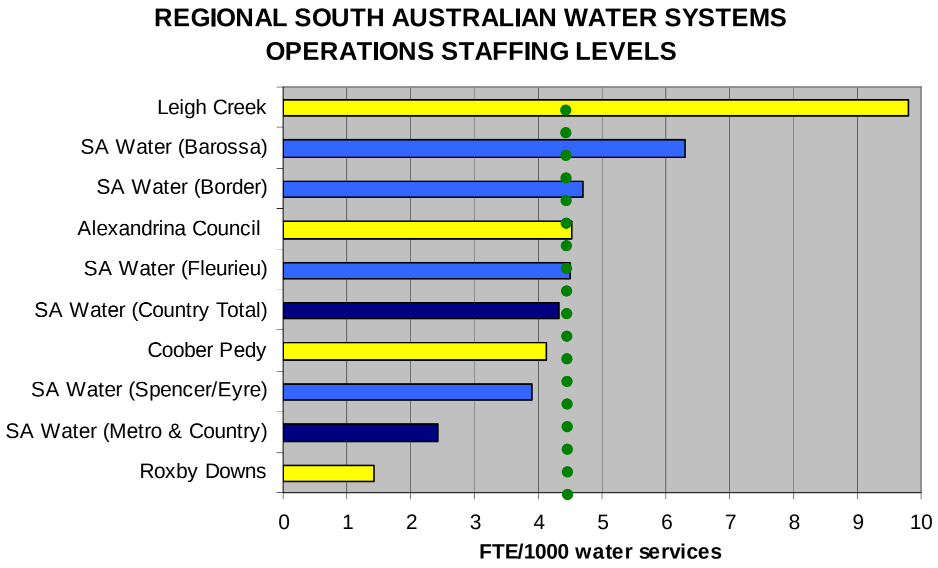
**Figure 77 Historical Staffing Levels for SA Water Systems**

Over the 18 year period, there has been a significant reduction from around 8 FTEs per 1000 properties down to just over 2 FTEs per 1000 properties to operate the government water supply systems. Until 1990/91, SA Water still carried out construction activities in-house using a large day labour construction workforce. The size of the construction workforce was systematically reduced and by 1995/96 in-house construction works had been phased out, ie. construction works are largely carried out by contract.

United Water, a private company, was awarded a 15 year contract, commencing 1 January 1996, to operate and maintain the water and wastewater systems for metropolitan Adelaide (SA Water continued to manage billing). At that time, around 400 employees left SA Water to continue employment with United Water. The United Water contract area essentially covers South Australia's single '*major urban*' water supply system and is being operated with around 1 FTE per 1000 properties excluding customer service and billing functions. A second major contract was let in 1996 for the construction and management of ten new water filtration plants to serve more than 90 rural communities (SA Water 1999d).

Since 1996, SA Water has operated the three '*non major urban*', six '*small*' and numerous smaller independent water supply systems in regional areas of the State. Over the last decade, the average staffing levels in regional areas has reduced from around 8 to just less than 6 FTEs per 1000 properties (including support functions). At first glance, the current staffing levels for SA Water may seem relatively high until compared with other Australian '*non major*' utilities (ie. those serving between 10,000 and 50,0000 properties).

No coordinated regular published information on total employees per 1000 properties served for '*small*' water supply systems (ie. those serving less than 10,000 properties) is available in Australia. In 2005, some information was prepared by SA Water as part of a series of strategic planning workshops. Information on staffing levels has also been obtained from selected regional non-government water utilities serving less than 2,000 properties. The average full time equivalents (FTEs) per 1000 properties for each region or town are presented in Figure 78.



*Sources: SA Water (2005) Towards 2010 Visonary Workshop Outcomes*
*Individual Operators for the Non-State systems (2006)*

**Figure 78 '*Small*' Regional South Australian Water Utility Staffing Levels**

In 2004/2005, the water utility staffing levels in South Australia spanned a range of 1.4 to 9.8 with a median of 4.5 FTEs per 1,000 properties. For very small water supply systems, such as Leigh Creek with 250 services and two operators, this measure is distorted and shows high normalised figures. The small size of many regional South Australian communities, combined with small community budgets, impede delivery of mainstream services (ie. services comparable to urban centres).

## 5.10 SUMMARY

The provision of water services in South Australia has been a triumph of adaptation and experimentation. This has included water supply, wastewater management, stormwater and irrigation systems throughout the state. In the face of disease, engineering trial and error and changing public attitudes, many obstacles have been overcome. Water has been a fundamental part of the political and social history of this State, and the spirit of adaptation and striving for improvement continues today.

Over the past decade, changes occurred in governance at a State and Federal level, as well as in the attitudes of consumers. These conditions, combined with the COAG Australian water reform process, have created an ideal opportunity for country towns to develop local water reuse projects. This has been particularly important where the existing water infrastructure is approaching its maximum capacity, or where the age of the infrastructure is approaching the end of its useful life. South Australia's urban areas have an advantage over their rural counterparts, because they possess a stronger revenue base. However, the balance between economies of scale and technological innovation is gradually shifting, which will serve to enhance the development of local water reuse projects (Clark *et al*. 1997).

**Table 38 Treated Effluent Reuse in South Australia**

| **Communal Wastewater Systems** | | **Effluent GL/y** | **Reuse %** |
|---|---|---|---|
| Metro Services | Sewer - SA Water (1) | 89 | 20 |
| Country Services | Sewer - SA Water (1) | 10 | 34 |
| | STEDS (Existing) (2) | 7 | 50 |
| | Sewer – Other /Private (3) | < 1 | 100 |
| State Estimate (rounded) | | 106 | 22 |
| | STEDS (Required) (2) | 3.5 | ? |

1. *Grant Lewis, SA Water (2006), these are communal deep drainage sewers. In addition to services in metropolitan Adelaide, SA Water services 21 towns in country region.*
2. *Lightbody & Endley (2002), these are communal effluent drainage systems operated by local councils serving in excess of 100 country communities.*
3. *Accounts for instances of communal sewers provided by local council or other bodies, ie. Coober Pedy, Leigh Creek, Roxby Downs and Woomera.*

Reuse is an effective alternative to wastewater disposal. The economics of reuse are site specific and depend on several factors including the cost of developing other sources of water; the costs of treating and disposing of wastewater; and the costs to treat, store and distribute water (Turcotte 1997). Reuse is not likely to be developed in many areas because it is less costly to dispose of wastewater and/or develop other water supplies. Where it is decided that a water reuse or a wastewater harvesting scheme is going to be adopted in regional or metropolitan South Australia, the question of what system is ideal, depends on a very broad set of factors. Some of the factors which need to be considered include:

- Temperature;
- Humidity;
- Sunshine hours;
- Wind velocity;
- Precipitation;
- Topography;
- Soil type;
- Available water resources;
- Available skilled workers;
- End use water quality requirements;

- Existing infrastructure; and
- Period of 'payback' required.

Water reuse needs to be considered as one of a range of alternatives for meeting the community's water needs. In some cases, it may become evident that it is not the best option for a particular region. Among the many direct benefits that flow from developing alternative water reuse resources, the most important ones for small or rural communities are:

- provision of alternative water sources that will relieve demand on current limited town water supplies;
- reducing pollution loads, especially phosphorus and nitrogen in effluent discharge and stormwater to surface waters;
- extending or developing recreational areas near townships;
- enhancing appreciation of water conservation techniques; and
- long-term potential for expenditure savings.

Several new technologies offer the potential to revolutionise water system designs, these being (Clark 1998):

- ever improving small-scale package treatment plants (technologies);
- the storage and recovery of excess surface waters in underlying aquifers (ASR); and
- ever-improving methods for designing, monitoring and controlling more complex water systems.

These technologies will allow the introduction of three new major water sources as listed below, all of which have been under utilised in the past (Clark 1998):

- urban stormwaters;
- recycled wastewaters; and
- brackish groundwaters.

The development of these reuse sources and their integration into existing sources via more efficient systems could more than double the availability of local water in South Australia. In general the new sources are located close to areas of demand and thus have a potential low cost of development. Since they are often associated with environmental degradation, their use can bring additional environmental benefits, with the input of limited low development cost (Clark 1998).

The existing practice of using water treated to drinking water standard for irrigation purposes is identified as inefficient. The adoption of local water reuse sources within small towns is often cost efficient and offers relief to existing potable water schemes. More extensive reuse of treated wastewater in South Australia is feasible, but is dependent on a greater awareness of its value as a resource, and greater acceptance by the authorities and public to its use. Investigations into reuse proposals should cover features necessary to safeguard public health and the possible long term detrimental effects on soils. Redeveloping the necessary infrastructure, management structures and changing community attitudes will be a very gradual and incremental process. As a state South Australia has already come a long way in improving the efficiency of our water use, which should be remembered when considering the enormity of the task that lays ahead.

# Chapter 6
# Case Studies from South Australia

*"It's tragic that this is so foreign to everyone."*

Christopher Sargent (2000)

## 6.1 INTRODUCTION

Water reuse is not a new concept in South Australia. There are records of it occurring as early as the 1930s. Early water harvesting and reuse schemes were inherently simple, often assembled with readily available materials and local construction expertise. Approximately 30 years ago, some progressive towns in South Australia recognised the potential of stormwater and treated effluent as water resources. In generally, only minimal record keeping has occurred; these projects were not implemented with research in mind. Nevertheless, the pioneering efforts have been a powerful endorsement for water conservation, by increasing awareness and demonstrating that communities which practise water harvesting and reuse can achieve positive outcomes. Other towns have subsequently been motivated to investigate opportunities to reduce their reliance on reticulated water supply, especially for the irrigation of recreational areas.

Since the early 1990s, interest in these schemes has increased sharply in South Australia inline with the progressive introduction of consumption based water pricing. The volume of treated wastewater effluent and urban runoff being reused in South Australia has almost trebled since 1986 (GSA 1999). With the implementation of permanent water use regulations in 2003 - the first for more than forty years - local water harvesting and reuse initiatives will become a more important water resource strategy for small communities. While considerable success has already been achieved, scaling up (ie. transforming) these '*local*' successes into more widespread water resource management reform to benefit more rural communities in South Australia still poses many challenges.

Water harvesting and reuse projects operating in different socio-economic and environmental conditions have been documented, however literature on small-scale initiatives is far more limited. A major obstacle to the research and development of small water harvesting and reuse projects has been the lack of data for the existing operational schemes to validate their sustainability, particularly in terms of social, economical, environmental, technological and institutional performance. A significant part of this research was therefore the collation of operational and financial information for selected South Australian water harvesting and effluent reuse schemes.

One of the objectives of this research is to develop a series of South Australian case studies that focus on assessing the challenges to achieving viable small non-potable water supplies. This chapter provides an overview of the common challenges and experiences encountered by South Australian communities during the planning (initiation), implementation (delivery) and operation of their local water harvesting and reuse projects. The aim of this chapter is to present a basic illustration of different schemes that have been implemented including what has been learnt through the experiences of different towns and organisations. However, given the small number of cases detailed below, the experiences and findings should be considered as illustrative rather than definitive. More detailed information about eleven selected full case studies is detailed in Part II.

## 6.2 SELECTION OF CASE STUDIES

Water harvesting and reuse is a sensible reality for the dry South Australian climate. Naturally, there are many small towns and urban centres scattered across South Australia have operational non-potable water supplies used for the irrigation of amenity plantings and sports fields. The source of water for these non-potable systems is locally harvested stormwater runoff and treated effluent generated by normal township development. The existing schemes also often incorporate a variety of practical, innovative or water saving technologies that are equally applicable to other areas. The assets are usually under the council’s care and represent a considerable investment by the community. However, to date sustainability of the systems performance appears to be a secondary objective to making the non-potable water supply successful.

Many South Australian initiatives have been documented, but few publications include candid discussions of both successful and failed strategies during the planning, implementation and operation phases. Fewer publications still document findings of critical analysis on historical operational and financial information of small systems. Critical examination of existing projects can offer information about how to facilitate more frequent development of water harvesting and reuse schemes in South Australia. These evaluations would be a valuable contribution toward helping existing initiatives reaching more communities (ie. scaling up) and improving understanding so that more sustainable water strategies and policies can be implemented in the future.

### *6.2.1 Location of Selected South Australian Case Studies*

Communities with alternative water supplies are generally enthusiastic about sharing their experiences. The case studies discussed have been chosen because of their diverse climates, population size, the type and complexity of the technology used, age of the systems, local access to spare parts and other resources, management and ownership arrangements. Figure 79 shows the location and prevailing climate for the twenty South Australian water harvesting and reuse schemes reviewed. Many other schemes exist around the State, which were not reported on as part of this research.

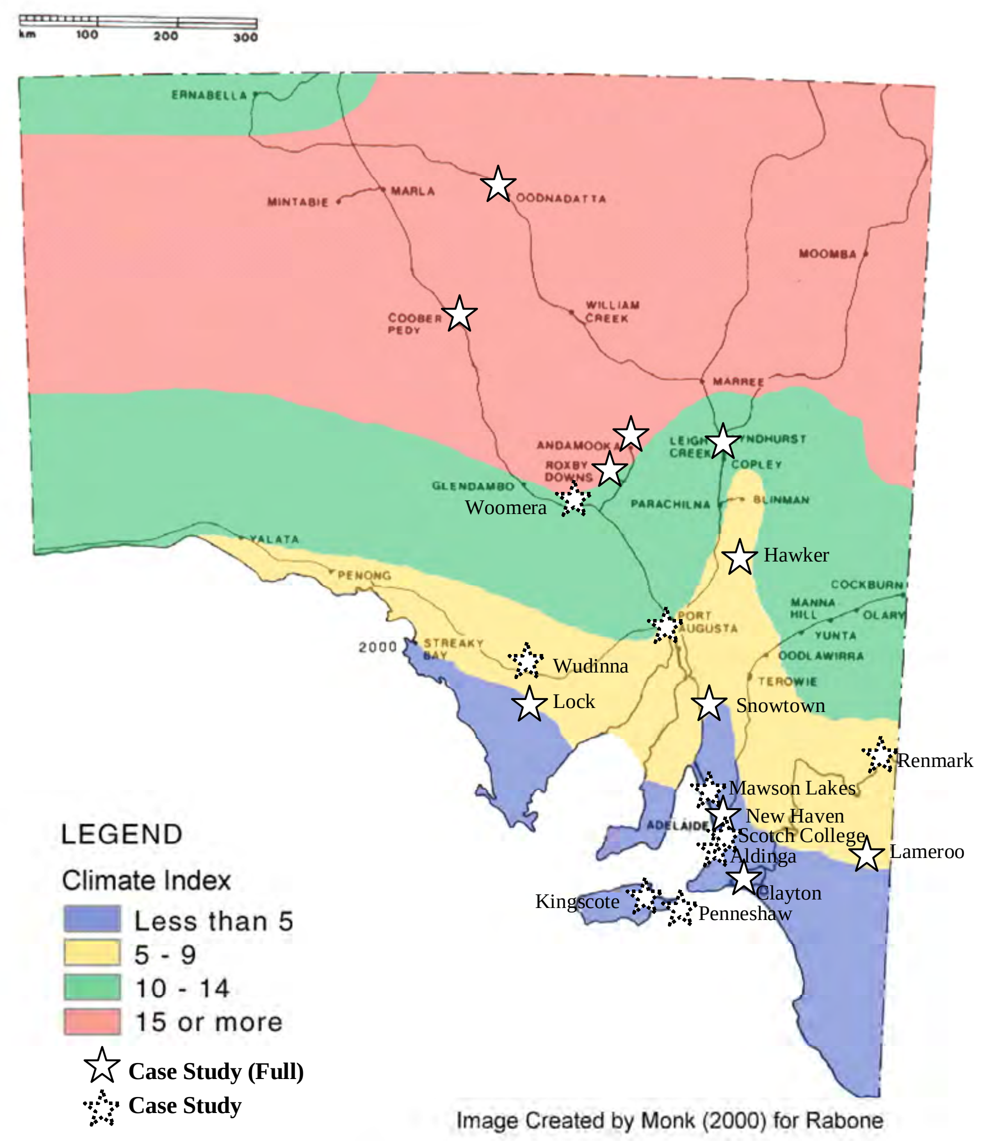


Image Created by Monk (2000) for Rabone

**Figure 79 Location & Climate Index for Selected Case Studies**

The twenty towns and schemes shown in Figure 79 were visited in order to gather valuable data and listen to the local experiences. Where published data existed, it has also been reviewed. More details and information about eleven of the selected schemes, marked as ‘full’ case studies can be found in Part II.

### 6.2.2 *Features of Selected Case Studies*

Table 39 lists the specific features of interest for the selected case studies and an indication of the availability of historical operational, financial and other information. Specific aspects of some case studies, including the fully written up ones and those referred to in forming the broad findings discussed, are highlighted in separate example boxes.

**Table 39 Selected South Australian Non-Potable Water Systems & Related Technology**

| TOWNSHIP / SCHEME | WATER RESOURCE MANAGEMENT REGION | CLIM. INDEX | POP(1) | TOWN WATER SUPPLY | | | NON-POTABLE WATER SUPPLY | | | | | RELATED INNOVATIVE TECHNOLOGY | | | | DATA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Admin. by | Source (Prime) | Potable Quality | Admin. by | Runoff | Effluent | Other | Distribution | RO | ASR | Subsurface Irrigation | Other | (Financial, operational, & other) |
| Andamooka | Far North | 15 | 491 | Community | Imported groundwater | ✓ | Community | - | - | Surface (Dams) | Carted | - | - | - | Individual conservation | Yes |
| Aldinga WWTP | Adelaide & Mt Lofty Ranges. | 3 | 4,638 | SA Water | River Murray | ✓ | Private (2) | - | ✓ | Groundwater | Dedicated | - | - | - | Public-Private Partnership | No |
| Clayton | Murray-Darling Basin | 4 | <200 | Local Govt(3) | Recovered surface water | Non-potable (4) | Local Govt | - | - | Raw River Murray water | Reticulated | - | ✓ | - | - | No |
| Coober Pedy | Far North | 22 | 2,762 | Local Govt | Groundwater | ✓ | Local Govt | - | ✓ | Saline groundwater | Dedicated | ✓ | - | ✓ | Household conservation | Yes |
| Hawker | Mid North | 9 | 319 | SA Water | Groundwater | ✓ (marginal) | Local Govt | ✓ | - | - | Carted | - | - | - | Uses abandoned local assets | Limited |
| Kingscote | Kangaroo Island | 3 | 1,529 | SA Water | Surface water | ✓ | Local Govt | - | ✓ | Potable water top-up - | Dedicated | - | - | - | Membrane Filtration | No |
| Lameroo | Murray Mallee | 5 | 459 | SA Water | Groundwater | ✓ | Local Govt | ✓ | ✓ | Groundwater | Dedicated | - | - | - | - | No |
| Leigh Creek | Far North | 14 | 585 | Private | Surface & Groundwater | ✓ | Private | - | ✓ | Potable water top up | Dedicated | ✓ | | - | Water conserving landscaping | Yes |
| Lock | Eyre Peninsula | 5 | <200 | SA Water | Groundwater | ✓ | Community | ✓ | - | Potable water top-up | Dedicated | - | - | - | Rainwater from silo sheds | Limited. |
| Mawson Lakes | Adelaide & Mt Lofty Ranges. | 4 | ~5,000 | SA Water | River Murray | ✓ | SA Water | ✓ | ✓ | Potable water top-up | Dual Reticulation | | | - | - | Limited. |
| New Haven Village | Adelaide & Mt Lofty Ranges | 4 | <200 | SA Water | River Murray | ✓ | Local Govt(3) | - | ✓ | Potable water top-up | Dual Reticulation | | | ✓ | On-site sewerage treatment | Limited. |
| Oodnadatta | Far North | 21 | <200 | SA Water | Groundwater | Non potable | SA Water | - | - | Groundwater | Reticulated | - | - | - | - | Yes |
| Penneshaw | Kangaroo Island | 3 | <200 | SA Water | Seawater | ✓ | Not Applicable | - | - | - | Dedicated | ✓ | - | - | - | No |
| Port Augusta | Mid North | 11 | 12,516 | SA Water | River Murray | ✓ | SA Water | - | ✓ | Potable water top-up- | Dedicated | - | - | - | - | Limited. |
| Renmark | Murray-Darling Basin | 8 | 4,291 | SA Water | River Murray | ✓ | Local Govt & Private | - | ✓ | Raw River Murray water | Dedicated | - | - | - | - | No |
| Roxby Downs | Far North | 17 | 3,454 | Local Govt | Groundwater | ✓ | Local Govt | ✓ | ✓ | -- | Dedicated | ✓ | - | - | Water conserving landscaping | Yes |
| Scotch College | Adelaide & Mt Lofty Ranges. | 3 | NA | SA Water | River Murray | ✓ | Private | - | - | Brownhill Creek (surface) | Dedicated | - | ✓ | - | - | Limited. |
| Snowtown | Mid North | 5 | 358 | SA Water | Surface water | ✓ | Community | ✓ | - | Potable water top-up | Dedicated | - | - | - | - | No |
| Woomera | Far North | 16 | 544 | Private | River Murray | ✓ | Private | ✓ | ✓ | Potable water top-up | Dedicated | - | - | - | Water conserving landscaping | No |
| Wudinna | Eyre Peninsula | 5 | 1,005 | SA Water | Groundwater | ✓ | Local Govt | ✓ (Rock) | - | Potable water top-up | Dedicated | - | - | ✓ | Uses abandoned local assets | No |

*Notes:* (1). *Population as published by the Australian Bureau of Statistics Census 2001*
(2) *SA Water has recently taken over the facility upon receivership of the company.*
(3) *Local Council is seeking to hand over assets to SA Water.*
(4) *From 2006 see Part 11 for more details*

## 6.3 DISCUSSION OF FINDINGS FROM CASE STUDY REVIEWS

Qualitative and quantitative data (where available) was gathered for the selected successful South Australian water harvesting and reuse projects. From this information, an array of common and contrasting opportunities and challenges encountered during initiation (planning), delivery (implementing) and operation of small-scale non-potable water supplies has been identified. Despite an observed high degree of congruence in experiences between schemes and communities, the broad findings discussed here should be considered illustrative rather than definitive. This is primarily a result of a widespread lack of specific and validated records available for most of the existing operational schemes. Nevertheless, the broad findings can contribute to the effort to develop policies and practices to achieve more sustainable water infrastructure in South Australia.

### *6.3.1 The Common Driving Forces*

Many towns in South Australia use harvested stormwater runoff and/or treated sewage effluent for the irrigation of amenity plantings and sports fields. The many direct benefits which have been experienced by towns that have developed local, alternative water resources for small communities can include:

- **FINANCIAL SAVINGS** by using harvested stormwater runoff, treated effluent or brackish groundwater to supplement or replace mains water to irrigate ovals, parks, or other public areas, the expense of purchasing potable mains water for irrigation can be reduced significantly. In some cases, assistance with the capital funding is provided by government bodies.
- **EXTENDED or NEW RECREATION AREAS** where water is scarce, developing alternative water resources may be the only opportunity to green the town oval or cultivate a park, (also using low water use landscaping principles) providing a place for people to congregate.
- **INCREASED COMMUNITY PRIDE** when members of the community have been involved in working together, they feel a sense of ownership over the project and its outcomes; they are proud of the new assets.
- **WATER CONSERVATION AWARENESS** the planning and development of alternative, non-potable water supply schemes can provide an opportunity to enhance appreciation for water conservation techniques.
- **POLLUTION ABATEMENT** meeting increasingly stringent effluent and stormwater discharge requirements to surface waters can be quite costly, but can have far-reaching benefits.
- **SOURCE SUBSTITUTION** using alternative water sources for non-potable purposes offers relief where town potable water supplies are limited or stressed such as local underground resources and the River Murray. By replacing the potable water used with non-potable, an increased population can be served by an existing supply.

### *6.3.2 Summary of Influencing Factors*

The case study reviews revealed that the factors impacting on the viability and sustainability of water harvesting and reuse projects are different for small rural communities and large urban centres. Using urban solutions and standards without holistic consideration of rural social, economic and environmental realities is unlikely to meet the long-term needs of small communities. The influence of these factors for each scale are summarised in Table 40 below.

**Table 40 Factors Affecting Water Harvesting and Reuse Projects**

| FACTORS | RURAL/SMALL | URBAN |
|---|---|---|
| **Political Environment** | | |
| • Political pressure | Medium - High | Varied |
| • Political awareness | Medium | Medium |
| **Human Resources** | | |
| • highly skilled level staff | Unlikely | Available |
| • medium skill level staff | Unlikely | Available |
| • voluntary labour (unskilled) | Often available | Generally absent |
| **Maintenance Arrangements** | | |
| • repair skills | Low – medium | Medium - High |
| • spare parts | Generally absent | Sometimes available |
| • back-up support | Not available | Generally available |
| **Income** | | |
| • potential for revenue collection | Low | High |
| **Non-Public Options Available** | | |
| • for water supply (potable) | Sometimes available | Not available |
| • for sewerage | Available | Sometimes available |
| **Public Land** | | |
| • availability of land | Available | Limited |
| **Community Involvement / Interfaces** | | |
| • user involvement in decision making process and implementation | High | Limited |
| • government input | Backup support advice and coordination | Coordination |
| • legislation and control requirements | Difficult to negotiate | Achievable |
| • industrial developments | Limited | Substantial |

Literature fostering sustainability in small water supply services often identifies features that tend to be associated with smaller scale initiatives. However, many challenges remain with verifying just how sustainable local water harvesting and reuse systems are in small communities. Nevertheless, the existence of small-scale non-potable water supplies in towns across South Australia, including some with the harshest climatic conditions (ie. high climate index), suggests that strategies can be developed to overcome the impact of these challenges on their viability. Increased use of stormwater, rainwater, brackish groundwater and treated effluent in other urban and country areas of the State is achievable.

## 6.4 FACTORS THAT SUPPORTED SUCCESS IN TOWNS

Analysis of the challenges and opportunities may help other communities develop their assets (ie. water resources, existing infrastructure, human and other resources) in a way that takes best possible advantage of the strengths available to the town. By looking critically at the experiences of communities with an operational water harvesting and reuse project, it is possible for others to craft a strategy to plan and implement a viable non-potable water supply in their own. The common factors that supported success of water harvesting and reuse project in South Australian towns are now discussed.

### 6.4.1 *A Catalyst to Meet Needs*

Recreation and social aspects of community life in many South Australian towns revolve around sport. However, the increasing price of reticulated water made it difficult for small communities to meet the cost associated with continued irrigation of the town oval. Financial relief was the catalyst for the small communities of Snowtown and Lock to seek an alternative independent supply of water that would enable adequate, continued irrigation of the town oval. For Lameroo, the catalyst was the need to solve increasing stormwater and septic tank effluent disposal difficulties in the mid 1970s. In Roxby Downs, the catalyst was the need for recreation facilities and a pleasant urban landscape for the resident mining workforce within a harsh environment.

### 6.4.2 *Feasibility Investigations*

The proper use of feasibility studies was observed in the successful development of a several small of South Australia's the non-potable water supply schemes. For example, the District Council of Elliston, on behalf of the Lock community, engaged an engineering consultant to assess the feasibility of water harvesting and reuse projects for Lock before embarking on their original and subsequent stages in 1993 and 2006 respectively. Similarly, the community of Snowtown sought specialist assistance with its investigations into the feasibility of harvesting stormwater runoff for irrigation purposes. In both cases the recommendations of the feasibility study enabled the community to make an informed '*decision to proceed*' with the non-potable water supply project and strengthen support within the community.

The feasibility study provides a broad review of the primary issues that need to be considered when embarking on a possible water harvesting and reuse project. It provides a logical structure and a direction to progress the idea from conception, through to design, construction and operation. It provides a description of the possible influencing issues that need to be considered, their limitations and how to apply them so as to ensure a meaningful outcome. Simple checkpoints can be executed before committing additional resources and cost thereby ensuring that the objectives and/or expectation of the stakeholders and community are satisfied.

When undertaking the feasibility study for a township, some of the fundamental information to be collected and resolved, relates to:

- the amount and sustainability of the water available for harvesting;
- the most appropriate harvesting and reuse options;
- the minimum quality of the reuse water acceptable;
- the economic viability of the project; and
- security of public health related issues.

The collection of sufficient baseline data is needed to permit simple cost determinations for water harvesting and reuse systems in each town. This helps to establish a reference point for stakeholders and the community when discussing the various systems. It is also helpful if stakeholders and the community can review other background data which has relevance to the systems being examined. The final arrangement of a water harvesting and reuse scheme depends on a number of components and objectives to suit the needs of the local community.

### 6.4.3 Regional Lifestyle

People living in rural and regional areas of Australia choose to live there for a multitude of lifestyle related reasons such as clean air, reduced congestion, accessibility to open spaces and a stronger sense of community (Productivity Commission 1999). These attributes continue to draw people to country areas and retain those who already live there. Lifestyle factors are difficult to quantify, but were identified by many participants in this research as being the reason they chose to live in country South Australia. Many people living in rural and regional areas have lifestyles which place high priority on water conservation as they appreciate the surrounding environment. This can be an important when attempting to connect with regional communities and gain their support.

### 6.4.4 Community Spirit & Pride

South Australian rural communities are generally self-reliant because of their remoteness. People tend to concern themselves with how things will impact on the success and future of their own community. This community spirit can be harnessed to stimulate interest in the development their alternative water resources which was key in the success of the case studies detailed. Each water harvesting and reuse project must be tailored to suit the community's unique social and economic environment. Projects that are locally owned and controlled, locally relevant, capable of local management tend to be the most successful. These characteristics are all interrelated and co-dependent.

The self reliant potential of local communities should be encouraged more widely to ensure the effective use of use of water within South Australian country towns. In the *Draft Guidelines for the Assessment of Water Management Opportunities for Country Townships* (see Appendix 19), Hoffrichter, Swift and White (1999) promote the formation of alliances with the local community that facilitates efficient use of water and supports community growth. If adopted, such an approach can be expected to support capacity building programs and information exchange to ensure the effective use of use of human, financial, and technical resources for water management in South Australia.

### 6.4.5 Motivated Individuals & Steering Committees

New initiatives in regional areas are generally conceived, planned, resourced and managed from the time the existing infrastructure, human and natural resources of the community. The case studies demonstrated that a community-wide catalyst is needed to focus energy and thinking about what must be altered and what the initiative needs to achieve. The development of the local non-potable water supplies for Lameroo, Snowtown and Lock was a long, slow process and their success was a result of the work of dedicated members of the community and council steering the process. The experience for each community is that a small number of motivated individuals can be responsible for developing and using the required commitment from the local council and the community.

In the case of Lock, the steering committee came up against a few people in the community who were reluctant about the project and initially offered little support. However, publicity about the need to fund the project and the community's role in undertaking much of the work encouraged interest and an atmosphere of anticipation. Because significant investment of community resources was made, people were interested in how the investment was performing, and widespread support slowly grew within the community. The community of Lock is understandably proud of the new assets created and celebrated their achievements with an opening day. The school children where given the task of naming the dam through a competition. The winning name, '*Kukatha*', is the name of the Aboriginal tribe that used to pass through Lock on its trade route.

### 6.4.6 Optimising Effective Use of Existing Infrastructure

It has become apparent through the case studies that communities need to learn to see the potential benefits that can be obtained from infrastructure and landscapes that are already in existence. Physical resources of a community cover a variety of areas including water supply infrastructure, private facilities (ie rainwater and bores), the availability of operational and maintenance personnel and information gathered from prior studies (Hoffrichter *et. al.* 1999). For a harvested non-potable water supply, existing road infrastructure (ie. sealed or unsealed, road width, kerbed), stormwater drainage system (ie. deep drainage or surface, discharge points) and wastewater system influence the local opportunities. The existing township infrastructure is likely to be an integral part of any solution and therefore a good understanding of its limitations is necessary.

A number of operational non-potable water schemes incorporate early water infrastructure developed to harvest local water resources. The water needs of early South Australians were met by local water management schemes, however these frequently suffered water shortages due to extended periods of low inflow (ie. dry spells). Many of these were eventually abandoned in favour of the convenience and reliability provided by major pipelines. Hawker (climate index 9) in the mid north of South Australia and Wudinna (climate index 5) on Eyre Peninsula are good examples where abandoned water infrastructure has been incorporated into local water harvesting projects.

The aim of the Wudinna local water harvesting project was to reduce the community's reliance on State Government reticulated supply, provide improved quality, and provide a cheaper water supply for community managed sporting facilities. Until 1998, Wudinna was totally reliant on water that is piped from the Tod Reservoir, some 220km to the south, or on rainwater tanks for domestic use. Prior to the completion of the Tod Pipeline in the 1920s, the original supply for Wudinna was a granite rock outcrop known as Polda Rock. After 75 years, the abandoned local rainwater harvesting infrastructure has been recommissioned by the community as described in Example 30 below.

**Example 30 Local Water Harvesting: Wudinna, South Australia**

*Aboriginal people belonging to the Ku-Ku-Tha tribe, camped around the granite rock outcrops, living on the plentiful supply of wild game and freshwater from the granite pools. By the mid 1800s, central and western Eyre Peninsula was known to have potential for agriculture, but unavailability of surface water and irregular rainfall hindered development. Commencing in 1913 with the scheme at Minnipa Hill, and continuing throughout the 1920s, a number of local granite outcrops were developed by the State Government, to harvest rainwater for use by pastoralists, the railways and townspeople.*

*Polda Rock was the original supply of water to the Wudinna township prior to the Tod Pipeline completion in the 1920's. Rainwater falling onto the surface of the rock is caught by a stone drain surrounding the base of the rock. The water is then channelled into a reservoir and three 2ML tanks. Water at Polda Rock can be gravity fed the entire 7km from this reserve into the township. At Polda Rock, the walls, drains and tanks (see* Figure 80*) were constructed in 1919-1920 and the reservoir was constructed in 1922. These assets formed an important component in the water catchment facility for nearby farms and the town of Wudinna.*

**Low walls around base of rock**

**Reservoir**

**Open drains** **Storage Tanks**

**Figure 80 Polda Rock Water Harvesting Facility (Rabone 2006)**

*In 1928, a more reliable water supply was established with the development of the Tod Reservoir Scheme and piping of water from near Port Lincoln (about 220km south). Most of the granite catchment schemes were then abandoned and deteriorated (ie. were no longer functional). In 1998, after 70 years, the District Council of Le Hunte, in recognition of the Eyre Peninsula's water scarcity, undertook a major integrated project to harvest storm and rain water runoff for the irrigation of public amenities in the Wudinna township. The project involved installation of several storage tanks within the township and approximately 40km of sub-surface irrigation under the grassed playing surfaces.*

**Irrigation Storage Tanks** **Irrigated Oval**

**Figure 81 Wudinna – Non-Potable Water Assets (Rabone 2006)**

*The recommissioning of this local water supply scheme has allowed the community of Wudinna to maintain a green playing surface on the oval during summer, despite the introduction of permanent water use regulations in December 2002 on Eyre Peninsula. Approximately 24ML per annum of water can be harvested from this catchment. Formal usage of the water under the scheme started 1 July 2002 and presently, the town oval, Wudinna Area School, Apex park playground area, Wudinna Bowling Club, and community parklands are linked to it. To date around 100ML of water has been run through the scheme as a direct saving to mains water previously used to irrigate the recreational facilities and reserves of town. Users are levied for water use and consumption. Currently under consideration is effluent reuse from the Septic Tank Effluent Disposal ponds.*

*Source: District Council of Le Hunte (2000) & Andrew Buckman (2006)*

At Hawker, the two open water storages to the south-east of the town to harvest surface water and supply the railway and township were constructed 1985 and 1900. By the mid 1965s, the two dams were abandoned because of unreliable yields and poor water quality in favour of more reliable but poor quality groundwater supply (SA Water 1998). The extensive array of contour drains, storage dams, weirs and pumping systems that formed part of the previous Hawker water supply was no longer required (van der Wel & McIntosh 1998). Mr Bernie Matthews, a resident of Hawker, initiated a community project in the late 1970s to return part of the abandoned infrastructure to service, one dam and the elevated railway tank, to provide a source of low salinity water suitable for garden watering. In this case, the sealed roads and topography of the town also contribute to maximizing the runoff. This community stormwater harvesting system in Hawker is still in operation (refer case study review in Part II).

Despite being low rainfall districts with few conventional water catchment options, the communities of Hawker and Wudinna have successfully incorporated previously abandoned water infrastructure into their water harvesting projects. These schemes deliver a service that has been welcomed by the community and for which they have a developed sense of ownership. However, as with the early systems in the past, the reliability of the local non-potable water supply systems will be strongly affected by the rainfall variability. It is imperative that these communities investigate strategies to manage customer expectations during times of water shortages caused by extended periods of low rainfall.

### *6.4.7 Willingness to Charge*

In South Australia, few local government authorities provide local water supply and sewerage services. Where this occurs, these small scale services usually operate as separate independent businesses from local government operations, ie it is effectively community owned. As far as practicable, council and private water supply systems follows standards of operation for water equivalent to the standards set by the state government agency (SA Water). Unlike SA Water, for these independent systems, the local operating authority is not constrained by the State-wide pricing policy and does not receive a '*community service obligation*' payment from the South Australian Government. These non-State government systems demonstrate that financial sustainability, in terms cost recovery for operational costs, is possible for small water supply systems with less than 2,000 services where there is a willingness to charge for water services.

Substantial government funding was required for capital works, however the Coober Pedy potable water supply has subsequently been run at full cost recovery for nearly 20 years, with sufficient revenue to allow for operation and maintenance costs. To achieve this level of financial sustainability, residents of Coober Pedy purchase their potable water at a cost of more than double the State-wide price. Similarly, the local water supply administration in Andamooka, Clayton, and Roxby Downs raise revenue to cover the operations and maintenance costs without a subsidy from the South Australian Government. In fact, in Andamooka where no local government exists, revenue raised by the sale of water is an important source used by the Progress Association to deliver other services within the community.

### 6.4.8 Low Water Use Landscapes

It is possible to create pleasant external areas in towns situated in arid or semi-arid regions of South Australia where water is in short supply and the climate is harsh (Zwar 1985). Some good examples of low water budget public landscaping in the areas with a climate index of 10 or more are Leigh Creek, Roxby Downs and Woomera. Use of adept landscaping and sensible water practices has allowed the modern townships of Roxby Downs and Leigh Creek be attractive country towns despite their harsh climates. The arrangement of landscape elements such as trees, shrubs, landforms, walls and fences in conjunction with buildings can have an influence on microclimate in and around homes, schools, parks, shopping areas and other public spaces.

In terms of water and maintenance, lawns are one of the most expensive elements in public landscaping and private gardens. Hence, reducing the area of grass results in considerable savings (Zwar 1993). In low use areas, hardy native groundcovers make effective lawn substitutes and they also require minimal mowing or pest control treatments. In high use areas, lawns can be replaced by paving or small areas of lawn combined with shade from pergolas and large trees. In Roxby Downs, the main grassed playing areas are supplemented by other sporting and recreational facilities, such as bowling greens, tennis and netball courts where artificial turf has been incorporated. Where lawn is used it should be maintained without wasting water. Some excellent low water use grasses, suitable for arid climates are now available.

The means by which the water is applied is also important. Drip irrigation is the most efficient way of watering trees and shrubs in the arid zone and is ideal for establishing new plantings. Once installed, a drip irrigation system may be left in place permanently but after the fourth year trees may receive only supplemental irrigation when drought conditions prevail. In Roxby Downs, drip irrigation is used on all plantings and some routine maintenance is required. Stone, bark and other natural mulches should be used to reduce the evaporation of soil moisture. Pergolas, awnings, and shaded areas can provide protection for plants and create external environments which are largely protected from temperature extremes.

The principles applied in water efficient public landscaping in Roxby Downs and Leigh Creek are portable and can be applied across a broad range of climatic conditions and scales of development in many areas of South Australia. Woomera was encouraged to undertake significant redevelopment of public landscapes based of the success achieved in Roxby Downs and Leigh Creek. Many other towns with access to reliable water piped are not constrained by local climate (Murray-Leach 2003; Marohasy 2003) and persist with landscaping and gardening practices that evolved in gentler climates (ie. climate index less than 5). .

Substantial water and cost savings can be achieved by developing water harvesting and reuse schemes together with water conservation techniques, careful planning, good irrigation practices and sensible plant selection. Obviously the climate, and also soil types, availability and quality of water, can greatly affect the development of parklands and gardens in regional towns. Incorporating water conservation measures as part of the overall landscape planning and design process presents few if any problems.

### *6.4.9 Appropriate Technology*

Historically, large centralised organisations have done well installing improved water supply services, however they have often been unsustainable. Smaller and/or locally based organisations, from community progress associations through to local government, often have better 'track records' regarding sustainability, but their systems are usually limited in scale. The limited nature of the scale of these operations is not a concern, as long as it meets the needs of the community in question. Selection of appropriate technology can bring advantages to people living in small communities or remote locations. In the context of small communities, appropriate technology can be viewed as small-scale, energy efficient, environmentally sound, and self-sustaining. Because of the small scale, many of these water harvesting and schemes only have a minimal impact on the local environment.

The process for developing and managing a small local water supply are the same as the public system, but may be carried out to a different level of service. Small communities are usually more flexible with lower standards than urban communities. Small communities with limited potable supplies should be given the opportunity to have access to non-potable water if it conserves their potable supplies and enhances their community. While small communities are not averse to accepting higher risk (lower standards), health authorities in generally impose conservative standards across the board for all situations that do not account for possible less demanding local conditions or local integrated water, wastewater and reuse systems. Sourcing skilled people to operate and maintain the equipment in regional areas is therefore very difficult. The more inherently simple systems developed primarily using local expertise, were better understood and maintained by local resources and therefore appeared more likely to succeed in the long term.

## 6.5 KEY CHALLENGES FOR REGIONAL AREAS

Learning to reconcile different perspectives is an important part of the process of introducing sustainable new technologies. Some of the common challenges that tended to constrain success of water harvesting and reuse projects are discussed.

### *6.5.1 Government Liaisons & Approvals*

The water industry operates within a complex regulatory framework, subject to relevant Federal and State legislation and regulations, operating licences, and guidelines. Consequently, liaison with and seeking approvals from appropriate government agencies is an important part of the planning process for a water harvesting and reuse scheme. Early water harvesting and reuse projects found this a complex process and time consuming activity which added significant delays and much frustration to the implementation of individual projects. There were no clear guidelines on how to handle this aspect of water harvesting and reuse projects and the legislation that applies require liaison with a number of different government departments.

In retrospect, the lengthy delays observed in obtaining approvals for the early small-scale water harvesting and reuse initiatives stemmed largely from institutional resistance towards locally managed non-potable water supply systems. The key reason cited by the dominant water supply organisation and other regulatory agencies for the entrenched resistance to the new local water resource management approach was the potential increased risk to public health. A common strategy to avoid institutional resistance is for the government to grant exceptions with respect to subsidy levels, technical standards and cost sharing policy to some demonstration projects when a proposal favours the current political climate. These artificial institutional arrangements can allow progress to be made more quickly and reduce the need for lengthy negotiations that typically accompany policy changes.

Nevertheless, development of early independent non-potable water schemes in South Australia irrespective of the scale (ie. small or large) has typically been a long slow process, sometimes taking as long as five to ten years to fully implement. Factors that contributed to the delay in commissioning these schemes in South Australia include (Sickerdick & Desmier 2000):

- Developing and evaluating options for a reuse scheme;
- Sourcing and seeking agreement on funding commitments;
- Prepare legal documents to protect the interests of parties involved; and
- Time to obtain the necessary regulatory approvals.

Despite these difficulties in developing water reuse schemes, the large and small scale schemes operating in South Australia show that success is possible. They were needed to establish success and generate support for the new local water resource management approach and reduce the length of negotiations required for subsequent proposals. For example, it took four years to upgrade and recommission in 2002 the local stormwater harvesting system at Wudinna. In the case of the Renmark effluent treatment plant and reuse scheme it was three years from inception to commission in 1997 (see Example 27).

**Example 31 Reuse of Treated STEDS Effluent: Renmark, South Australia**

*Renmark is one of more than one hundred towns which rely on septic tank effluent disposal schemes (STEDS) for the provision of wastewater services in South Australia. The effluent evaporation lagoons in Renmark were overloaded, causing untreated effluent to leach directly into the River Murray. In addition to contributing to environmental damage, a valuable community resource was being lost. In November 1994, a new effluent treatment and management program was announced for Renmark. Instead of relocating and increasing the capacity of the ponds, a new effluent treatment plant was to be built near the existing evaporation ponds. The system will allow treated effluent water to be used for irrigating parks, ovals and gardens within the township.*

*The Renmark WWTP, constructed by Adelaide-based firm Hickinbotham Aquacycle, was opened on 5th November 1997. The WWTP treats 650kL of town effluent per day from 4,000 homes. The existing ponds were retained as drying basins for sludge from the treatment plant, which can be dried and used as fertilizer in accordance with guidelines. The ponds are also able, in an emergency, to store untreated or partially treated effluent should the new system fail to meet the reclaimed water quality standards.*

**Treated Effluent (front right) & Emergency Storage (background)**

**Treated Effluent Storage Tanks (background)**

**Figure 82 Renmark - Reuse Facilities (Rabone 1997)**

*The plant treats water to quality standards that enable the council to reuse it. Nearly 8km of irrigation pipe distributes the treated effluent to almost 10ha of the community facilities around Renmark. It was estimated that the reuse system would more than half the town's irrigation expenditure.*

**Irrigated Ovals 1 & 2(of 3)**

*Irrigated Tennis Courts*

**Figure 83 Renmark - Irrigated Assets (Huppatz 1997)**

*The award winning $1.25m effluent treatment plant facility was solely financed by the Renmark Paringa District Council ratepayers. The council indicated that debts incurred in building the system would be cleared by 2001, thanks to lower interest rates and refinancing the plant's 15 year loan. As for the quality of the water, Cr Richard Stewart showed his confidence in it by actually drinking the treated effluent. Happily, independent tests reveal that the treated effluent presents no danger to public health.*

*Source: Hickinbotham (1997); Murray Pioneer (1994 & 1997)*

### *6.5.2 Obtaining Project Funding*

Prior to 2000, many communities that successfully initiated a water harvesting and reuse project in their town were unable to attract financial support from the grant and subsidy programs in existence. Difficulty in obtaining funding has been a common experience for many regional areas wanting to embark on reuse or alternative water harvesting projects. To be attractive to investors, projects have to be demonstrably technically feasible and environmentally and socially sustainable. For the pioneering water harvesting and reuse projects in South Australia, this was often overcome through contributions and grants made available for '*demonstration projects*'. Demonstration projects, like the original aquifer storage and recovery at Andrews Farm and the small onsite wastewater treatment plant at New Haven Village, are also initially supported by government agencies and research bodies for the first few years of operation.

Many of the early South Australian regional projects were funded by accessing progress association revenue (where land was held for cropping), support from local commercial enterprises and community fundraising efforts. For example, all grant applications submitted by the Lock community for Stage 1 of the stormwater runoff harvesting project were overlooked and not supported. Lock was fortunate to have an active progress association that holds land cropping that generates a revenue stream for the community. Without it the community could not have financed their 70% share of their stormwater harvesting project in 1993. Because of the progress association, the local council made a $30,000 loan to the community, in addition to providing a 30% in kind contribution towards the capital cost. Over a 10 year period, the football club and progress association were able to pay the loan back.

The situation for Snowtown was similar. Here the community was required to raise nearly 60% of the funding to construct their stormwater harvesting scheme in 1982. The balance of the capital cost was sourced from the local government. Moore (1990) reported a 5 year payback period for the capital cost in terms of continued purchase of an equivalent volume of water from SA Water at the state-wide price. Many other towns, without the capacity to raise funds from community holdings, have not been able to invest in the necessary infrastructure. In complete contrast, community facilities provided by the Andamooka Progress and Opal Miners Association are funded from the revenue stream generated by the sale of water.

Today, attracting financial support for small regional water harvesting and reuse projects is becoming less of an issue as more communities demonstrate their ability to recover costs for at least the operation and maintenance costs. Under the 2004 National Water Initiative, the Australian Government established the Australian Water Fund with a contribution of $2 billion. The fund is comprised of three programmes - Raising National Water Standards ($200million), Water Smart Australia ($1.6billion) and Community Water Grants ($200million). The Water Smart Australia Programme is targeted for large-scale projects with the minimum level of funding through the program being $1million. The Community Water Grants Programme will provide up to $50,000 to communities to provide for projects that will result in wise water use and involve local community.

The specific financial assistance programs for which a project may be eligible would depend on the type of organisation applying, other organisations participating in the project (if any), and the specific type of study or project funds for which the application is being prepared. Subject to eligibility requirements, funding may be available from Community Water Grants Programme and Water Smart Australia Programme for South Australian towns and regional communities to develop non-potable water supply projects and infrastructure. However, neither of these programmes are currently available should the level of financial support required fall in the $50,000 and $1million range. Based on the case studies reviewed, the capital cost of a majority of the water harvesting and reuse scheme towns in South Australia are likely to fall within this range.

Regrettably, the current levels of funding set in the Australian Water Fund initiative will have limited impact in '*scaling up*' of small scale non-potable water supplies to more Australian communities. It is obvious that funds to finance small-scale water projects still need to be increased in the coming years to continue to accelerate the development and uptake of smart technologies and practices in water use across Australia. This will enhance the sense of local ownership that is essential to increase the efficiency of water projects and small-scale projects make it easier to find local funds to finance them.

Financing of water harvesting and reuse projects must be carefully evaluated to ensure the amount of money needed for proper operation and monitoring of the system is available. Financial assistance can be obtained from government agencies, service charges, connection fees and public revenue (taxes). Financial entities participating in a project may include investor-owned utilities, private firms, individual and users of the goods and services.

### *6.5.3 Commissioning*

The review of selected water harvesting and reuse case studies revealed that the commissioning phase, which can sometimes be a complex process in its own right, is often overlooked and consequently inadequately planned. Design and construction deficiencies often become apparent during the commissioning and early operation of a new system. The commissioning of water supply infrastructure and facilities is a common challenge regardless of scale (large or small) or ownership (private or public).

For example, problems were encountered during the commissioning and first six months of operation of the council's Coober Pedy desalination treatment plant in the mid 1980s. A review of the performance of the plant found the raw water quality was outside the range the desalination plant was designed to treat. The additional pre-treatment facility required to overcome this was costly for the local council. Similarly, the original seawater desalination plant installed by contract at Penneshaw encountered problems. Over the next few years, at significant expense, the facility was upgraded several times and the process changed to improve the performance of the plant. The Renmark effluent treatment plant, designed and constructed by a private contractor for the council, also required modification of the process to achieve the required quality performance.

The operation of all equipment and the plant as a whole should be fully tested during the commissioning. Following commissioning the plant should undergo a minimum three to six month of quality assurance proof testing. The plant should be in full normal operation during this time except that reclaimed water should be diverted to storage and not supplied to customers. Should the plant fail to meet quality standards remedial action should be undertaken and the proof testing repeated. Local operators should be trained by supplier before the external support is withdrawn.

### 6.5.4 External Support

A major issue highlighted through the case studies was the importance of an appropriate level of ongoing support for councils and other organisations, to manage alternative water systems in the longer term. Simpler systems that were understood and maintained primarily by locals seemed more likely to succeed over a long period. The higher the level of intervention and assistance provided by 'outside' stakeholders, the more likely failure in the long run seems to be. In general, the more innovative the technology or water resources management approach is, the higher the initial level of external support from the State Government and private industry attracted.

In the case of New Haven Village, after the 3 year period of intense government involvement ended and the stakeholders withdrew, the council has been unable to effectively manage the wastewater treatment plant and the non-potable water supply infrastructure. Since 2000, the reticulated non-potable water supply has not been operating as designed. This is due to problems meeting the water quality supply requirements set by the State Government. Excess treated effluent is being disposed of via the subsurface irrigation system under the oval to avoid risking public health. When external support from the State Government and private industry was withdrawn, the treatment process was too complex to be managed locally. The council has recently commenced negotiations with SA Water to take over the provision of wastewater services to this 64 house development. In the case of New Haven Village this may led to the expensive on-site wastewater infrastructure being retired after only 10 years in operation.

Another example is the small independent Clayton Water Scheme which now incorporates aquifer storage and recovery (ASR) technology. This is the first ASR site in Australia established with the intention of providing a potable supply (Alexandrina Council 2005) and attracted external interest. Since 1995, water has been injected into the underlying aquifer during the winter months (when algal counts are low) and the recovered water is used all year round. The artificially recharged freshwater lens sits in a hyper-saline aquifer (ie. salinity varies between 28,00mg/L and 37,000mg/L). Within the freshwater lens, the potable water supply is developed and maintained. Therefore, the recovered water must be composed of at least 98% lake water to maintain acceptable salinity for drinking water supply. The complex aquifer management and specialist expertise required has compelled the DWLBC to continue to operate the system on behalf of the Alexandrina Council. The traditional water supply infrastructure had been operated and maintained by the local council for more than more than 30 years. As some new types of water harvesting systems are not yet widely used, the training infrastructure does not yet exist.

Externally supported water harvesting and reuse initiatives often use scale to explain the disappointing results of some projects. An appropriate level of external support is essential to the success of alternative water supply systems. It is recommended that planners involved with water harvesting and reuse projects in South Australia learn from the experiences of recently implemented projects, both successful and abandoned. The viability of integrated water supply should be measured by the commercial viability and simplicity of operation for the local council (post 3 year support from partners).

### 6.5.5 Data collection and monitoring

Despite the number of operational small water harvesting and reuse projects that exist in South Australia, difficulty in obtaining sound operational and financial data was a major obstacle when researching the performance of many of these small water supply projects. This is not due to the unwillingness of communities to share their experiences, but because these projects were implemented to meet specific needs, rather than with research in mind. Record keeping processes were not deemed a priority when these projects were initially established. Local residents or local council often possess a wealth of anecdotal or intuitive information about the projects as in the case of Snowtown, Lameroo and Lock. However, a mechanism is needed to enable urban water resource planners and others to collect relevant data and to exchange this information.

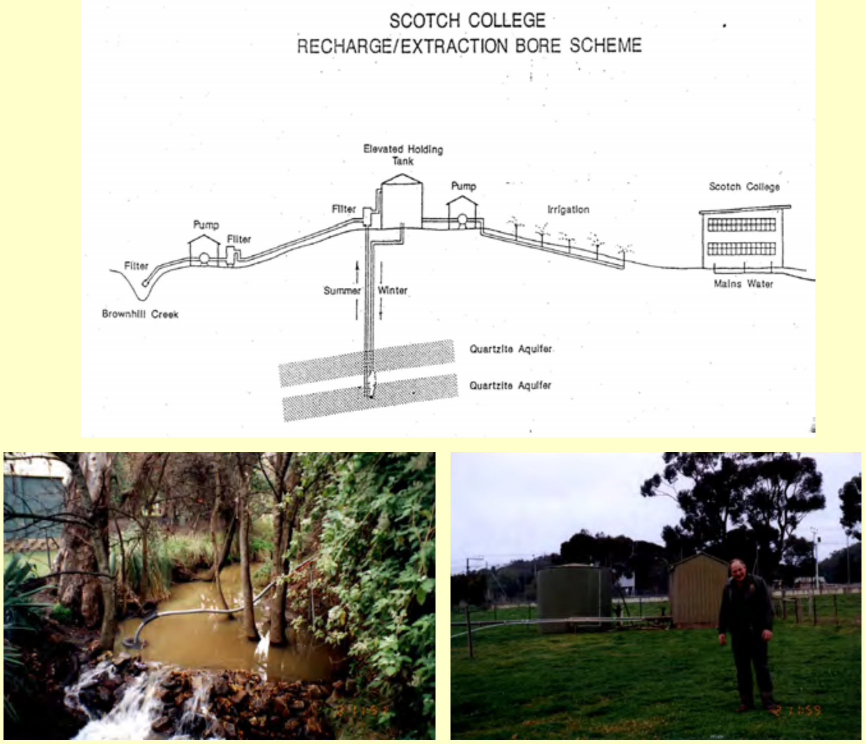
When reliable data can not be provided it is necessary to make some major assumptions. A consequence of limited operational information includes difficulty in establishing the performance and sustainability of a given water harvesting and reuse project. In addition, new schemes can not be planned and designed with any more confidence than the pioneering one (ie. sluggish improvements in designs). Where operational data is collected, it usually limited, incomplete or difficult to access (ie. stored within an inflexible information management systems). For example, the software used to manage accounts in Coober Pedy and Roxby Downs has restricted reporting functions and information stored in it is difficult for the operators to assess for historical analysis. In both cases, while the systems should store financial information required for this analysis the operational and administrative staff were unable to extract it for this research. Where operational and financial information has been recorded, it is usually filed in hard copy and required subsequent data entry before it was available for analysis. Better record keeping practices are required.

Example 32 describes the private aquifer storage and recovery system at Scotch College and shows some of the data records available.

**Example 32 Aquifer Storage & Recovery: Scotch College, South Australia**

*Scotch College has some 12ha of ovals and gardens which account for 85% of its annual water consumption. Increasing water charges encouraged the school to develop an alternative source of water to meet its irrigation needs. The strategy for decreasing water related expenses was to investigate the amount, quality and variability of local supplies and match these to the irrigation requirements.*

*A well (48m deep) was drilled in 1985 which found marginal quality (2300mg/L) water. The well was connected to the irrigation system, but after one pumping season the water level had fallen to the level of the pump intake and recovered very slowly (ie. not sustainable). In 1988, a new well was drilled to 150m and started production in the 1988/89 irrigation season. Artificial recharge was commenced in the winter of 1989 using the old well as a recharge well and pumping water from Brown Hill Creek through a sand filter at a rate of 7l/s.*



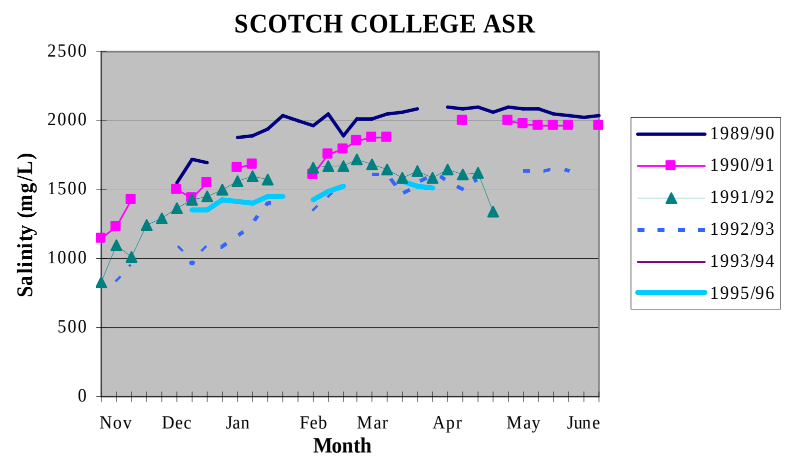
**Brown Hill Creek Intake** **Storage and pump station**

**Figure 84 Scotch College - ASR Facility (Rabone 1999)**

**Figure 85 Scotch College – Irrigated Oval (Rabone 1999)**

*Armstrong (1992) estimated that even with two separate pumping operations, the cost of delivery is about one third of the cost of mains water. A quick look at the excellent condition of the grounds of Scotch College indicates that the quality of water produced is adequate for the purpose.*

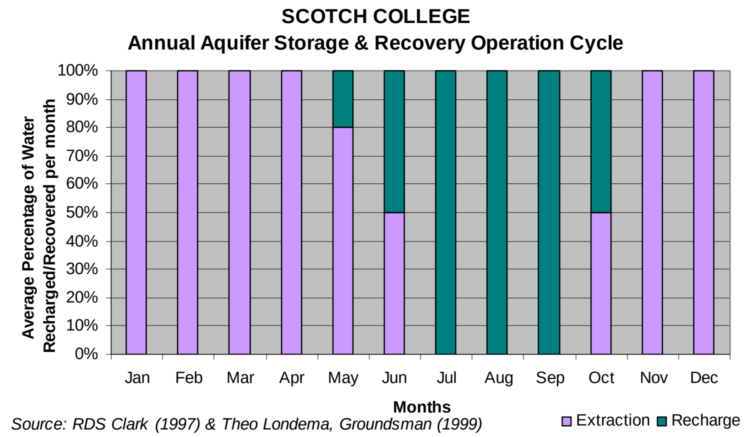
*Since 1989, water quality, water levels and irrigation volumes have been intermittently recorded and a pattern of gradually improving water quality has emerged (see Figure 86). The water extracted from the bore ranges from 1100mg/L to 2000mg/L over the pumping season, compared with the natural groundwater salinity of 2300mg/L. There has been a definite decrease in the salinity of the pumped water over the years with the band narrowing to 1100mg/L to 1600mg/L.*



*Source: Theo Londema, Groundsman (1999) & RDS Clark (1997)*

**Figure 86 Scotch College – Water Salinity Records**

*Based on nearly 10 years of operational data, Figure 87 shows when the water is being recovered from the aquifer for irrigation and when the aquifer is being recharged with water from Brown Hill Creek.*



*Source: RDS Clark (1997) & Theo Londema, Groundsman (1999)*

**Figure 87 Scotch College – Storage & Recovery Operation Cycle**

*Source: Armstrong (1992); Clark (1997), Theo Londema (1999)*

Data collection for existing and planned water harvesting and reuse schemes needs to be increased dramatically compared to current levels. Data does not have to be expensive or complicated to collect. To get a '*feel*' for the systems performance, the data collection program need not be elaborate. It is important to target the data collection program. It is pointless collecting enormous quantities of information that will never be used. Another thing to remember is that long records are more useful than short or broken records. The longer the record the more extremes are likely to be included. To encourage the use of collected data it must be easily retrievable and made available at minimal cost.

Due to limited reliable data, estimates of the effectiveness of the water harvesting and reuse projects vary widely and remain subject to considerable uncertainty. Without at least minimal data it is not possible to investigate or examine the feasibility or wisdom of '*scaling-up*' innovative ideas. In the future, it will be increasingly important to be able to justify the investment made. The provision of more accurate and specific performance monitoring will be necessary when funding contributions from government sources or private enterprise are sought.

### *6.5.6 Effective Cost Management*

The value of a non-potable water supply to the users (ie. landscape manager, sports club) depended on availability and price of potable water supplies and the characteristics of the non-potable water supply. If freshwater is readily available at a low price then the non-potable water supply is less desirable. When purchasing 'mains' water from SA Water, the consumer already knows how much to budget for their irrigation, there are no hidden costs. Budgeting for operation and maintenance of a non-potable water supply is more difficult as the data is not as readily available and highly variable.

A significant variation in the annual operating costs for these small schemes is observed which makes the task of budgeting and setting an appropriate tariff more difficult. At Lock, the actual annual cost of providing the non-potable water supply varied between 18% and 85% of the current $1.06/kL state-wide unit cost for reticulated water. The elevated annual operating cost for 2003/04 was due to the high volume of potable water purchased (low annual rainfall and dry summer) and the large maintenance expenditure for the major pump overhaul in the same year. This variability in the annual operating costs was also noticed for Snowtown's stormwater harvesting scheme. Despite the significant variation observed between the annual operating costs, the stormwater harvesting schemes at Lock and Snowtown remain an affordable alternative for irrigation.

However, the cost effectiveness of the ongoing management of the small local integrated water management system at New Haven Village has not been demonstrated. The annual cost to treat wastewater on site at New Haven Village ranged between $3.60 and $4.70/kL, with an average of $4.40/kL over the 5 year period from 1999/2000 to 2003/04. The rating policy adopted by the council limits the revenue received for its wastewater service from the 64 homes to an amount equivalent to charges levied by SA Water for wastewater services. Further analysis of financial information shows that the tariff required to recover costs for the provision of treated effluent for non-potable use is about 2 times the current cost of mains water. This includes the cost of purchasing potable water at the State-wide price to 'top-up' the non-potable system to meet the seasonal demand. No historical financial information was available for analysis of the small Aldinga or Renmark wastewater treatment plants.

The cost of providing a community non-potable water service depends very much on the price of the inputs, such as energy and infrastructure required. Based on an estimated average volume of water used each year and historical cost information where available, the unit cost of providing the non-potable water supply for each selected case study is as set out in the Table 41 below.

**Table 41 Calculated Tariff and Actual Tariff Levied for Selected Case Studies**

| Selected Case Study | Source(s) for Non-Potable Supply | Tariff Required[(1)] ($/kL) | Actual Tariff Levied[(2)] ($/kL) | Comments |
|---|---|---|---|---|
| Andamooka | - NA | NA | NA | No local scheme |
| Clayton | - NA | NA | NA | No local scheme |
| Coober Pedy | - Treated effluent | $2.20 | $1.50 | |
| Hawker | - Stormwater | $0.54 | Nil | Voluntary service fee |
| Lameroo | - Groundwater<br>- Treated effluent<br>- Stormwater | Unknown (3) | <$0.25 (Average) | Annual operating cost shared between user and council. |
| Leigh Creek | - Treated effluent<br>- Potable water | $0.68 | Nil | All used by town management. |
| Lock | - Stormwater<br>- Rainwater<br>- Potable water | $0.40 (Average) | $0.20-$0.90 | Users meet annual operating cost. |
| New Haven Village | - Treated effluent<br>- 1st flush stormwater<br>- Potable water | $2.34 (Average) | $1.78 (Average) | Residents subject to additional council rate levied based on property value. Water use not metered. |
| Oodnadatta | - Groundwater | Unknown (3) | $0.46/$1.06 | Town supply is non-potable. State price. |
| Roxby Downs | - Treated effluent<br>- Stormwater<br>- Potable water | Unit cost not determined (3) | Nil | All used by Council on public recreation facilities. |
| Snowtown | - Stormwater | $0.60 (Average) | $0.28-$0.97 | User meet annual operating cost |
| Wudinna | - Rainwater | Unit cost not determined (3) | $0.97 | Water use is metered. Annual revenue is around $25,000. |

*Operational costs obtained from individual operators as presented in Part II*

*(1) Tariff calculation method recommended by World Bank (WSP 2002). Assumes no access fee.*
*(2) Unit cost for non-potable supply paid where applied. Most often user meets operating costs.*
*(3) Financial records for operation and maintenance not available or not provided.*

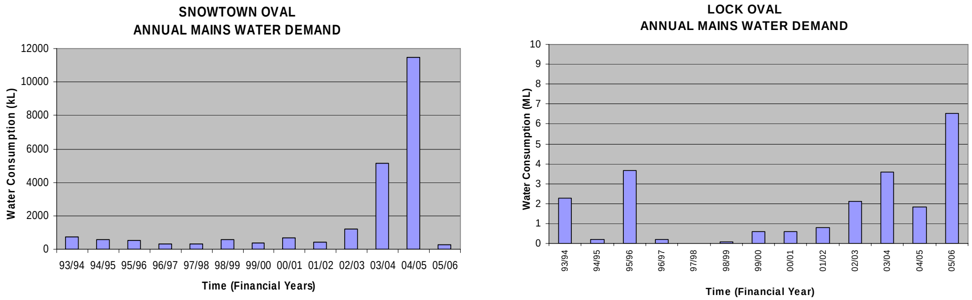
Although cost recovery can be achieved in small-scale water harvesting and reuse systems, it can be significantly more expensive than the ‘state-wide’ price for the end user. This make these initiatives politically sensitive and it can be difficult to gain widespread community support.

The pricing system needs to generate revenues for the efficient operation (and debt service) of the present system and its maintenance, operation, and future replacement and upgrades. In many country centres, the cost of constructing and operating water supplies is not covered by the income generated from water charges. In South Australia, the public subsidy cost per kilolitre ranges from very low in some centres to very high in smaller and more remote centres. In the short-and medium-term, the potential step change towards optimal sustainable water use practices continues to be limited by the State government's reluctance to make transparent the true cost of providing water to each country township (ie. camouflaged by the state-wide pricing policy for the majority of towns) and its unwillingness to charge efficient commercial prices.

### 6.5.7 Security of Supply

The value of non-potable water depends on how well the timing and quantity matches the demand for the water. The value of the non-potable water supply is less if reliability in its supply requires backup freshwater supply. The vagaries of Australia's climate and weather mean that the availability of runoff to harvest and store varies from year to year. Extended periods of low inflow (ie. dry spells) frequently caused shortages in the early local water management schemes. The convenience and reliability of a reticulated water supply from a distant source led to many small schemes being abandoned.

Security remains a common feature of local water supply schemes. An alarming pattern that emerged throughout the case studies was that of increased community expectations after schemes had been operating for a number of years. After an alternative water harvesting scheme had been operating in a town for several years, members of the community become accustomed to the benefits it supplied, including the greening of public areas. As periods of drought have since occurred, the community demonstrated an expectation that the areas watered by the system would remain green. This is clearly demonstrated in Figure 88 which shows the volume of potable reticulated water purchased to maintain the oval in Snowtown and Lock.



*SA Water (1993-2006) Water Consumption Statistics*

*SA Water (1984 - 2004) Water Consumption Statistics*

**Figure 88 Annual Irrigation Demand for Potable Water**

Over time, people's perceptions changed and they were reluctant to accept that sacrifices were necessary on their part, in terms of allowing the oval to die back for a season. Consequently, low annual rainfall and a dry summer led to large amounts of water being purchased from SA Water to maintain the green surfaces. Through the case studies, it is apparent that the everyday decisions of members of the community can have a significant impact on the total water consumption in any town. It is important to overcome this type of response to water shortages and the associated pattern of consumption as the many public reticulated water supply systems in regional South Australia are already overburdened.

### *6.5.8 Local Skill & Resources*

Small water systems can find it difficult to reliably deliver services, even where appropriate technologies have been adopted, unless their operators are adequately trained. Accordingly, training local people to operate the system and maintain associated equipment is as important as establishing the technology itself. Attention should be paid to whether the specified equipment, especially sophisticated equipment, is in use elsewhere in the community. In addition to the problem of learning to use complex equipment, having a unique piece of equipment may mean that advice and spares will be difficult to find (ie. no local serviceperson). Increased reliance on external support (which can be expensive) is often a direct result of the installation of more complex equipment.

In general, in well planned and constructed water harvesting and reuse systems, any small problems arise can be corrected with regular maintenance. These assets, usually in the councils' care, represent a considerable investment by the community, ie. they need maintenance to avoid semi-neglect. Operators of small regional or local water supply systems need periodic opportunities to meet, to take stock of their learning and to discuss new developments in technology to guide the efficiency of their operations. Unfortunately, funding for such activities is more difficult to access than for project applications.

Specific initiatives are needed to create awareness and provide skills and experience to members of small rural communities. Past education, training and skilling programs to increasing the skill level of irrigators in South Australia have proven records (GSA 1999). Some of these programs include RiverCare in the River Murray irrigation districts, Six Steps to More Efficient Irrigation in some surface and groundwater districts, Property Management Planning and FarmBiz. The common features of all these programs is the collection of relevant information by the irrigator from their own farm, in workshop discussion, analysis and evaluation of practices, and in the implementation of new irrigation management on the irrigator's farm (GSA 1999). It should be possible to draw on this experience and scale up these initiatives to reach a larger number of individuals and benefit more South Australian communities so that more sustainable, effective water management and use approaches are encouraged.

Another challenge is the shallow skills base in regional communities, often with only a one or two people trained in operation and maintenance of the water supply system. Staffing levels for selected South Australian case studies showed they spanned a range of 1.4 to 9.8 full time equivalents per 1,000 properties with a median of 4.5 full time equivalents per 1,000 properties. This is based on available information for four independent small-scale schemes serving between 200 and 2000 properties. For many small and remote communities, sourcing skilled people to operate and maintain the equipment can be quite difficult. Consequently, the reliable operation of the system is vulnerable to vital staff being sick or leaving. Simple systems, developed primarily using local expertise, are better understood and can be maintained by locals and seem more likely to succeed over a long period.

### *6.5.9 Impact of Input Water Quality*

Poor quality source water often presents difficulties for existing public and private infrastructure in many parts of Australia. Naturally occurring minerals in the reticulated water supply for the townships of Hawker (climate index 9) and Oodnadatta (climate index 21) has a detrimental effect on the structural integrity of concrete components in their septic tank effluent drainage system (STEDS). In Oodnadatta, for example, septic tank dividers corroded away in less than 20 years which meant that the sewage was not actually treated on-site before entering the STEDS. Concrete corrosion lead to spalling of the concrete manholes and failure of the septic tanks in the collection system, increased maintenance costs and a reduced useful operating life of these components. The failure of septic tanks could result in potential environmental and health problems in the community, particularly where the effluent is being or planned to be reused. The impact and risk to communities can be mitigated by careful selection of materials and components incorporated into the system.

The salinity of wastewater effluent increases during the treatment process. The salinity of treated effluent from a given system, and therefore its value as a non-potable supply, is a combination of the salinity in the reticulated water supply and concentration by evaporation from the common effluent lagoons. Saline irrigation waters can also have a detrimental affect on the soil and flora in combination with certain soil structures. Among other factors, irrigation with high salinity water can increase the risk of salinisation, (ie. salt build up in the soil) which reduces plant growth, causes foliage damage and even kills plants. This phenomenon has been observed in Hawker, Leigh Creek and Oodnadatta following the use of saline waters to irrigate gardens. The damage to the soil structure is very difficult to reverse.

In addition to sewage or septic effluent from homes, wastewater systems also collect ‘trade waste’ generated by industries, businesses, and manufacturing processes. Trade waste can contain high levels of grease, dissolved solids (a measure of salinity), heavy metals or heavy organic loads (SA Water 1999d). In small systems, there is a risk of relatively small step changes in the total pollution load adversely affecting the performance of wastewater treatment processes and the quality of treated effluent available for reuse. Vigilant and effective management of trade waste is an essential component to the sustainability of operational non-potable water supply systems, protection of public safety and protection of the environment.

Facilities should be provided for diversion or emergency storage when treatment of effluent fails to meet the reclaimed water quality standards. The system needs to be designed so that bypassing of untreated or partially treated wastewater direct to the point of use is not permitted or possible.

## 6.6 SUMMARY

Rural towns in South Australia are being driven to become increasingly water conscious with respect to the cost of maintaining community recreation areas. There are a number of successful water harvesting and reuse projects operating in the harshest climates of South Australia (ie. high climate index). This suggests that increased use of stormwater, rainwater, brackish groundwater and effluent in other urban and country areas of the State is achievable. It is recommended that planners involved with water harvesting and reuse projects in South Australia learn from the experiences of recently implemented projects, both successful and abandoned. Understanding that other communities practice water harvesting and reuse as a matter of choice can act as a powerful endorsement. Most importantly, the health risk to the community for an efficiently operated and well maintained scheme is minimal. The trend towards developing more water harvesting and reuse projects can be an important water resource strategy for South Australian towns in semi-arid and arid areas. Every independent water source which is developed reduces pressure on the State Government reticulated system.

The case studies discussed demonstrate that in regional South Australia there are many benefits available to the community by using alternative water resources. The potential benefits of using alternative water resources include:

- Financial savings;
- Additional recreation areas for the community;
- Increased community pride;
- Increased water conservation awareness; and
- Reductions in pollution.

For these benefits to be realised, there are a number of challenges to be overcome including:

- Shortfalls in local skills bases;
- Lengthy approval processes;
- Speculative budgeting;
- Difficulty obtaining funding; and
- A lack of reliable data.

It has become apparent through the case studies that communities achieved the best results where water reuse and harvesting programs were combined with smart water use practices and appropriate landscaping. Incorporating water conservation measures as part of the overall landscape planning and design process presents few if any problems. This makes irrigated areas less susceptible to drought, alleviating some of the security issues that arise during long periods of dry weather. In addition to a low water use landscape, outdoor entertainment, play areas and enhancement of views may result. However, the level of benefits achieved will vary depending on local site conditions.

When schemes had been operational for a number of years, an alarming pattern of increased community expectations emerged throughout the case studies. Members of the community, now accustomed to green public areas, expected these areas to remain green even during periods of low flow. This expectation led to large amounts of potable water being purchased from SA Water and adds pressure on the already stretched public reticulated water supply system. It is extremely important to overcome this pattern if local water supply systems are to remain a viable option.

Another issue highlighted through the case studies was the importance of an appropriate level of ongoing support for councils and other organisations, which need to manage alternative water systems in the longer term. In several cases, after the period of intense government involvement ended and the stakeholders withdrew, the council was left unable to effectively manage the infrastructure. The higher the amount of intervention and assistance provided by ‘outside’ stakeholders, the more likely failure in the long run seems to be.

Best value for the community’s water is realised by combining water harvesting and reuse with good irrigation practices, sensible plant selection and the selection of appropriate areas to irrigate during the planning process (eg appropriate topography for infiltration). All of these factors assist in keeping the financial cost of greening parks and ovals minimal, allowing maximum funds to be allocated to areas such as maintenance.

There is no common approach to delivering water services to small towns that meet the performance standards of good quality, affordability, sustainability and ability to expand to accommodate growth. The challenge is to undertake planning, management, and funding reform that will guarantee effective use of water resources, minimise adverse impact on the environment and provide long term sustainability of local economies. Selection of appropriate technology can bring advantages to people living in small communities or remote locations.

South Australia will be obliged to adopt water conservation measures (reduce demand for selected purposes, modify management of existing systems to enhance availability of water) and develop and treat other sources of lower quality water. Water harvesting and reuse will increasingly become an attractive option for either extending available water supplies to support increased population or to reduce dependence on the River Murray. The growing desire of South Australian communities to live within the capacity of their regional ecosystems will probably ensure that local reforms to the urban water and wastewater cycles will pioneer the way to genuinely sustainable and liveable urban communities in the future. The primary goal of a sustainable community is to meet its basic resource needs in ways that can be continued in the future.

# Chapter 7
# Feasibility Assessment Method for South Australia

*"Put it before them briefly so they will read it, clearly so they will appreciate it, picturesquely so they will remember it and above all accurately so they will be guided by its light."*

Joseph Pulitzer
American newspaper pioneer

## 7.1 INTRODUCTION

Stormwater runoff and domestic effluent present a potential water resource that can supplement or replace other sources, but the community needs to be informed to fully appreciate and understand the benefits. Additionally, a thorough feasibility study is necessary to prevent costly errors being made. With the use of extensive feasibility studies and adequate research, positive water reuse outcomes can be achieved. A community spirit can be harnessed to stimulate interest in the development of alternative water resources. The main objective of community involvement is to influence 'public opinion' in order to increase the level of acceptance and support for a project. It can also serve to increase public tolerance towards problems that may arise in the initial stages. The involvement of the key stakeholder; the community is imperative in successfully achieving these goals.

Effective assessments of the possibilities in the region of a proposed water harvesting scheme will always consider multiple factors including physical, climatic and biological limitations as well as technological and financial restrictions. Treated municipal wastewater represents a significant potential source of water for use as the effluent is generated in close proximity to urban areas. When community members come to understand the benefits that water harvesting and reuse can have for the wider community, the environment, the economy and themselves it is more likely that they will support and participate in programs. Additionally, the project coordinators need to listen to the needs of the end users if they are going to be able to convince them that they are able to meet them. Resistance from existing institutions and the community is often based on a simple fear of the unknown, which can be easily addressed through listening to their concerns and presenting them with factual information.

## 7.2 PLANNING PROCESS FOR THE FUTURE

The simplest approach to designing and installing a reuse water treatment plant (sewage or stormwater) for a rural cluster (small community), would be to adopt proven technology (where available) using packaged plants. Factors to be considered when planning for small communities include (Polin 1977):

- expected growth of the community;
- demand on the existing scheme water supply;
- the relative cost of potable water as opposed to treated reuse water; and
- the environmental impact of the proposed scheme.

The feasibility study is an analysis of a project's viability. It is considered a desirable checkpoint that should be completed before committing any resources. The primary objective of a feasibility study is to assess three types of feasibility (Overton 2002):

- Technical Feasibility - can a solution be supported with existing technology?
- Economic Feasibility - is existing technology cost effective?
- Operational Feasibility - will the solution work in the organisation if implemented?

Establishing the feasibility of a project is a critical factor in the success of a water reuse scheme. However, many new projects, which have passed feasibility studies, have failed as a result of unexpected events such as (Overton 2002):

- changes in legislation;
- demographic shifts;
- an inability to recruit and/or keep suitable staff;
- the failure of a major customer;
- withdrawal of financial support;
- new technology; and
- poor management.

A key factor in any feasibility study must be ensuring that one is dealing with correct information, correct assumptions and up-to-date financial data. Many projects fail because assumptions were based on incorrect information. When complex problems and opportunities are to be defined, it is desirable to conduct a preliminary investigation called a feasibility study. This is conducted to obtain an overview of the problem and to roughly assess whether feasible solutions exist prior to committing substantial resources to a project. The final product of a successful feasibility study is a project proposal for consideration by the stakeholders.

### *7.2.1 Importance of Planning*

The importance of planning for a water harvesting and reuse supply scheme should not be underestimated. Figure 89 shows the dependency and benefits of forward planning on the final cost of a project. The benefits gained are seen by way of eliminating the need to make changes once the project has commenced.

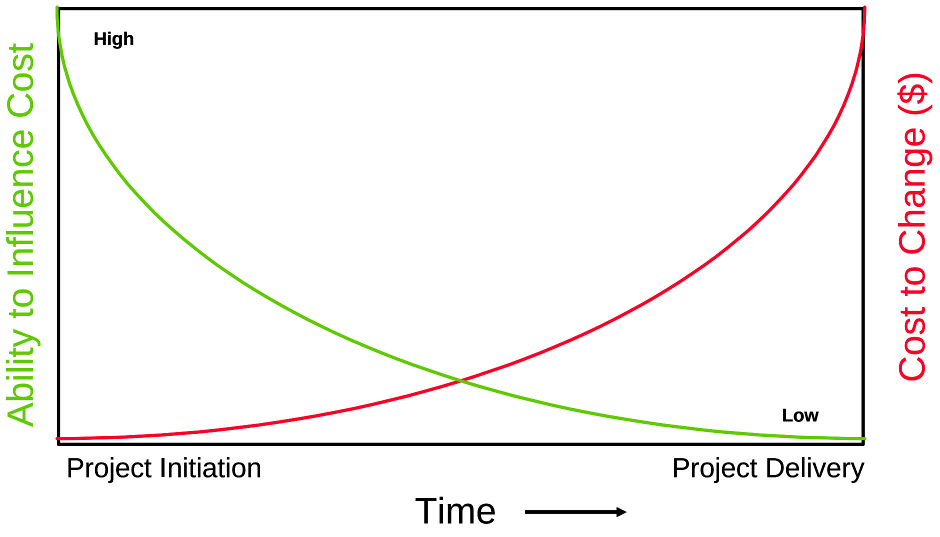


**Figure 89 Project Phases and Ability to Influence Cost**

The major capital cost savings on most projects can usually only be achieved in the early phases of the project's conception and design (Stallworthy & Kharbanda 1986; AIPM & CIDA 1995; GSA 1996), when evaluating options and innovative process technologies. Also, the 'cost to change' any aspect of the project is lower in the early phases, but increases rapidly in the final phases (AIPM & CIDA 1995).

Therefore, it follows that the costs of an alternative water reuse scheme can be minimised when a wide range of options are fully analysed from the outset, before any commitment to proceed is made.

Through every step of planning for a new reuse scheme (or the augmentation to an existing), the community and stakeholders should be involved to provide guidance through the planning process (US EPA 1992), and steps taken to foster support and encouragement for the project. The typical planning process to be adopted is outlined below in Figure 90. This includes activities ranging from the identification of the idea, through to the operation and maintenance of the assets. For small-scale water resource projects, the recommended steps for the total planning process consist of:

- defining the 'ideas' to meet needs;
- forming a steering committee (working group) to drive the project;
- developing options;
- evaluating and selecting the most appropriate option;
- preparing detailed design of the preferred option;
- constructing and commissioning;
- operating and maintaining the scheme; and
- reviewing performance.

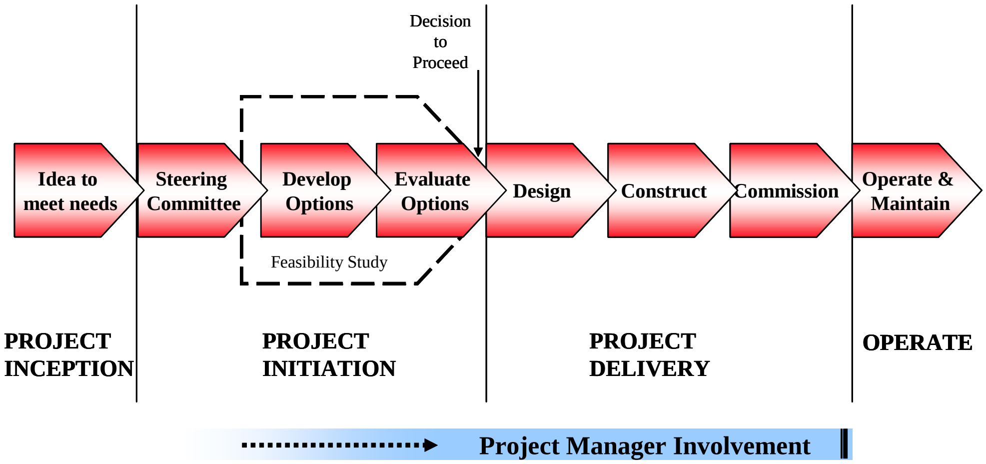


**Figure 90 System of Planning Flowchart**

### *7.2.2 Community Involvement*

South Australian rural communities are generally self-reliant because of their remoteness. Most people concern themselves with how things will impact on the success and future of their community. A community spirit can be harnessed and used to stimulate interest in the development their alternative water resources. Encouraging community participation and involvement is not always an easy task when introducing new ideas because most people are wary of change, particularly if they perceive a specific change to be detrimental to their interests, or controlled by others. That said, a broad cross-section of the community is usually willing to share ideas when a community involvement process has been designed to include them and is directed by trusted local leaders (Nugent *et al.* 1997).

The process should be introduced in the earliest stages of the system of planning described in Chapter 3 to allow ample time for the dissemination of information and acceptance of new ideas among the community. Active participation from the beginning is likely to create a cooperative rather than competing or conflicting relationship (Dugdale 1989; US EPA 1992) between the Project Sponsor, the Steering Committee and the community. The process may accelerate the implementation of a project by uncovering any opposition early enough to adequately address concerns raised (US EPA 1992).

### *7.2.3 Community Acceptance and Support*

Water reuse projects enjoy their greatest public acceptance where water resource issues and pollution abatement issues have been combined. This is because ‘The Community’ tends to support environmentally beneficial projects, such as water conservation, water quality protection of water resources and public health protection. The main objective of community involvement is to influence ‘public opinion’ in order to increase the level of acceptance and support for the proposed project. Black (1993) defined ‘Public opinion’ as the predominant attitude of a community, the collective will of the people, or the summation of public expression regarding a specific issue. Extensive studies have been carried out to determine the general public's knowledge and attitude towards treating effluent to drinking water standards. The main obstacle limiting direct potable reuse has been community acceptance (Water Pollution Control Federation 1989) and will continue to be for some time yet.

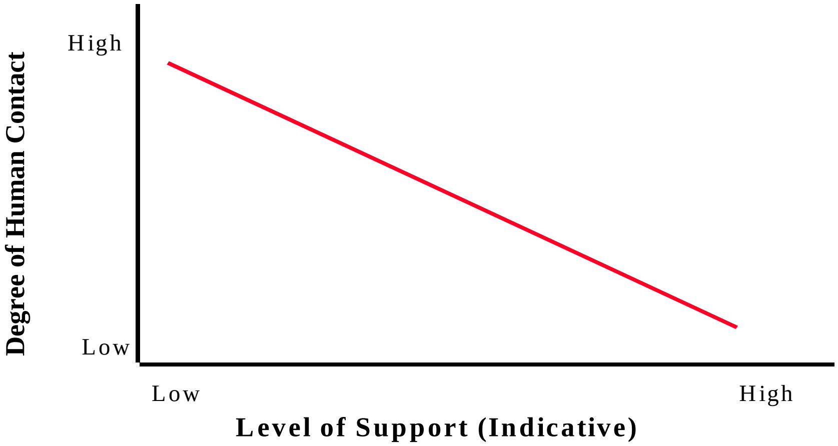


**Figure 91 Level of Support (Indicative) for Water Reuse Projects**

Burvold (1988) developed two significant hypotheses which provide clear guidelines for assessing public acceptance of an effluent reuse project. They are:

- For specific reuse applications, where water reuse was an imminent possibility (i.e. construction to provide reclaimed water service was being considered) the more important determinants of public opinion became:
    - the ability of the project to conserve water;
    - environmental enhancement achieved by the project;
    - protection of public health;
    - the cost of treatment required; and
    - the cost of distribution.
- In general reuse surveys, the degree of human contact was the more important determinant of public opinion on effluent reuse.

## 7.3 STORMWATER RUNOFF ESTIMATION

Stormwater is a potential water resource that can be harvested to supplement or replace potable water, particularly for non-potable uses such as irrigation of township public areas. Estimating the quantity of runoff resulting from rainfall on a surface is an important component in assessing the feasibility of a stormwater project. The potential volume of runoff from a catchment depends on the temporal and spatial distribution of rainfall as well as the permeability of the catchment. The variables that determine the ability of a community to fulfil irrigation demand using stormwater are the local rainfall, characteristics of the available catchment area, and financial budget. When conducting a feasibility study for water reuse, the quantity and reliability of stormwater that can be harvested in the proposed area needs to be established.

### 7.3.1 Selection of Assessment Technique

The volume of runoff is equal to the volume of rainfall on a catchment minus losses. The losses in urban catchments are caused by the same hydrological processes as in natural catchments, although in different proportions. Under natural conditions, permeability depends largely on soil type and can vary with soil wetness. Changes in permeability can influence the size of the contributing area that sheds rainfall as runoff discharged from an urban area (Tomlinson *et al*. 1993; Codner *et al*. 1998). The relationship between rainfall and the volume of runoff generated from a catchment is complex, involving a large number of variables.

Estimation methods for stormwater runoff are needed because of the difficulty in obtaining accurate field measurements. The methods often need to be applied under climatic conditions very different from those under which they were developed. Empirical rainfall-runoff data has not been collected for operational stormwater projects such as Lameroo, Snowtown, and Lock commissioned in 1974, 1982, and 1992 respectively. The three towns have a climate index value of 5. It would have been valuable (from a research point of view) if methods to assess flow into the stormwater storage (runoff) had been installed (or added) to the scheme to facilitate estimating yields for other towns in similar climates. For feasibility assessment, quick and relatively simple techniques for estimating the yield are required. However, methods for rapid assessment are only considered preliminary investigations.

McMahon and Mein (1986) recommend estimating the mean annual runoff as the most appropriate starting point of any discussion about the yield or hydrological characteristics of a region. Fleming (1994) investigated a range of techniques developed to model the runoff process and found the vast majority of rainfall-runoff models to be event based for estimation of flood peaks rather than runoff volumes. The techniques require expertise in application and interpretation. A simple preliminary technique is the application of volumetric runoff coefficients (VRCs) that relate rainfall volume to runoff volume using the following formula:

$$\text{Volumetric Runoff Coefficient (VRC)} = \frac{\text{Catchment Runoff (mm)}}{\text{Rainfall (mm)}}$$

Clark and Mitchell (1987) compared the annual runoff from over 30 catchments (all modified for either agricultural or urban use) in the Mt Lofty Ranges (within climate index range <5). It established a line of best fit that approximated to 0.15 when average annual rainfall was greater than 300mm. Moore (1990) derived an annual VRC of 0.28 for the 62 hectare Snowtown catchment (climate index 5) based on anecdotal evidence and 10 years of stormwater harvesting. Tomlinson *et al*. (1993) determined the annual VRC for a 60 hectare urban catchment in Salisbury (climate index 4) to be 0.23 based on recorded inflow to The Paddocks wetland for 1991 and 1992 (a very short period). Moore (1992) found the annual runoff coefficient from a 6.1 ha engineered catchment at Kalabity Station near Olary (ie. within climate index range 10 to 14) was about 0.10 based on 12 years of data (considered a short record in an arid climate). The performance of the Kalabity catchment was observed to lose efficiency (approaching that of a rural catchment) when vegetation growth was not controlled.

Fleming (1994) refined this method by determining volumetric runoff coefficients (VRC) for each month of the year, based on the results of previous research for catchments with a temperate climate, that reflect the influence of climate and land use on runoff volume. Figure 92 shows the distribution of the VRC for urban and rural catchments recommended by Fleming. The distribution equates to an average annual VRC of 0.28 and 0.11 for urban and rural catchments respectively, which compares well with results of previous research in South Australia.

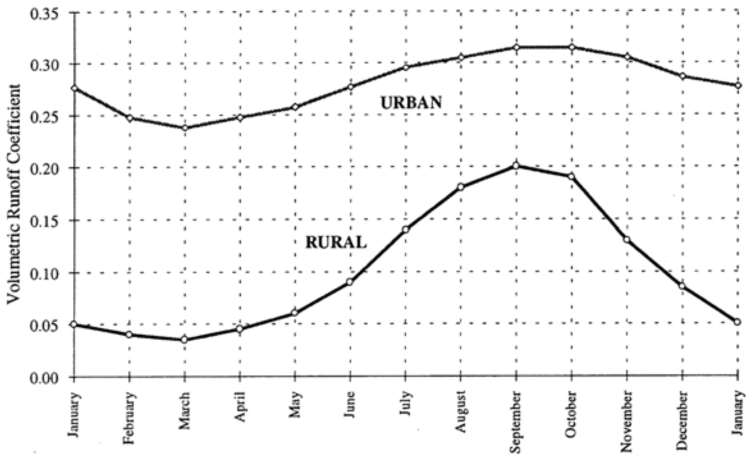


**Figure 92 Volumetric Runoff Coefficients for Catchments (Fleming 1994)**

The distribution of the VRC for urban catchments is flatter and consistently higher than the corresponding VRC for a rural catchment, primarily the result of increased impervious areas and the introduction of gutters and stormwater pipes (Tomlinson *et al.* 1993; Clark *et al.*1997; Codner *et al.* 1988). Hence, quantity of runoff arising from urban catchments is less variable than from rural catchments which exhibit seasonal changes primarily based on the catchment wetness. For example, over the summer period when a rural catchment is relatively dry, the rate of infiltration of rainfall is high and corresponding proportion of rainfall that becomes runoff is low until the soil is saturated. The summer runoff is a distinct advantage which urban catchments have over rural catchments in projects where stormwater runoff is harvested. It is precisely this phenomenon that can be used to advantage by small or isolated communities in the efficient development of a stormwater reuse project.

The monthly VRC provide a good preliminary estimate of the potential stormwater yield on a monthly basis for regions in South Australia with a climate index up to 9, and up to 14 for rural and urban catchments respectively. In areas with higher climate index, the most important contributor to runoff is the intensity and duration of rainfall events. The application of VRC to average rainfall is not considered relevant as the variability in rainfall is high and the length of time between rainfall events can be extensive. Typically, stormwater runoff projects are not viable for towns with a climate index of more than 15.

### *7.3.2 Average Annual Runoff Estimation*

Fleming's monthly VRC have been applied to a group of 220 South Australian towns for which average monthly rainfall data was available as follows:

*Catchment Runoff (mm) = Volumetric Runoff Coefficient . Rainfall (mm)*

Appendix 16 presents the estimated average monthly and average annual catchment runoff expressed as a 'depth of water' for towns (urban) and adjoining (rural) catchments in South Australia respectively. The results have been grouped according to climate index to allow broad estimation of potential stormwater yield for regions in South Australia. Table 42 summarises the average annual runoff expressed as a volume per hectare for the given climate index. The maximum and minimum average annual runoff is estimated for towns falling within the given climate index range.

**Table 42 Average Annual Runoff in South Australia by Climate Index**

| Climate Index | Sample No. | Urban Area Runoff (kL/ha/year) | | | Rural Area Runoff (kL/ha/year) | | |
|---|---|---|---|---|---|---|---|
| | | Max | Min | Average | Max | Min | Average |
| **2** | 21 | 3131 | 1724 | 2252 | 1445 | 792 | 1035 |
| **3** | 29 | 2204 | 1191 | 1600 | 1015 | 541 | 728 |
| **4** | 40 | 1733 | 1051 | 1381 | 797 | 445 | 621 |
| **5** | 47 | 1380 | 976 | 1186 | 617 | 415 | 526 |
| **6** | 17 | 1262 | 929 | 1060 | 562 | 404 | 464 |
| **7** | 26 | 1079 | 801 | 915 | 463 | 332 | 395 |
| **8** | 19 | 942 | 720 | 829 | 411 | 296 | 354 |
| **9** | 6 | 871 | 675 | 768 | 372 | 276 | 318 |
| **10-14** | **8** | 767 | 577 | 673 | *324* | *219* | *264* |
| **>15** | **7** | *579* | *439* | *492* | *210* | *156* | *180* |

*Note: For climate index values >10, the estimated rural runoff is unreliable because of the high variability in rainfall as is the estimated urban runoff for climate index >15.*

The information presented in Table 42 above can be used to make a rapid assessment of the potential for stormwater harvesting in a particular town. For example, a town with a climate index of 7 and a contributing stormwater catchment of 50 hectares of which 35 hectares is urban (town area with sealed streets) and the balance rural can estimate that average annual runoff to be between 33 and 45 ML with an average of 38 ML per year. The same town located in a region with a climate range of 13 would estimate an average annual runoff range to be between 20 and 27 ML with an average of 24 ML per year (with rural contribution excluded). If this quantity can be harvested and stored it can be used to meet part or all of the irrigation demand of the town or school oval.

### *7.3.3 Runoff Reliability*

The reliability of stormwater runoff is influenced by the reliability of rainfall for a given region. Figure 93 and Figure 94 show the average annual runoff reliability curves for towns (urban) and adjoining (rural) catchments in South Australia by climate index range. The graphs have been constructed by applying the respective annual average Fleming VRC to the average annual rainfall curves.

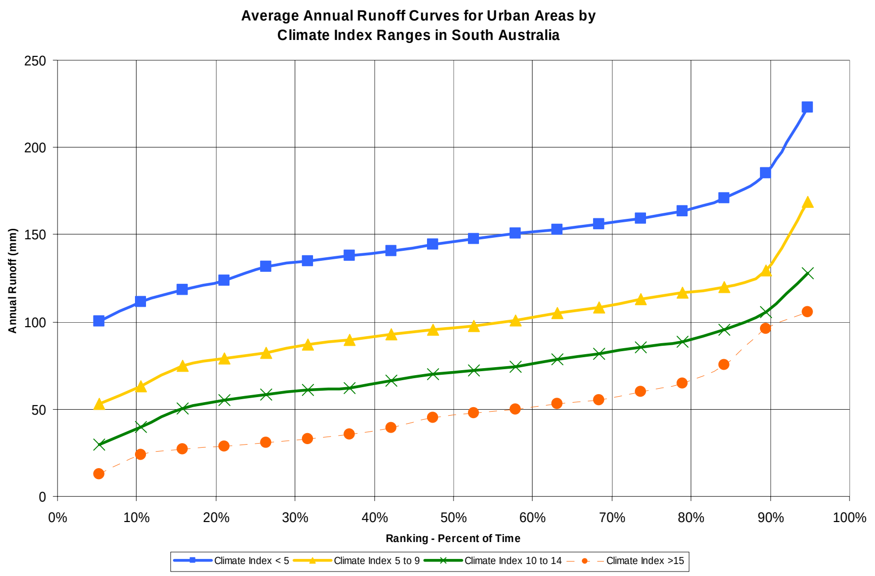
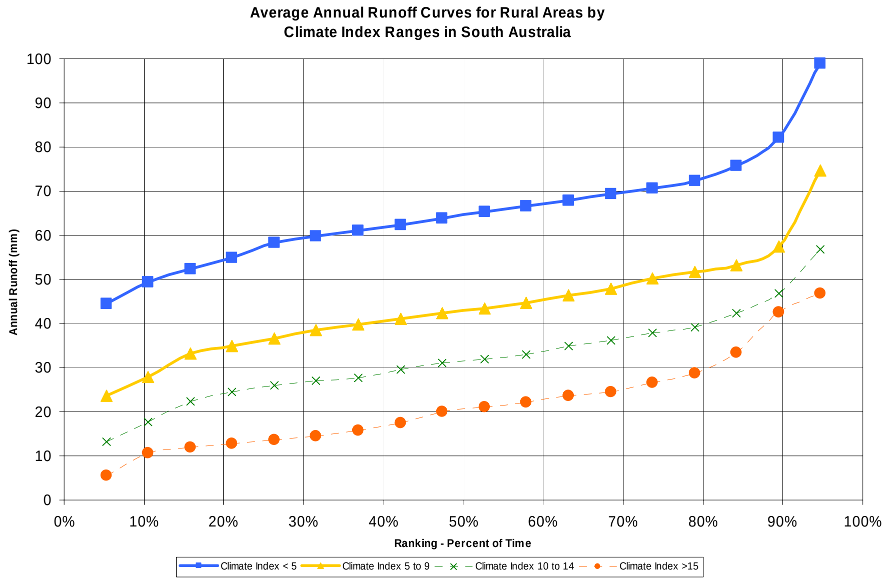


**Figure 93 Urban Runoff Reliability Curves by Climate Index Range**



*Runoff estimate for Climate Index >10 is unreliable because of the high variability in rainfall*

**Figure 94 Rural Runoff Reliability Curves by Climate Index Range**

The graphs show the percentage of time that runoff of that magnitude will not be exceeded for a particular climate index range. For example, in a town with a climate index of 7, rainfall from the town (urban) area will be lower than 95 mm per year for 50% of the time. It also indicates that the annual rainfall in this town will fall between 65 mm (10% value) and 130 mm (90% value) per year for 80% of the time. In comparison, a town with a climate index of 13 or more, rainfall from the urban area will be lower than 70 mm per year for 50% of the time. It will fall between 40 mm and 105 mm per year for 80% of the time.

### *7.3.4 Monthly Distribution of Runoff*

The monthly distribution of rainfall and runoff is also important for designing and sizing a stormwater system. Average annual data does not indicate how much stormwater can be expect from one month to the next, or just as important, how much rainfall can be expected in any one given month. Table 43 and Table 44 below present the estimated "*average monthly runoff*" distribution (expressed as a depth of water) from towns (urban) and adjoining (rural) catchments for the given climate index. Care should be exercised when interpreting the average runoff figures as the actual runoff can deviate widely from the estimated average, particularly as climate index increases (reflecting the increased variability of rainfall) above 9 for rural catchments and 15 or more for urban catchments.

**Table 43 Estimated Average Monthly Urban Runoff by Climate Index**

**Estimated Average Monthly Urban Runoff (mm)**

| Climate Index | Sample No. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 21 | 7 | 7 | 7 | 16 | 24 | 29 | 34 | 32 | 26 | 21 | 13 | 9 | **225** |
| **3** | 29 | 6 | 5 | 5 | 11 | 17 | 20 | 23 | 22 | 19 | 15 | 10 | 7 | **160** |
| **4** | 40 | 5 | 5 | 5 | 9 | 14 | 17 | 18 | 19 | 16 | 14 | 9 | 7 | **138** |
| **5** | 47 | 5 | 5 | 4 | 8 | 12 | 14 | 14 | 15 | 14 | 12 | 8 | 6 | **119** |
| **6** | 17 | 5 | 5 | 4 | 7 | 11 | 12 | 12 | 13 | 12 | 11 | 8 | 6 | **106** |
| **7** | 26 | 5 | 5 | 4 | 6 | 9 | 10 | 10 | 11 | 10 | 9 | 7 | 5 | **92** |
| **8** | 19 | 5 | 5 | 3 | 5 | 8 | 9 | 9 | 10 | 9 | 9 | 7 | 5 | **83** |
| **9** | 6 | 5 | 5 | 4 | 5 | 7 | 8 | 8 | 8 | 8 | 8 | 7 | 5 | **77** |
| **10 - 14** | 8 | 6 | 5 | 4 | 4 | 6 | 6 | 6 | 6 | 6 | 7 | 6 | 5 | **67** |
| **>15** | 7 | *5* | *6* | *4* | *3* | *4* | *4* | *3* | *4* | *4* | *5* | *4* | *4* | ***49*** |

*Note: For climate index values >15, the estimated runoff is unreliable because of the high variability in rainfall.*

**Table 44 Estimated Average Monthly Rural Runoff by Climate Index**

**Estimated Average Monthly Rural Runoff (mm)**

| Climate Index | Sample No. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 21 | 1 | 1 | 1 | 4 | 8 | 15 | 21 | 21 | 15 | 8 | 5 | 3 | **103** |
| **3** | 29 | 1 | 1 | 1 | 3 | 6 | 10 | 14 | 14 | 11 | 6 | 4 | 2 | **73** |
| **4** | 40 | 1 | 1 | 1 | 2 | 5 | 9 | 11 | 12 | 10 | 6 | 4 | 2 | **62** |
| **5** | 47 | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 10 | 8 | 5 | 3 | 2 | **53** |
| **6** | 17 | 1 | 1 | 0 | 2 | 4 | 6 | 7 | 9 | 7 | 4 | 3 | 2 | **46** |
| **7** | 26 | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 7 | 6 | 4 | 3 | 2 | **40** |
| **8** | 19 | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 6 | 5 | 4 | 3 | 1 | **35** |
| **9** | 6 | 1 | 1 | 0 | 1 | 2 | 4 | 5 | 5 | 5 | 3 | 3 | 2 | **32** |
| **10 - 14** | 8 | *1* | *1* | *0* | *1* | *2* | *3* | *3* | *4* | *4* | *3* | *2* | *2* | ***26*** |
| **>15** | 7 | *1* | *1* | *0* | *1* | *1* | *2* | *2* | *2* | *2* | *2* | *2* | *1* | ***18*** |

*Note: For climate index values >10 the estimated runoff is unreliable because of the high variability in rainfall.*

The information presented is based on limited data, and liable to imprecision, but it does provide a valuable initial review. When reviewing the above tables, it is possible at a "glance" to estimate the likely stormwater runoff yields from towns and catchments across South Australia.

### *7.3.5 Collection Efficiency*

Methods for more efficiently harvesting rainfall and stormwater runoff involve collection from a variety of surfaces such as roads, roofs, driveways, parking areas and lawns. These surfaces have the ability to serve as catchment areas for vast quantities of stormwater, which can be directed using conventional methods of design such as sealed roads, raised kerbs and drains to the reuse system or directed to planted areas to maintain garden or landscape features, rather than disposal away from the catchment area. The volume of runoff that can be collected is limited to the storage system.

**Grainstore** **Sealed Roads**

**Figure 95 Impervious Surfaces for Harvesting Stormwater (Rabone 1993)**

The efficiency of harvesting stormwater runoff depends on several considerations. Runoff yield varies with the size and texture of the catchment area. A smoother, cleaner, and more impervious roofing material contributes to better quality and greater quantity. There is always a small loss of rainfall needed to wet the catchment surface as well as the rate of rainfall. Table 45 below provides a comparison of the relative runoff that can be expected from surfaces with varying impermeability.

**Table 45 Varying Impermeability from Various Surfaces (Bartlet 1976)**

| Runoff Surface | Impermeability |
|---|---|
| Large paved areas | 100% |
| Small paved areas | 50%-70% |
| Residential and Industrial properties | 30%-60% |
| Playgrounds | 50%-90% |
| Roofs | 75%-95% |
| Lawns (depending on slope) | 5%-35% |

*Bartlet 1976 in Fleming 1994*

Roads and car parks are very useful water harvesting areas during low rainfall events, but adequate provision for stormwater discharge for high rainfall events also needs to be made (WA WRC 1986).

## 7.4 EVALUATION OF DOMESTIC EFFLUENT

Treated municipal wastewater represents a significant potential source of water for beneficial use as the effluent is generated in close proximity to urban areas. In areas of growth and new development, completely new wastewater collection, treatment and recycled water distribution systems may be designed from the outset with water reuse in mind. However, for towns in South Australia the existing wastewater management facilities will be incorporated into the water reuse system. In areas where centralised treatment is already provided by conventional sewers or septic tank effluent disposal schemes (STEDS), the existing wastewater treatment plant (WWTP) is a potential source of water.

Wastewater flows generated by a given community can vary from town to town, depending on many factors such as cultural background and the availability, pressure and quality of the reticulated water supply. The generation of wastewater is dependent on the number of people living in the household, the level of water consumption for activities within the household and the level of water saving devices in use. Previous studies have identified a range of typical ADWF for Australia of between 100 and 250 litres per person per day, with more common values in the range of 150 to 220 litres per person per day (DNRE 1997). The type of wastewater management scheme (conventional or STEDS) also influences the wastewater design flows. Other townships with central collection systems in the general climate region of the town under review can provide a useful benchmark where this data is available.

### *7.4.1 Population Information*

Plausible figures for the existing and future population of each community need to be determined as realistic assessments of town wastewater needs are to be made. Town populations can be influenced by seasonal industries such as fruit and vegetable harvesting, farming or tourism. Fluctuations in transient populations should be carefully considered to ensure that the additional loads on any potential sewerage system are taken into account. The season in which the fluctuations occur is also important, for example, the additional loading by summer tourism may be less than the peak seasonal flow of a significant industry. Terms commonly associated with assessment and sizing of wastewater schemes are as follows (DNRE 1997):

| | |
|---|---|
| Population | An estimate of the number of people within the township under consideration. |
| Equivalent Population (EP) | Includes domestic population and the conversion of commercial and industrial wastewater flows to a comparable basis. |

The existing population can be estimated from current occupied dwellings within the township under investigation. Occupancy rates are usually available from such sources as the Australian Bureau of Statistics Census Data. The average occupancy of dwellings in Australia typically varies between 2 and 4 (DNRE 1997). Table 46 below presents the occupancy of dwelling range exhibited by towns in South Australia.

**Table 46 Summary of Occupancy Rates for South Australian Towns**

| Occupancy Rates | |
|---|---|
| Maximum | 5.9 |
| Minimum | 2.0 |
| Average | 2.4 |

***Based on ABS Census 2001 for 117 towns.***

Appendix 12 contains information about the permanent population, growth rate over the 10 year period 1991 to 2001, and an estimate of the seasonal flux based on the total number of dwellings by the number of dwellings occupied for the 117 towns in South Australia. The information relating to population and population growth needs to be read in conjunction with each other to determine the reliability of the volume of effluent. For example, towns with a declining population base can expect a reduction in the total amount of effluent available over time, while those areas experiencing growth may expect increased volumes of effluent to be available (subject to impact of demand management measures adopted for water supply use).

### *7.4.2 Average Annual Effluent Flow*

The average annual effluent flow per allotment can be determined from the average daily contribution per person and the average occupancy of dwellings for that community which typically varies between 2 and 6 in South Australia (refer to Table 46). The adopted value varies depending on the extent of permanent dry weather infiltration and catchment size, because as the community size increases the effect of peaking decreases, due to influences such as variation in sewer travel times.

$$\text{Average Annual Flow in kL/allotment} = \frac{(ADF.\ 365).\ OR}{1000}$$

where

*ADF* = *Average daily flow contribution in litres per person*
*OR* = *Occupancy Rate for township (refer Appendix12)*

The ADF adopted depends on the type of wastewater system and the availability of reticulated water supply as shown in Table 47 below.

**Table 47 Average Daily Per Capita Effluent Contribution**

| Type of Sewerage System | ADF (L/person/day) |
|---|---|
| Conventional Sewer | 200 |
| STEDS | 160 |
| Effluent (no reticulated water) | 90 |

The figures adopted in this report for estimating the potential average annual yield of effluent for towns in South Australia have been based on previous work as described in Appendix 13.

A preliminary estimate of the average annual flow (AAF) for a community wastewater system can be determined from the average daily contribution per person and the population for that community.

$$\text{Average Annual Flow in kL } (AAF) = \frac{(ADF.\ 365).\ POP}{1000}$$

where

*ADF* = *Average daily flow contribution in litres per person (refer Table xx above)*
*POP* = *Base population (excluding periodic influx)*

Figure 96 provides a comparison of the potential effluent generation between South Australia's metropolitan and country communities with access to reticulated water supply and communities without. Where collection systems are prone to infiltration and inflow, significant fluctuations in flow may occur during the rainy season.

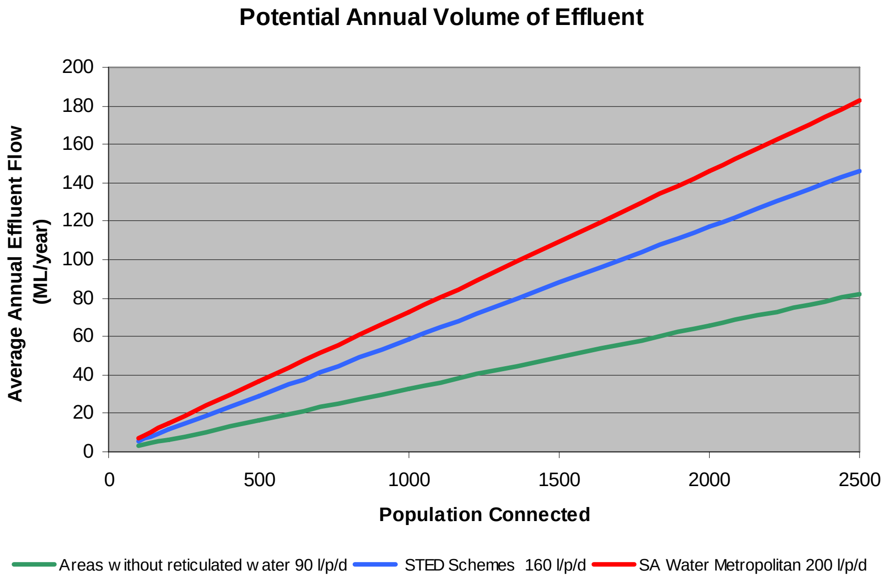
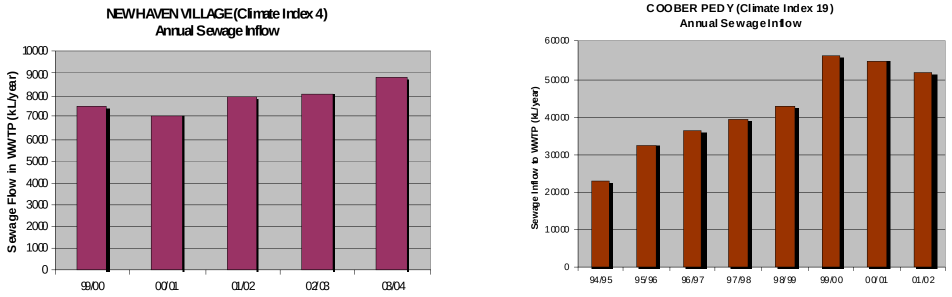


**Figure 96 Potential Effluent Generation by Population**

This information is useful in evaluating the potential yield of effluent as a source of water on an annual basis. If the expected annual average demands of a reclaimed water system are approximately equal to the average annual available supply, storage is required to hold water for peak demand months. However, care must be taken to select data representative of future conditions, ie. reduced per capita water use and less sewage effluent. For example, towns with a declining population base (negative growth rate) can expect a reduction in the total amount of effluent available overtime, while those areas experiencing growth may expect increased volumes of effluent to be available. This is subject to impact of demand management measures adopted for water supply use.

The township of Lameroo (climate index 5) is served by a STEDS scheme and has used treated effluent blended with stormwater harvested from the town area to irrigate the golf course since 1975. The permanent (base) population recorded in the 2001 Census was 459 (see Appendix 12) and has been declining at a rate of -2% for ten years prior. The AAF in 2001 was around 27 ML but could be expected to reduce to 25.5 ML by 2005 as the base population approaches 422 people. Information should be sought to determine if this rate of decline is expected to continue, or alter significantly if new industry moves to the town.

The increase in annual sewage flow into the local WWTP for the communities of New Haven Village and Coober Pedy, is illustrated in Figure 97 below.



*Note: Development reached 100% in 2001/02*
*Data courtesy David Potter (Aeroflow) & George Levay (Port Adelaide Enfield Council)*

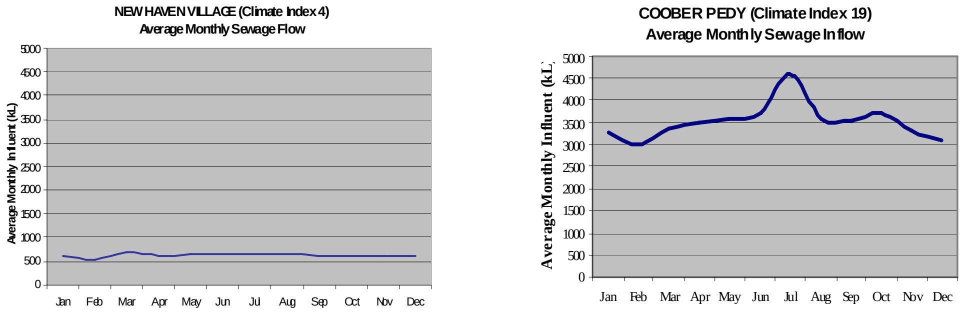
*Operational data courtesy Les Hoad (Coober Pedy Council)*
*Reticulated water supply commissioned in 1985.*
*Sewerage system commissioned in 1994 to replace effluent disposal by deep shaft*

**Figure 97 Annual Total Sewage Flow**

In the case of New Haven Village the increase in annual sewage flow is associated with the progress of the housing development, ie. connected population which was around 70% complete in 1999/2000 and fully developed by 2001/2002. Other the other hand, the increase in total annual sewage flow in Coober Pedy (which serves central commercial premises) is the result of an increase in potable water use and a growing tourist industry. The significant increase in total flows from 2000/2001 coincides with decrease in the presiding potable water price from $5.00 per kL to $3.50 per kL. The increased availability in the supply of treated effluent has allowed the reuse system to be extended and a town oval to be established.

### *7.4.3 Monthly Distribution of Effluent*

The monthly volume of effluent supply may exhibit seasonal changes (elevated flows) reflecting the region's seasonal influx of tourists or transient workforces. Seasonal flow fluctuations may occur in areas subject to periodic influx of tourists, and seasons of high flow do not necessarily correspond with seasons of high demand. Figure 98 illustrates the fluctuations in volume of effluent for the wastewater systems at New Haven Village and Coober Pedy. The effect of the tourism industry is visible at Coober Pedy.


NEW HAVEN VILLAGE (Climate Index 4)
Average Monthly Sewage Flow

COOBER PEDY (Climate Index 19)
Average Monthly Sewage Inflow

*Operational data for 5year period from June 1999 to July 2004 courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*

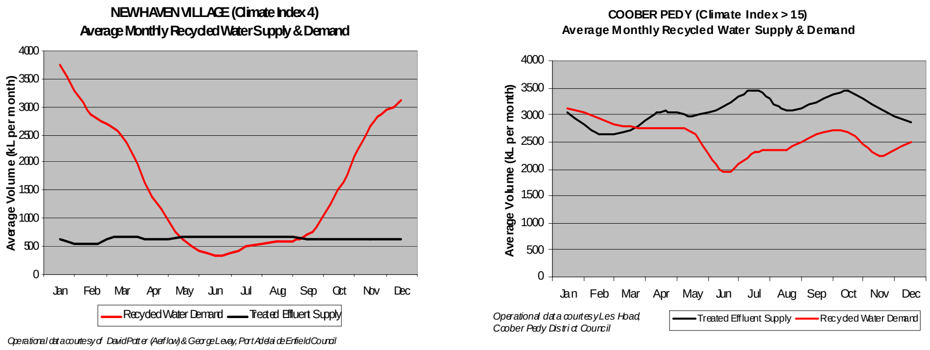
*Operational data for 8 year period from August 1994 to December 2002 courtesy Les Hoad (Coober Pedy Council)*

**Figure 98 Average Monthly Distribution of Sewage Flow**

The wastewater treatment facilities are also subject to the fluctuations in flow throughout the year. Defining the expected fluctuations in the supply of effluent is accomplished by averaging historic flows for each month from the available data. A long record is desirable for developing this average. Unfortunately, STEDS are not routinely monitored for flow and there is limited data to quantify rates of increases in effluent quantities passing through schemes over time (Pugh & McIntosh 1992).

To determine the likely potential seasonal influx, the number of occupied dwellings and the total number of dwellings in a given township have been compared in Appendix 12. For example, the townships of Port Vincent and Port Victoria on the Yorke Peninsula have maintained a steady population base over the ten year period from 1991 to 2001. However the high level of holiday homes (difference between occupied and total number of dwellings) in the township indicate a potential seasonal population increase of 250%. The same ratio indicates that the seasonal/ultimate population increase for Hawker, Lameroo, Orroroo, Peterborough and Quorn is of the order of 130% of the base (permanent) population. However, this is unlikely given these townships have all experienced a decline in base population of about 20% over the ten year period from 1991 to 2001. Consequently, the seasonal fluctuation in population is not likely to exceed 10%.

Information on flow quantities and fluctuations (peaking factors) is important in sizing the storage facilities necessary to balance supply and demand in water reuse systems. Figure 99 illustrates the fluctuations in reclaimed water supply and demand in for the water reuse schemes at New Haven Village and Coober Pedy.



*Operational data courtesy of David Potter (Aeflow) & George Levay, Port Adelaide Enfield Council*

*Operational data courtesy Les Hoad, Coober Pedy District Council*

**Figure 99 Matching Reclaimed Water Supply and Demand**

Where the recycled water demand curve is above the supply curve then water is added to the system from storage or external source. Where the demand curve is below the supply curve then effluent can be sent to storage or alternative disposal.

## 7.5 DEMAND ESTIMATION

The stormwater or treated effluent supply must be available when the consumer demands it. If these resources are to be viewed as a commodity, the users' needs must be accommodated in a similar manner to potable water supplies. User demand must be calculated to determine if the expected annual average demands for these resources is approximately equal to the average annual available supply as well as the most cost effective means to meet the pattern of demand, ie. storage may be required to hold water for peak demand months.

The need for irrigation at a specific location is a function of the crop being irrigated, stage of growth, irrigation system, and local rainfall patterns, all of which may vary considerably from site to site (Desmier 1989; US EPA 1992; WSAA 1998; Hazeltine & Bull 2003). The quality of the treated effluent has to be assessed to determine the correct balance of the irrigation rates with the land and crop requirements at any given site. The quantity of reclaimed water to be applied to a given area can sometimes be limited by loading rates of nutrients.

Where uses other than irrigation are being investigated, other factors will be the driving force on demand. These demands could be estimated based on past water use records (if available) or a review of the water use practices of the given customer segment.

### *7.5.1 Selection of Assessment Technique*

Estimation methods for crop water requirements are used because of the difficulty of obtaining accurate field measurements. The methods often need to be applied under climatic and agronomic conditions very different from those under which they were developed. Testing the accuracy of the methods under a new set of conditions is a time consuming and costly exercise, and yet crop water requirement data is needed for project planning. Methods for estimating how much water is needed are useful when planning for irrigation of landscaped recreational areas.

The primary factors controlling the need for supplemental irrigation are evapotranspiration and rainfall. A preliminary technique that relates the effect of variations in climate is the application of monthly water budget as follows:

*Irrigation Demand = [Crop evapotranspiration* ($ET_{crop}$) *+ Conveyance & other losses] – [Rainfall]*

Some of the variables, such as evapotranspiration which is strongly influenced by temperature are difficult to quantify. The magnitude of the evapotranspiration also varies according to local conditions. Doorenbos & Pruitt (1977 in Desmier 1989) undertook a worldwide review on crop water use and introduced the term *reference crop evapotranspiration (ETo)* that is related to local climatic data. *ETo* is defined as ‘the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water’ (FAO 1984).

A number of methods have been developed to estimate evapotranspiration (ETo) including, the Penman equation (energy balance but relies on meteorological data), pan evaporation method (water loss from an open surface related to consumptive use of a crop under similar conditions), and many empirical equations using commonly measured data like temperature (US EPA 1992). The choice of method used is typically based on the type of climatic data available.

Evaporation pans provide a measurement of the integrated effect of radiation, wind, temperature and humidity on evaporation from a specific open water surface. In a similar fashion the plant responds to the same climatic variables but several factors may produce significant difference in the loss of water. Notwithstanding these differences, evaporation pans can be used to predict crop water requirements for periods of 10 days or longer (FAO 1984). Desmier & Schrale (1988) undertook a review of three methods for determining the component “*ETo*” (in the above formulae) for crops grown in South Australia being:

- the Penman equation;
- directly from pan evaporation; and
- based on the Lysimeter studies.

The Penman and pan evaporation methods had a tendency to overestimate the water requirements, particularly during the summer months, as they did not take into account the following (Desmier & Schrale 1988):

- diurnal heat stress of plants (inability of the plant to respond linearly to high summer temperatures, ie. plants wilt on hot days because physically cannot keep up with evaporative demand;
- partial waterlogging of root zone as a result of irrigation; and
- salinity effect on the osmotic gradient at the soil water plant interface.

Desmier & Schrale (1988) found that the Lysimeter method was the most suitable and reliable for South Australia. Lysimeter studies were conducted at Murray Bridge (climate index 5), Mount Gambier (climate index 2) and Monarto (climate index 4) by the Department of Agriculture in South Australia. Estimates of *reference crop evapotranspiration* (*ETo*) can be made using:

$$\text{Reference crop evapotranspiration } (ETo) = Kp \cdot E_{pan}$$

where

$Kp$ = *monthly correction factor*
$E_{pan}$ = *mean monthly Class A pan evaporation (mm)*

To relate pan evaporation ($E_{pan}$) to reference crop evapotranspiration (ETo) an empirically derived monthly correction factor (Kp) is used to take into account the climate in South Australia are set out in Table 48 below. The monthly Lysimeter correction factor provides a good preliminary estimate of the reference crop evapotranspiration on a monthly basis for regions in South Australia with a climate index of up to 9. These will also be applied in regions with higher climate index in the absence of any better information.

**Table 48 Monthly Correction Factor Kp for South Australia**

| Monthly ETo Lysimeter Correction Factor Kp for South Australia | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| 0.64 | 0.58 | 0.62 | 0.55 | 0.56 | 0.55 | 0.59 | 0.77 | 0.87 | 0.8 | 0.72 | 0.64 |

*Desmier & Schrale (1988) based on South Australian experimental data*

### 7.5.2 Estimating Crop Water Use

Crop water use is then defined as 'the depth of water needed to meet the water loss through evapotranspiration ($ET_{crop}$) of a disease free crop, growing in large fields under non restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment.' The effect of crop characteristics on crop water requirements is given by the *crop efficient* ($K_{crop}$) which relates *reference crop evapotranspiration* (ETo) and *crop evapotranspiration* ($ET_{crop}$) as follows:

$$\text{Crop Water Use } (ET_{crop}) = K_{crop} \cdot ETo$$

where

$ETo$ = *Reference crop evapotranspiration for each month*
$K_{crop}$ = *Specific crop coefficient for each month*

The water requirements of individual crops are related to the reference crop during any month of the year by the crop coefficient where $K_{crop} = 1$ represents an actively growing grass 100 mm tall that is not stressed in any way. Values of $K_{crop}$ are shown to vary with the crop, its stage of growth, growing season and prevailing weather conditions (GSA 1987; US EPA 1992; WSAA 1998; Hazeltine & Bull 2003). $K_{crop}$ also varies from region to region depending on grower practices (Desmier 1989). For example, if the crop is hay, the value of $K_{crop}$ will vary depending upon how many hay cuts are taken off the area in a season.

### 7.5.3 Calculating Turf Irrigation Demand

Urban open space provides a range of benefits to the community. It provides recreation opportunities and settings, habitat for flora and fauna, visual amenity, mitigation of the extremes of our climate, and visual relief from the urban built form. Any element or technique that can increase the diversity of the landscape of urban open space, or enhances its development increases the value of the open space to the community.

For the purposes of this discussion, irrigation demands of turf grass (recreation areas) have been calculated because this is a common use of stormwater and treated effluent resources. Irrigation also exhibits the largest seasonal fluctuations, which can affect water harvesting and reuse system reliability. A preliminary calculation of the "*Irrigation Requirement*" for a given crop that relates the effect of variations in climate has been made using:

$$\text{Irrigation Requirement (mm)} = [Kp \,.\, K_{crop} \,.\, E_{pan}] - [\text{Rainfall (mm)}]$$

where

$E_{pan}$ = *pan evaporation (mm)*
$K_{crop}$ = *crop coefficient (constant)*
$Kp$ = *monthly correction factor (constant)*

When calculating the "*Irrigation Requirement*", the "*crop coefficient* $K_{crop}$" for turf grass and recreation areas can generally be assumed to be constant throughout the year. A value of $K_{crop} = 0.7$ has been adopted as turf grass (recreation areas) are generally only irrigated to avoid crop stress and keep them growing (Desmier *pers. comm.* 2003). The "*monthly correction factor Kp*" set out in Table 48 derived for South Australia on a monthly basis from the Lysimeter studies by the Department of Agriculture has been used.

Appendix 15 presents the average monthly irrigation demand expressed as a 'depth of water' for 220 towns in South Australia. The results have been grouped according to climate index to allow broad estimation of average irrigation season for regions in South Australia. The model uses estimates of average climate data and assumes that rainfall and evaporation are evenly distributed throughout each month.

Table 49 below summarises the average monthly irrigation requirements expressed as depth of water for irrigation of recreation within the given climate index range. A value for irrigation application efficiency is used to estimate the actual monthly pumping requirement. The average monthly rainfall has been excluded (ie set to zero) from the calculation for towns located with a climate index greater than 10 where rainfall is highly variable.

**Table 49 Average Monthly Turf Irrigation Demand by Climate Index**

| **Estimated Average Monthly Irrigation Requirement (mm)** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Climate Index** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total** |
| **2** | 79 | 59 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 47 | 66 | **299** |
| **3** | 92 | 69 | 52 | 3 | 0 | 0 | 0 | 0 | 3 | 28 | 64 | 81 | **391** |
| **4** | 112 | 85 | 65 | 13 | 0 | 0 | 0 | 0 | 14 | 45 | 83 | 100 | **517** |
| **5** | 119 | 89 | 72 | 22 | 0 | 0 | 0 | 0 | 29 | 59 | 95 | 109 | **594** |
| **6** | 125 | 93 | 76 | 28 | 0 | 0 | 0 | 7 | 40 | 71 | 104 | 117 | **661** |
| **7** | 130 | 98 | 81 | 36 | 5 | 0 | 0 | 15 | 51 | 80 | 110 | 123 | **729** |
| **8** | 132 | 101 | 84 | 39 | 9 | 1 | 3 | 22 | 57 | 85 | 114 | 126 | **771** |
| **9** | 140 | 106 | 90 | 45 | 16 | 3 | 6 | 29 | 67 | 97 | 125 | 135 | **859** |
| **10 – 14** | 173 | 138 | 119 | 72 | 49 | 35 | 38 | 67 | 110 | 143 | 166 | 169 | **1279** |
| **>15** | 196 | 146 | 135 | 82 | 55 | 37 | 46 | 80 | 128 | 155 | 175 | 186 | **1421** |

*Note. 1. The estimate for areas with climate index > 10 excludes the average annual rainfall*
*Note. 2. The estimate does not make provision for the type of irrigation method*

In most areas of South Australia, it is not possible to grow lawns, gardens or shrubs without irrigating for at least part of the year. Even in areas with moist winters (ie. climate index less than 5) it is necessary to supplement the natural rainfall to maintain plant growth and parks and gardens all year round.

Grass and recreation areas are usually irrigated with reticulated water at a considerable and escalating cost to the local community. Tree and shrub planting, unless permanently irrigated, has to survive summer conditions of high soil moisture stress for periods of up to 6 months. The average irrigation season for the southern parts of the state is between October and March where the climate index is less than 5, whilst areas with a climate index of more than 6 usually require irrigation all year round. In areas with a climate index greater than 15, the adoption of irrigation should be an exception rather than the rule.

To illustrate the influence that the prevailing climate has on the demand for water the estimated irrigation demands of turf grass in a hot, arid location (Coober Pedy) and a more temperate climate (Lock) are discussed. Figure 100 presents the average monthly potential evaporation and average monthly rainfall in Lock (climate index 5) on the Eyre Peninsula and Coober Pedy (climate index 19) in the Far North. In both locations the shape of the potential evaporation curve is similar over the course of the year while the distribution of rainfall at Lock and Coober Pedy differs significantly.

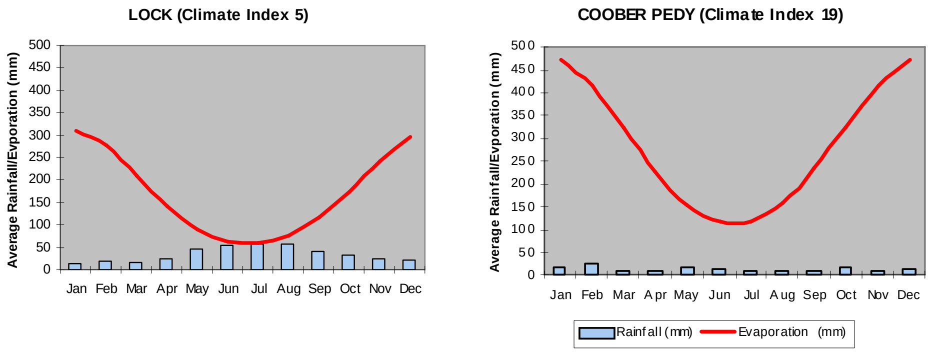


**Figure 100 Average Monthly Rainfall and Pan Evaporation**

Once the seasonal evapotranspiration and rainfall have been identified, water irrigation demands throughout the seasons can be estimated. The expected fluctuations in monthly need for irrigation of grass in Lock and Coober Pedy are presented in Figure 101 below. The figure illustrates that the pattern of supplemental irrigation and seasonal variation are different for the prevailing climate at each location.

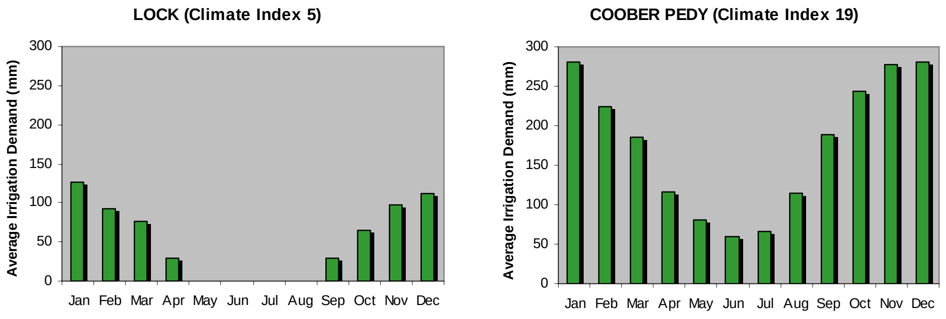


**Figure 101 Average Turf (Recreation Area) Irrigation Demand**

Because crop water requirements vary with climatic conditions, the need for supplemental irrigation will vary from month to month throughout the year. Therefore when planning a water harvesting and reuse project, it is important to quantify the seasonal demands as well as fluctuation in the supply of reuse water (be it wastewater or stormwater) to assure that the demand for irrigation water can be met. A value for irrigation application efficiency is used to estimate the actual monthly pumping requirement.

### *7.5.4 Adjustment for Efficiency of Irrigation Method*

The choice and operation of an irrigation system depend on several factors (WA WRC 1986):

- type of plants (growth form, crop factors, root zone);
- climate (especially evaporation rate and wind factors);
- soil type (infiltration rate and available water capacity);
- topography;
- water supply (water quality, volume available, flow rate);
- costs; and
- maintenance needs.

To calculate the "*Pumping Requirement*" the "*Irrigation Requirement*" needs to be adjusted for the efficiency of the irrigation systems being used, by applying (dividing) the appropriate factors presented in Table 50 below:

$$\textit{Pumping Requirement (mm)} = \frac{\textit{Irrigation Requirement for Crop}}{\textit{Efficiency of Irrigation Method}}$$

**Table 50 Assumed Efficiency of Irrigation Method**

| | |
|---|---|
| Flood | 0.50 |
| Spray irrigation | 0.70 |
| Drip Irrigation | 0.85 |
| Subsurface Irrigation | 0.90 |

*GSA 1987 & Desmier pers. comm. 2003*

The efficiency of the irrigation system adopted can reduce water wastage. Significant reductions in irrigation water uses are possible now by increasing efficiency with known technologies. Improved irrigation practices and technologies developed over recent years (moisture sensors, micro/drip irrigation) can reduce outdoor consumption by at least 30%-60% (Fleming 1999). A combination of reduced lawn areas, careful garden design, wise plant selection, and improved irrigation efficiency can readily provide a reduction in water use.

### *7.5.5 Irrigation Management*

The use of treated effluent to irrigate land used for agriculture or recreation requires extra management to ensure sustainability. Not all water is suitable for use as an irrigation source. Prior to implementing an irrigation system, the water source should be tested for water quality. The results of the test will determine if the water is suitable for irrigation or reveal if any special strategy will be required to overcome quality deficiencies (Parson *et al.* n.d.). Poor quality water can have an impact on crop production, especially when it is used for irrigation, affecting the health of plants and so reducing the quantity and quality of crops produced.

This is particularly evident in terms of the impacts of saline water on many horticultural commodities (WA WRC 1986; MDBC 1997). The salinity of treated effluent depends largely on the salinity of the reticulated water supply. Semi-saline waters containing around 1000 mg/L Total Soluble Solids (TSS), and in some cases, water containing only 700 mg/L can cause a build-up of salt in the soil to the detriment of plants (WA WRC 1986). To overcome this risk, an added water component should be allowed for leaching (normally between 10% and 20% of plant water requirements). The higher the water salinity the higher the leaching factor needed.

The soil must have sufficient drainage capacity to allow the saline leaching water to drain away. Soils vary in the amount of water they can hold. The sodium adsorption ratio is an indicator of the impact the water quality would have upon the soil structure which in turn affects the soil’s permeability. Applying more water than the soil can store, wastes water and contributes to salinity problems.

The quality of the water must be such that it will not be harmful to crops or to the soils on which it will be used. Maintenance of soil quality is essential for long term sustainability of irrigation schemes. Consequently, it is a legal requirement to develop an irrigation management plan for projects where treated effluent from municipal areas is used to irrigate land used for agriculture or recreation (EPA 1999). The irrigation management plan requires a regular sampling and analysis program to ensure that no harm is being done to the soil structure and chemistry.

## 7.6 SUMMARY

To achieve optimal outcomes when attempting water harvesting and reuse, gaining community support and conducting exhaustive feasibility studies are as important as gaining economic and technological backing. The main obstacle in the past limiting direct potable reuse has been community acceptance (Water Pollution Control Federation 1989).

Stormwater runoff and domestic effluent present a potential water resource that can supplement or replace other sources, but the community needs to be consulted for them to fully appreciate and understand the benefits. Alternative water resources can enhance regional communities by increasing the reliability of water supply and reducing the cost and providing water for communal areas such as ovals and parks. Communal, landscaped space provides a range of benefits to the community including recreational settings, habitats for flora and fauna and visual amenity. However, without extensive feasibility assessment and support from the community, chances of success are remote.

Before proposing water reuse schemes, a thorough feasibility study is necessary to prevent costly errors being made. A feasibility study is an analysis of a project's viability. It is a checkpoint that should be completed before committing any resources. The final product of a successful feasibility study is a project proposal for consideration by stakeholders. The 'cost to change' any aspect of a project is lower in the early phases and increases rapidly in the final phases (AIPM & CIDA 1995), so a thorough feasibility study can prevent costly blunders. The costs of alternative water reuse schemes can be properly examined and compared. A wide range of options must be fully analysed from the outset, and the needs/desires of the end user and limitations of the region (ie. climate, infrastructure, environment etc.) should be properly examined and understood. Through every step of planning for a new reuse scheme (or the augmentation to an existing scheme), the community and stakeholders should be involved to provide guidance (US EPA 1992), and steps taken to foster support for the project. Community stakeholders can provide significant contributions to the project assessment process.

Treated municipal wastewater represents a significant potential source of water for use as the effluent is generated in close proximity to urban areas. Methods for more efficiently harvesting rainfall and stormwater runoff involve collection from a variety of surfaces such as roads, roofs, driveways, parking areas and lawns. In areas of growth and new development, completely new wastewater collection, treatment and recycled water distribution systems may be designed from the outset with water reuse in mind. However, more often existing systems and communities are required to change.

The end user's needs must be accommodated if the project is to be a success. Stormwater or treated effluent must be available when the consumer demands it. User demand must be calculated to determine if the expected annual average demands for these resources are approximately equal to the average annual available supply. Storage may be required to hold water for peak demand months. Accurately determining the end user's needs and/or desires and differentiating between the two is an integral part of the design and consultation process. In some instances, the end user may have unrealistic expectations and need to be informed of the limitations of the system.

A community spirit can be harnessed to stimulate interest in the development of alternative water resources. The main objective of community involvement is to influence ‘public opinion’ in order to increase the level of acceptance and support for a project. It can also serve to increase public tolerance towards problems that may arise in the initial stages of implementation. The process should be introduced in the earliest stages of the system of planning to allow ample time for the dissemination of information and acceptance of new ideas. Active participation from the beginning is likely to encourage cooperation rather than a relationship of competition (Dugdale 1989; US EPA 1992) between the Project Sponsor, the Steering Committee and the community. The consultation process may accelerate the implementation of a project by uncovering any opposition early enough to adequately address concerns (US EPA 1992). Community members will be willing to share ideas when a community involvement process has been designed to include them and is directed by trusted local leaders (Nugent *et al.* 1997).

The forum for consultation should be designed with the specific nature of the community in mind to maximise accessibility. Water reuse projects enjoy their greatest public acceptance where water resource issues and pollution abatement issues have been combined, which can be demonstrated through the public consultation process. For specific reuse applications, where water reuse was imminent, the most important determinants of public opinion were:

- the ability of the project to effectively conserve water;
- environmental enhancement achieved by the project;
- measures to protect public health (the cost of treatment if required); and
- the cost of distribution/access to the water.

Appropriate community involvement can increase their ability not only to support large projects, but also to develop small harvesting and reuse projects on their own properties.

With the use of extensive feasibility studies and adequate research, positive water reuse outcomes can be achieved. The involvement of the key stakeholder, the community, is imperative in successfully achieving these goals. Effective assessments of the possibilities in the region of the proposed water harvesting scheme will always consider multiple factors including physical, climatic and biological limitations as well as technological and financial restrictions. When community members come to understand the benefits that water harvesting and reuse can have for the wider community, the environment, the economy and themselves it is more likely that they will support and participate in programs. Resistance from the community is often based on a simple fear of the unknown and this can be easily addressed through listening to their concerns and presenting them with factual information.

# Chapter 8
# Conclusion & Recommendations

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> *"Water recycling is a critical element for managing our water resources. Through water conservation and water recycling, we can meet environmental needs and still have sustainable development and a viable economy."*
>
> Felicia Marcus
> Regional Administrator

## 8.1 SUMMARY DISCUSSION

Water supply will always be a contentious subject as it is essential to so many spheres of human activity. It is vital for life and critical to our economy. New technology often requires high capital investment, and it is difficult to gain support from the community when it may mean increased expenditure for them. In decision-making, the direction taken by society is usually that of least cost. Society's course is largely dependent upon decisions made in the political arena, as governments are responsible for environmental, economic and social policy. Individuals can however have a significant influence through the decisions they make as part of their everyday lives.

Water conservation is a necessity for South Australians as we live in an extremely dry environment. With appropriate water conservation policies and the adoption of suitable landscaping practices, sustainability can be achieved even in South Australia's dry climate. The recent practice of stormwater harvesting has proven to be a sensible strategy in addressing wastewater disposal problems. When treated for use, it has provided the additional benefit of alleviating localised water supply problems in several South Australian towns. This has often been largely due to the initiative of the community.

It has been demonstrated that towns which organise water harvesting and reuse of non-potable water for themselves can be successful, and the benefits are far-reaching. This exercise has demonstrated that an informed community can and will find innovative solutions to address their local problems. Community success can, however, be considerably improved through the provision of appropriate government support. Promotion of water harvesting and reuse in urban and rural areas can educate the community as to the potential benefits, such as water conservation and added water security.

The potential for water harvesting and reuse in South Australian rural towns is often limited to non-potable irrigation of public areas, such as sports fields. While the benefits of this should not be overlooked, the adoption of dual water supply systems to households in rural towns has been inhibited by the following constraints:

- the high initial capital investment;
- the inability to raise capital for this additional public infrastructure;
- the inability to attract and retain suitably experienced and qualified operators;
- the additional financial pressure associated with ongoing operation and maintenance;
- the sustainability of the scheme with falling population; and
- meeting increasingly stringent health and environmental regulations.

This study identified that water harvesting and reuse systems have predominantly been successful in rural South Australia where community education and awareness (achieved largely through their involvement and consultation) has been used as the tool for identifying potential schemes. The normal channels of planning, design and implementation can then be used to influence and secure the sustainability and success of the scheme in terms of:

- affordability;
- technical appropriateness;
- current service delivery structures; and
- the level of skills and resources available in the community.

South Australia has a rich history of innovation in public water supply and wastewater management and has already established a strong community based approach to water resource management. There are encouraging signs that all levels of government are prepared to bring about the desired changes in attitude towards and management of Australia’s water resources. This has occurred largely as a result of falling water supply security. As a result of this, resources have been assigned by governments to identify and secure alternative or additional water supplies, especially in country towns of South Australia. Supplementary sources can often be comparable in cost with the existing true cost of providing reticulated supply in regional areas. As the cost of providing local water harvesting and reuse schemes becomes comparably less to implement, due to the increasing cost of existing reticulated supply, constraints are reduced for the South Australian State Government’s capital borrowing for these new schemes.

## 8.2 RECOMMENDATIONS

As the demand for water increases because of economic and population growth, the need to adopt water harvesting and reuse schemes in South Australian towns increases. Demand management, water conservation, stormwater collection and wastewater reuse are all now emerging as important aspects of urban and rural water systems. The recommendations made in this context are described below.

### *8.2.1 Community Involvement and Governance Regulations to Support Reuse*

It is recommended that:

- schemes be implemented to develop community awareness, eduction and participation in order to achieve consensus and support. By increasing awareness through education and training programs, we can change behaviour and attitudes, highlighting the value of water conservation schemes. The success of a water harvesting and reuse project depends on support from the local community. Individuals who have taken part in the planning process can be effective proponents of the selected options and become direct broadcasters of the water harvesting and reuse projects. Their understanding of the process will be communicated to the larger interest groups of whom they are apart. Involving the community takes time, raises expectations and requires allocation of sufficient budget and resources.

- water resource regulations be strengthened to support the momentum for non-potable water harvesting and reuse schemes. This encourages adoption of water reuse and harvesting schemes and identification of further potential sources. It is imperative that changes are streamlined to enable government to liaise with the community and provide rapid approval. This impacts on a project's viability as '*red tape*' often prevents progress. Websites should be used to centrally present information for community access. They should include the regulations, codes and legislation associated with the implementation of water reuse projects. This may require provision of access to software/hardware packages to aid preliminary exploration and development of options and their viability. Communities should be informed about agencies and consultants with specific areas of expertise to assist them in their involvement in the development of water reuse projects.

- increased incentives to adopt positive alternative smart water practices be pursued at all levels of government. The current institutional arrangements at both the national and state level are strongly aligned, thus presenting a positive environment for development of and training for local water harvesting and reuse projects in South Australian townships. The incentives to adopt alternative water supply practices are likely to increase in regional areas as the Government is obliged, under the recent National Water Initiative (June 2004) to either achieve full cost recovery for rural water supply systems or to publicly report the actual costs to the community providing these services. Under the terms of the Community Service Obligation (CSO), the Government is allowed to pay a service provider to take on the role of providing a service where full cost recovery is unlikely to be achieved. Under these regulations, Government provided services are contestable by private enterprise where they believe that they can provide the same or better service at a lower cost.

- simplified financing arrangement for small water harvesting and reuse projects be developed with government backing. The financing of water reuse has always been a limiting factor due to the lengthy nature of reviews/consultation required and the guarantees sought by financiers. The guarantees sought by most financial institutions make their funding unsuitable for small-scale, rural community schemes. A simplified financing option with government backing could achieve financial endorsement for many communities currently unable to fund water reuse or harvesting projects. A revision should be made of financial policies, so that water tariff charges are more closely linked to the cost of services provided. Tariff policy is an important issue and should be designed to sustain the financial viability of each system. Subsidies should be transitional and given to communities for a limited time. 100% recovery of operational and maintenance costs should always been the long term goal. Small towns should be provided with extensive assistance in tariff setting and financial management to allow for expansions and upgrades. This is important for projects of a size that falls into the gap in current funding (between $50,000 and $1M).

- <u>state agencies and regional providers continue, and where possible increase, their support to rural communities seeking to be actively involved in water issues.</u> Even with the current institutional arrangements, water supply will only be sustainable in rural communities where state agencies or regional providers have an ongoing support role. The ongoing role should include provision of specialist advice and '*public good*' research. It should ensure access to technical options and services providers, (project management, engineering, construction) increasing the technical capability of operators.

### 8.2.2 Water Sensitive Designs

It is recommended that:

- <u>design guidelines for small-scale water harvesting and reuse systems be developed and made accessible to rural communities.</u> The ability to achieve '*Water Sensitive Urban Design and Development*' principles depends on many variables including climate, population, topography, existing infrastructure and importantly, local culture. Perspectives and understandings of the potential of water reuse need to be promoted and fully understood as the right scheme is often very different in different regions. For example, Adelaide city has attempted to decrease runoff discharges, but some townships may want to maximise runoff and reuse it. A key advantage of stormwater harvesting is the fact that the volume of stormwater and effluent available for supply grows concurrently with the urban environment.

### 8.2.3 Demand Management

It is recommended that:

- <u>an appropriate pricing structure and level of service for water supply be developed.</u> The price of water provides a clear message about its value to consumers and encourages them to achieve an appropriate balance between the benefits and costs of water usage (WSAA 1998). Making water too cheap is often accompanied by increased water consumption and a loss of '*water consciousness*'. It must however also be acknowledged that a higher level of service provision also encourages water consumption that is higher than necessary. Establishing an appropriate pricing structure and level of service for water supply is an important part of the demand management strategy.

- <u>any pricing structure developed needs to take account of the special needs of remote South Australian communities.</u> The social impact of cost recovery associated with water supply systems within rural areas is very evident, especially in low-income regions. One of the keys to successfully recovering costs will be the government's willingness to price water supply services at a financially sustainable level. In most cases in South Australia, cost recovery for water supply schemes is not being achieved and subsidies are common in public utility services. There will always be some small community services that will not be economically viable, but need to be maintained to meet minimal public requirements.

- <u>management of community expectations be a key component of all water harvesting and reuse projects in South Australian towns and remote communities.</u> One of the observed issues with water harvesting and reuse projects has been the development of a level of complacence about their projects and an expectation that there will not be any reduction in the level of supply they have come to expect during difficult years. When times of low supply occur, the communities turn back to use of potable water to support the watering of community assets such as sporting fields and parklands. Community expectations need to be managed so that this does not occur and there continues to be an acceptance that there will be times of low supply and that potable water is too precious for this use.

- <u>government fund active community education of water conservation issues, including through promotion of water efficient devices and practices.</u> Active community education, and promotion of water efficient devices and practices, is vital to maintaining and further increasing community support for water conservation and improving self-regulation of community demand for water to sustainable levels.

### 8.2.4 Technology Verification Process

It is recommended that:

- <u>a national technology verification process be developed.</u> Simple solutions are required, particularly for smaller water harvesting and reuse systems. This could be facilitated through a procedure of technology verification, which would provide third party validation of the performance of pre-engineered, packaged treatment systems, specifically for Australian conditions. This verification process should be aligned with and endorsed by other, similar overseas organisations. By implementing the technology verification process from a federal level, it will be recognised across Australia, eliminating the need for expensive and repetitive qualifications. This reduced effort and cost for the end user will encourage the adoption of new technology to facilitate the early implementation of new innovative technologies. This support would encourage local communities and businesses to undertake self managed water treatment and reuse schemes in communities with a higher level of confidence so that compliance with standards will be achieved.

### *8.2.5 Increase Technical Capability on Water Reuse Schemes*

It is recommended that:

- <u>a centre for learning and excellence in small water supply schemes be established.</u> Establishment of a learning centre based around water harvesting and reuse schemes, where plant operators are provided with training, in monitoring, control, operations and maintenance, would be highly beneficial. This approach could be structured around existing education centres, utilising existing establishments and eliminating duplication. By improving the technical capability of operators, stakeholders and the public will be safer.

- <u>the collection and validation of minimal levels of data be compulsory, with appropriate funding support.</u> The collection and validation of hydrological data has deteriorated over the years, because government funding has not been available or maintained. Coupled with the lack of operational records for small water harvesting and reuse projects, this has resulted in the available design information being obsolete or outdated, causing '*over design*'. It has inhibited innovation, due to insecurity of outcomes and exposure to poor design. An increase in appropriate data collection to enable better designs for rural communities should be undertaken.

- <u>a national guide to water harvesting and reuse be developed, covering basic principles with an emphasis on residential and small-scale applications.</u> When considering harvesting water as a partial or total source of supply for an augmentation, this guide would provide the essential information to enable communities/engineers to design a system that meets their needs.

- <u>the following related technologies be promoted as suitable for inclusion in water havesting and reuse schemes appropriate for rural areas:</u>
    - *Subsurface drip irrigation* – potential for agricultural and water reuse applications (eg municipal and other industrial streams), operational and management procedures to be developed for South Australian conditions in order to overcome disadvantages (eg impact on native groundwater).
    - *Aquifer storage and recovery* - potential for agricultural and urban water reuse applications (eg municipal and other industrial streams). Operational and management procedures need to be developed for South Australian conditions in order to overcome disadvantages.
    - *Package treatment plants* - have the potential for agricultural and urban treatment on a small scale for potable or non-potable water. For these plants, is necessary to define the correct minimum water pre-treatment, because membrane and chemical levels will result in poor plant performance (ie. poor quality water) and high running cost.
    - *Renewable energy in the form of solar and wind* - can be used in remote areas for driving water treatment and reuse schemes. These areas of renewable energy are relatively new and as technology improvements continually being made, their cost is becoming more and more viable.
    - *Desalination technology* - has historically been expensive to establish, operate and maintain, but advances in this technology and the increasing demand on this type of facility is making these schemes more common.

- o *The construction of wetlands for stormwater management* - has multiple benefits as they are used for retention of stormwater and treatment by primary and secondary sedimentation as well as use UV before they are release for reuse. These types of schemes can be easily integrated into the urban environment as a landscape feature.

### *8.2.6 Performance Reviews of Demonstration Projects*

It is recommended that:

- a systematic review process to evaluate the performance and viability of the operational water harvesting reuse projects be developed and implemented. This would be particularly beneficial where funding is provided by government (public interest). It would allow further research to focus on improving existing systems and building new concepts and technologies; streamlining the water reuse industries by sharing knowledge. Performance evaluations should be provided as a service by the research community to review water harvesting and reuse schemes and offer suggestions for improvements.

- a monitoring and data collection program be implemented in South Australia to support the evaluation of existing and planned projects. There are no right and wrong answers for water reuse in South Australia. It is a process of continual learning and improvement. Successful introduction of an efficient water reuse scheme is very achievable, as has been demonstrated through the enthusiastic adoption of innovative water supply alternatives by South Australians in the past. Increased availability of monitoring equipment and better data collection would greatly assist communities in evaluating the performance of pre-existing schemes. In order for evaluations to be effective, a monitoring program would need to put in place as part of the routine operations.

### *8.2.7 Sustainability and Security*

It is recommended that:

- standards for security of water supplies be adjusted to take account of the needs and circumstances of small South Australian communities. The security and sustainability of reused or harvested water is difficult to guarantee, but essential for the success of any scheme. Contaminated water can be the cause of serious illness and even death. Factors influencing the security of water harvesting and reuse schemes in small rural communities vary from those in large urban communities which often require different solutions and standards. Small communities are not averse to accepting higher risk (lower standards), but health authorities in generally impose conservative standards that do not account for possible less demanding local conditions

- a range of alternative models be developed for water infrastructure projects in South Australian towns and remote communities. With sustainable development, there are no right and wrong answers. Alternative forms of water infrastructure are needed to complment traditional. This may include franchising, as well as other possible alternatives.

## 8.3 CONCLUSION

In conclusion, it is clear that considerable scope exists to manage current water supplies more efficiently and effectively so that further development of remaining fresh water resources in South Australia can become an exception rather than the rule. There is a limit to the sustainable use of water, which varies for each catchment in line with the interactions between available water resources within the catchment. The continued availability of water, in terms of both quality and quantity, is also open to change, not only through natural variation, but also through the impacts of water use within the natural water cycle. These constraints, in conjunction with local cultural water use characteristics will be the driving force for adopting sustainable practices into the design of current and future urban development and public infrastructure. More efficient use of existing supplies of water, including stormwater and wastewater, is one way of balancing society's needs with those of the environment.

Roof runoff, urban stormwater runoff, saline groundwater and treated effluent can be valuable water resources for many industrial, agricultural, municipal and domestic purposes, particularly in water scarce regions like South Australia. Water harvesting and reuse developments represent an additional local supply of water that can protect against water shortages (ie. water restrictions or system capacity constraints) and, at the same time, be used to improve the quality of life in individual rural communities. The value of the various alternative sources of water depends on how well the timing and quantity matches the demand for the water for a given location, both of which are a function of the prevailing climate.

Factors influencing the success of water harvesting and reuse project in a small rural community can be different to those in large urban centre, and often call for different solutions and standards. Innovation and experimentation will remain a key element to development of sustainable water harvesting and reuse systems for towns in South Australia. After all, what was considered best practice even a decade ago is sometimes quite different from what is deemed best practice today. Public perception of urban stormwater and treated effluent as sources of water supply also has a significant bearing on the success or failure of water harvesting and reuse projects.

Where it is financially feasible and health requirements can be satisfied, there is potential for increased water harvesting and reuse projects in towns in South Australia. However, for the foreseeable future, the potential for community-driven water harvesting and reuse projects in towns will be limited to non-potable irrigation of public areas, such as golf courses, town oval, median strip landscaping, parks and cemeteries. Although public understanding of the opportunities and liabilities related to water harvesting and reuse developments has increased, funding is always a major issue, especially for rural townships.

Water harvesting and reuse is not a radical new idea, but a sensible and necessary reality for Australians and in particular South Australians with their extra dry climate. Further more, when this is coupled with appropriate water conservation and the adoption of suitable landscaping practices, it can be made sustainable, even in South Australia's dry climate.

# Bibliography

## A

Abbott,K (1995): Water wastage. Letter from reader published in the *Sunday Mail* 10 December 1995; 56.

Abrams,L (1999): The African Water Page: An Experiment in Knowledge Transfer. International Water Resources Association, *Water International*, Volume 24 Number 2, 140-146, June 1999. [Online] Available: http://www.iwra.siu.edu. Accessed 16/04/00

Adar,E (2003): Transboundary aquifers - source of conflict or peace? *Water & Wastewater International* April 2003, 23-25.

*Advertiser* (1995a): Treatment Plant Start. Article appeared 11 July 1995, 7.

*Advertiser* (1995b): Insurance in the pipeline. Article appeared 25 March 1995, 12.

*Advertiser* (1995c): New house to tap into green future. Article appeared 19 May 1995, 6.

*Advertiser* (1995d): Mains water closer for tiny town. Article by Melissa King appeared 16 October 1995, 2.

*Advertiser* (1995e): Town takes water plea to Premier. Article by Melissa King appeared 18 October 1995, 13.

*Advertiser* (1995f): Pipeline deals to put town on tap. Article by Melissa King appeared 30 November 1995, 9.

*Advertiser* (1995g): $2.6m water project set to tap potential. Article by Colin Frearson appeared 16 September 1995, 39.

*Advertiser* (1999): Bottling what comes naturally. Adelaide, 10 March 1999.

*Advertiser* (2003a): Natural Remedies - Wind and Solar Power. Article appeared 17 September 2003, 66-67.

*Advertiser* (2003b): Wise water use. Article published in General News, 16.

*Advertiser* (2003c): Forecast 2070. Article by Catherine Hockley, political reporter appeared on 15 October 2003, 9.

*Advertiser* (2003c): Tanks in homes to water proof Adelaide. Article by Catherine Hockley appeared on 16 October 2003, 5.

Aeuckens,V; Harvey,MC (1985): *Review of Hydrometric Data Collection Practice in the Metropolitan Region of South Australia*. Engineering and Water Supply Department Report EWS LIB REF 85/38.

Akkad,AA (1990): Conservation in the Arabian Gulf Countries. *Journal AWWA*. Vol. 82, No. 5, 40-50.

Allan,JA (1996?): *Water Security Policies and Global Systems for Water-Scarce Regions*. [Online] Available: http://www.worldbank.org/mdf/mdfl/water.htm. Accessed 03/07/04.

Alvarez,K; Cleary,D; Wood,JF (1989): Rural Water Supply Management in New South Wales. *Proceedings of the National Workshop of Planning and Management of Water Resource Systems: Risk and Reliability*. Adelaide 23-25 November 1988. GC Dandy & AR Simpson (Editors).

American Water Works Association (1980): *Design and Construction of Small Water Systems - A guide for managers*, USA.

American Water Works Association (1982): *Basic Management Principles for Small Water Systems*. An AWWA small-systems resource book. USA.

American Water Works Association (1990): *Water Quality and Treatment*. A Handbook of Community Water Supplies. Fourth ed. McGraw-Hill, United States.

American Water Works Association (2000): *Principles of water rates, fees, and charges*. Manual of Water Supply Practices; M1; Fifth Ed. United States.

American Water Works Association (2004): *Small Utility Network Overview*. [Online] Available: http://www.awwa.org/science/sun/. Accessed 24/07/04.

ANCOLD (1994): *Guidelines on Dam Safety Management*. Australian National Committee on Large Dams, January 1994.

Anderson,JM (1995): Water Conservation and Recycling in Australia: Senarios for Sustainable Urban Water Use in the 21st Century. *Proceedings 16th Federal Convention of Australian Water and Wastewater Association*, Sydney, 389-395.

Anderson,JM (2005): Integrating Recycled Water into Urban Water Supply Solutions. SJ Khan,MH Muston, and AI Schafer (Eds); *Integrated Concepts in Water Recycling*, University of Woolongong, Australia; 32-40.

ANZAAS (1997): *Our Hidden State - South Australia through the eyes of its scientists*. Editor: Carey,C.

ANZECC (1992): *Australian Water Quality Guidelines for Fresh and Marine Waters*. Part of the National Water Quality Management Strategy. Australia, November 1992.

ANZECC; ARMCANZ (1999): *Australian and New Zealand Guidelines for Fresh and Marine Water Quality - Overview*. Public comment draft July 1999. Part of the National Water Quality Management Strategy. [Online] Available: http://www.environment.gov.au/science/water. Accessed 14 October 1999.

Anon. (1992): Wasser Difference? *Choice* January 1992, 6-9.

Anon. (1998): Reliable Water for Remote Community. Engineers Australia February 1998. [Online] Available:http://www.engaust.com.au/ea/0298pipes2.html. Accessed 27/04/00.

Anon. (2000): New name, new goals. *Asia Pacific Bottled Water*, Issue 3, 19.

Anon (2003): New checks and balanced: is business measuring up? *Waste Management and Environment* Volume 14 Number 4, 22-23.

Anon. (2003a): Grey water recycling proves popular in Jordon. *Water & Wastewater International* May 2003, Volume 18 Issue 3, 9.

Anon. (2003?): *Wastewater - A Resource for Reuse*. [Online] Available:http:\\www.onsiteconsortium.org/files/wastereuse. Accessed 20/10/2004. USA.

Archer,J (1991): *On the Water Front: Making Your Water Safe to Drink*. Pure Water Press, New South Wales.

Argue,J (1986): *Storm Drainage Design in Small Urban Catchments: A Handbook for Australian Practice*. Australian Road Research Board. Special Report SR 34.

Argue,JR (1991): A Short History of Water and Wastewater in Adelaide: 1838 to 1980. *Managing Stormwater in Adelaide Seminar*. Adelaide, South Australia.

Arid Lands Environment Centre (1992): *Gardens in the Desert - Imaginative Gardening in Arid Australia*. 2nd edition.

Armstrong,D (1992): Artificial Recharge and Reuse for Irrigation. Paper in *Irrigation with Storm Water - The Emerging Technology. IAA Urban Irrigation Seminar 19 July 1992*. Adelaide, Australia.

Asano,T; Mills,RA (1990): Planning and Analysis for Water Reuse Projects. *American Water Works Association* Volume 82 Issue 1, 38-47.

Asano,T; Smith,RG; Tchobanoglous,G (1985): Municipal Wastewater: Treatment and Reclaimed Water Characteristics. *Irrigation with Reclaimed Municipal Wastewater: A Guidance Manual*. (Eds: Asano,T; Pettygrove,GS) Lewis Publishers Inc, United States of America.

Aslin,HJ; Brown,VA (2004): *Towards Whole of Community Engagement*. A practical toolkit. Murray-Darling Basin Commission, Canberra, ACT.

Ashley,R; Blackwood,D; Butler,D; Jowitt,P (2004): *Sustainable Water Services - a procedural guide*. IWA Publishing, United Kingdom.

*Australian* (1995a): Creative solution to stormwater pollution. Article by Peter Trute appeared 22 July 1995, 70.

*Australian* (1995b): Salt clogs artery to the country's heartland. Article by Julian Chibb appeared 11 September 1995.

*Australian* (1995c): Stormwater a winner. Article by Amanda Annetts appeared 25 September 1995, 24.

Australian Academy of Technological Services and Engineering (1988): *Technology in Australia 1788-1988. Chapter 3 Water and Irrigation*. Developed by the Australian Science and Technology Heritage Centre. [Online] Available:http://www.austehc.unimelb.edu.au/tia/146.html. Accessed 29/12/2000.

Australian Academy of Technological Sciences and Engineering (1999): *Water and the Australian Economy.* A joint study of the Australian Academy of Technological Sciences and Engineering and the Institution of Engineers Australia. Victoria. April 1999.

Australian Bureau of Statistics (1998): *Census of Population and Housing: Selected Characteristics for Urban Centres and Localities South Australia*. Census 1996. Catalogue No. 2016.4 Commonwealth of Australia, Canberra.

Australian Bureau of Statistics (2003): *Census of Population and Housing. Selected Characteristics for Urban centres and Localities in South Australia.* 2001 Census. Report 2016.4.

Australian Institute of Project Management; Construction Industry Development Agency (1995): *Project Management Guide*

Australian Water Association (1999): ETV...what is it? *Crosscurrent* December 1999, 6.

Australian Water Association (2000a): Progress on COAG Reforms. Article appeared in *Crosscurrent* February 2000, 1.

Australian Water Association (2000b): Water, A Catalyst for Cooperation. Article appeared in *Crosscurren*t, April 2000, 1.

Australian Water Association (2000c): Urban Water in the Future. Article by Andrew Speers appeared in *Crosscurrent*, March 2000, 1.

Australian Water Association (2002a): *Australian Non Major Urban Water Utilities Performance Monitoring Report 2000-2001*. Written and compiled by AWA on behalf of the Australian non major urban utilities with funding from ARMCANZ.

Australian Water Association (2002b): The Future of Water. *Water* Volume 29, Number 8 December 2002, 18.

Australian Water Resources Council (1970): *Evaporation from Water Storages*. Hydrological Series 4 published on behalf of the Australian Water Resources Council by the Department of National Development, Australia.

Australian Water Resources Council (1992): *Public Participation and Involvement*. Planning Committee Occasional Paper PC No. 4 July 1992.

Australian Water & Wastewater Association (1994): SA Water Changes. *Crosscurrent,* Vol. 5 No. 1, 1.

Australian Water & Wastewater Association (1997): Treated Effluent for Sale. *Crosscurrent* 8 September 1997.

Australian Water & Wastewater Association (1999a): Review of South Australian Water Legislation. *Crosscurrent* 8 March 1999, 5.

Australian Water & Wastewater Association (1999b): Victor Harbor Wastewater Upgrade. *Crosscurrent*, 12 July 1999, 4.

Australian Water & Wastewater Association (1999c): Off-Peak Bulk Water Transportation. *Crosscurrent*, 8 February 1999, 4.

Australian Water & Wastewater Association (1999d): NSW Farm Dams Policy. *Crosscurrent*, 11 October 1999, 3.

Australasian Bottled Water Institute (n.d.): Australian Bottled Water Institute Home Page [Online] Available:http://www.bottledwater.org.au Accessed 15/11/00

Avbimelech,Y (1993): Irrigation with Sewage Effluents: the Israeli Experience. *Environment, Science & Technology* Vol. 27, No. 7, 1278-1281.

Ayers,RS; Westcot,DW (1985): *Water quality for agriculture*. Food and Agriculture Organisation Irrigation and Drainage Paper Number 29 Revision 1. Reprinted in Rome, 1989.

## B

Bachman,B (1995): Photographic Essay. *Club Marine*, Volume 10 Number 3, 48.

Bakken,JD; Bruns,TM (1991): Assessing the Reliability of Urban Reservoir Supplies. *Journal AWWA*, Vol. 83 No. 3, 46-51.

*Balaklava Producer* (1995): Check on Local Water Supplies. Article appeared 28 June 1995, 1.

Bates,GM (1995): *Environmental Law in Australia*. 4th ed. Butterworths, Australia.

Baumol,WJ; Blinder,AS; Gunther,AW; Hicks,JRL (1988): *Economics Principles and Policy*. Australian ed. Harcourt Brace Jovanovich, Marrickville, NSW.

Beder,S (2000): Making pollution data available on the internet. *Civil Engineers Australia* February 2000, 62.

Bell,S; Morse,S (2003): *Measuring Sustainability: Learning from doing*. Earthscan Publications, UK and USA

Benjes,HH; Alberts,R; Bowers,R (1994): Public Involvement Pays Off. *Water Environment & Technology,* February 1994, 60-63.

Berg,RR; Thompson,R; Little,PR; Gorgens,AH (1994): Evaluation of farm dam area-height-capacity relationships required for basin-scale hydrological catchment modelling. *Water South Africa* Vol. 20. No. 4 October 1994, 265-272.

Besley,AT (1998): Science, Technology and Innovation. Article published in *The Australian Academy of Technological Sciences and Engineering* (ATSE Focus No. 102 May/Jun 1998). [Online] Available: http://www.aste.org.au. Accessed 29/12/00. Revised 15/01/00.

Bidmeade,I (1989): *Health Law in South Australia*. A manual prepared for the South Australian Health Commission. 2nd edition.

Black,S (1993): *The Essentials of Public Relations*. Kogan Page, Great Britain.

Blackmore,DJ; Goss,KF; Newman,RJ; Powell,J (1999): Salinity Management in the Murray Darling Basin. Paper given at the *Australian Academy of Technological Sciences and Engineering Symposium*, November 1999.

Bowden,N (1999): *Water Supplies on Small Properties*. Farmnote published by Agriculture Western Australia. [Online] Available: http://www.agric.wa.gov.au/agency/pbns/farmnote/1998/f02298.htm. Accessed 28/04/00.

Bontrager,SL; Frieling,JL (1990): Siting Reuse Facilities in Existing Urban Areas. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s*, Aug 12-16, 1990, Phoenix, Arizona, 65-68.

Booker,N (2000): Economic Scale of Greywater Reuse Systems. *Water* September/October 2000, 22

Booth,M (2003): Winds of change. Article in The *Advertiser* 23 July 2003, 19.

Booth,R (1994): The cost/service compromise: the two sides of the coin. *Management Accounting* July/August, 48.

*Bordertown Chronicle* (1995): A start made on wetlands project. Article appeared 6 July 1995, 1.

*Borderwatch* (1994): Water pay decision bonus. Article appeared 6/12/1994; 2.

*Borderwatch* (1995a): Big turnout expected at Port Mac septic meeting. Article appeared 24 April 1995, 5.

*Borderwatch* (1995b): Port Mac septic and drainage plan approved. Article appeared 28 April 1995, 2.

BottledWaterWeb (1999): *The Worth of Water*. [Online] Available:http//www.bottledwaterweb.com/watervalue.html. Accessed 03/03/01.

Boully,L (2000): The Need for a New ICM Model. *Water* May/June 2000, 26-28.

Bowen,R (Ed.) (1986): *Groundwater*. 2nd ed. Elsevier Applied Science Publishers, London.

Brassington,R (1983): *Finding Water - A guide to the construction and maintenance of private water supplies*. Pelham Books, London.

Brisbane Water (2003): *Sustainable partnerships, solutions, commitment*. Report to Stakeholders 2003. Brisbane, Australia.

Briscoe,J (1996): Water as an Economic Good: The idea and what it means in practice. Paper presented at the *World Congress of the International Commission on Irrigation and Drainage, Cairo, September 1996*.

Broad,PA; Holroyde,RM (1989): Economics, Demand Management and Security of Supply Issues. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

Brock,TD (1974): *Biology of Micro-organisms*. Second edition. Prentice-Hall Incorporated.

Brown,GA (1994): *Environmental Audit Guidebook.* 3rd ed. Centre for Professional Development, Victoria.

Bruce,JP; Clark,RH (1966): *Introduction to Hydrometeorology*. Pergamom Press, Great Britain.

Buckles,D (1999): *Cultivating Peace. Conflict and Collaboration in Natural Resource Management*. International Development Research Centre, World Bank Institute, Canada.

Buisine,F; Oemcke,D (2002): A case study: wastewater quality treatment and management for reuse in the Willunga ASR project. *Proceedings of the 4th International Symposium on Artificial Recharge of Groundwater, ISAR-4*, 22-26 September 2002, Adelaide, South Australia; 203-207.

*Bunyip Gawler* (1995): Park extension vote deferred. Article appeared 7 June 1995.

Bureau of Reclamation (1977): *Design of Small Dams*. A Water Resources Technical Publication. Revised Reprint of Second Edition.

Burgess,C (1991): *Drinking Water Basics*. Water Board Sydney - Illawarra - Blue Mountains publication.

Burton,JR (1965): *Water Storage on the Farm - A manual of design, construction, and operation for Australian conditions.* Water Research Foundation, Foundation Bulletin No 9.

Byrne,RA (1995): *Life Cycle Asset Management: a best practice perspective*. Water (September/October 1995), 10-12.

## C

Cairncross,S; Feachem,R (1986): Small Water Supplies. *Ross Bulletin* 10 June 1986. The Ross Institute and Advisory Service.

California Environmental Protection Agency (1998): California Environmental Protection Agency Home Page. [Online] Available: http://www.calepa.ca.gov/publications/newsletters. Accessed 4/06/99

Campbell,RE (1983): *Microbial Ecology*. Second Edition. Blackwell Publications.

Campbell,R; Moore,P; Youl,R (1993): *Activating Community Involvement in Regreening Australia's Catchments*. River Publications. RIV PUB 0204. A series on ecological sustainable development.

Canada Mortgage and Housing Corporation (2003): *Denver Potable Water Demonstration Project*. [Online] Available:http://www.cmbc-schl.gc.ca. Accessed 18/09/03.

Cargill,R (1997): Water Factory to recycle water to drinking quality. *Civil Engineers Australia* October 1997, 31-32.

Carpenter,T (1998): WSAAfacts 1997 A Snapshot of the Australian Urban Water Industry. *Water* November/December 1998, 42-47.

Carson,L; White,S (1998): The Sydney Water contamination crisis:: Manufacturing dissent. *Science and Public Policy*, Volume 25, Number 4, August 1998, 265-271.

Carvan,J (1991): *Understanding the Legal System*.

CBC (2004a): Canada's worst-ever E. coli contamination. *CBC News Online* 20 December 2004. [Online] Available: http://www.cbc.ca/news/background/walkerton. Accessed 21/01/05.

CBC (2004b): Stan Koebel gets 1 year in jail, Frank 9 months house arrest. *CBC News Online* 21 December 2004. [Online] Available:http://www.cbc.ca/story/canada/national/2004/12/20/koebels-sentenced041220.html. Accessed 21/01/05.

Centre for Groundwater Studies (1999): Aquifer Storage and Recovery. Course notes for the 2nd national short course 27 - 29 October 1999, Adelaide, South Australia.

CEPA (1993): *Urban Stormwater - A Resource to Valuable to Waste*. Discussion paper issued by the Commonwealth Environment Protection Agency in response to a report from the CSIRO.

Chaloux,L (n.d.): Wastewater recycling and reuse: How far will we go?

Chartres,C; Stauffacher,M; Walker,G; Hatton,T (2003): *Is the River Murray Water Quality Deteriorating? A salinity perspective*. [Online] Available: http://:www.clw.csiro.au. Accessed 13/11/03. Modified August 2003.

Chaudhary,H; Pitman,C (2002): Implementing large-scale stormwater recycling schemes - meeting economic, environmental and community objectives. *Proceeding of the 4th International Symposium on Artificial Recharge of Groundwater, ISAR-4, 22-26 September 2002, Adelaide, South Australia*. 515-518.

Chlorine Chemistry Council (2003): *Drinking Water Chlorination: A Review of Practices and Issues*. February 2003. [Online] Available:http://c3.org/chlorineissues/disinfection/c3white2003.html Accessed 21/01/05.

Chrispijn,J (2003?): *Assessing Different At-source Stormwater Treatment Devices in Hobart: Sullivans Cove and Brooker Highway Performance Trials.* Hobart City Council.

*City Messenger* (1995): Recreational wetlands proposed for south parklands dry area. Article appeared 3 May 1995, 5.

Clark,RDS (1980): *Public Involvement in Planning for Water Supply in Metropolitan Adelaide*. Final Report prepared by PA Consulting for the Engineering and Water Supply Department, August 1980.

Clark,RDS; Mitchell,N (1987): *Annual Rainfall - Runoff relations in Mt. Lofty Ranges Catchments near Adelaide, SA*. Engineering Water Supply Department. EWS Lib. Ref. 87/19. Adelaide. July 1987.

Clark,RDS (1989): Assessment of Risks with Respect to Public Water Supplies in South Australia. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk & Reliability. Adelaide 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

Clark,RDS; Kotwicki,V; Tomlinson,GW (1991): *Hydrological Study of Bakers Range and Marcollat Water Courses*. Engineering and Water Supply Department. EWS Lib Ref 91/12. Adelaide. April 1992.

Clark,RDS (1992): Improved Water Management in Schools - Putting Theory into Practice. Discussion paper at the Australian Geography Teachers Association 13th National Conference "Geography and Future Lifestyles", Adelaide 13-17 January 1992.

Clark,RDS (1992b): Multi-objective Management of Urban Stormwater in Adelaide. Part 1 - technical Considerations. Paper presented at the International Symposium on Urban Stormwater Management, 4-7 February 1992, Sydney; 298-304.

Clark,RDS (1996): Stormwater, wastewater and groundwater - a potent mix for urban water systems in Adelaide. *Waterfall Newsletter* February 1996, Stormwater Industries Association.

Clark,RDS; Perkins,A; Wood,SE (1997): *Water Sustainability in Urban Areas - An Adelaide and Regions Case Study. Draft Report One - An Exploration of the Concept.* First report in the Water Sustainability in Urban Areas Series prepared as a contribution to the Better Cities II Program.

Clark,RDS (1998): A Wake-Up Call for South Australian Water Planning. Draft Paper, September 1998.

Clark,RDS (1999): Submission of the Water Corporation, Waterworks and Sewerage Acts. January 1999.

Clark,RDS (2003?): *Water Proofing Adelaide - Modelling the Dynamic Water Balances*. Richard Clark and Associates, Adelaide, South Australia.

Clark,RDS (n.d.): A Case Study of Scotch College Aquifer Recharge Scheme. Unpublished. Engineering and Water Supply Department. Adelaide.

Clark,RM; Goodrich,JA; Lykins,BW (1994): Package plant for small water supplies - the US experience. *AQUA* Vol. 3 No. 1, 23-34.

Cline,GC; Pirnie,M (1990): Assessing the Costs and Benefits of Water Reuse. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990*, Phoenix, Arizona, 159-161.

CMPS&F Environmental (1996): *Alternative Overseas Water Treatment and Supply Practices.* Urban Water Research Association of Australia, Research Report No 112, June 1996. Melbourne, Australia.

Cocks,D (1992): *Use With Care*. Managing Australia's Natural Resources in the Twenty First Century.

Codner,GP; Laurenson,EM; Mein,RG (1988): Hydrologic Effects of Urbanization: A Case Study. *Hydrology and Water Resources Symposium 1988*, ANU Canberra, 1-3 February 1988.

Cohen,N (1997): Implementing Community Advisory Panels: Essentials for Success. *Interact* Volume 3 Number 1, 30-37.

Colebatch,HK (2005): Governing the Use of Water: The Institutional Context. SJ Khan, MH Muston, AI Schafer (Eds) *Integrated Concepts in Water Recycling 2005*, University of Wollongong, Wollongong, Australia.

Collins,R (2003): Hard sell for "new" water. Waste Management and Environment Volume 14, Number 4, 39-40.

Columbia Encyclopaedia (2000): *Australia - Land*. Sixth Edition, Columbia University Press. [Online] Available:http://www.infoplease.com/ce6/world/A0856770.html. Accessed 03/07/00

Commonwealth of Australia (1983): *Water Technology, Reuse and Efficiency*. Department of Resources and Energy, Water 2000: Consultants Report No. 10. Australian Government Publishing Service, Canberra.

Commonwealth of Australia (1989): *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability*. 23-25 November 1988, Adelaide. GC Dandy & AR Simpson (Editors). Australian Water Resources Council Conference Series No. 17.

Commonwealth of Australia (1997): *B7 Water, Sewerage and Drainage. Implications of the Hilmer Report on the water, sewerage and drainage industry*. [Online] Available:http://www. pc.gov.au/research/irrs/hilmer/b7.pdf. Accessed 16/10/99. Modified 19/11/97.

Commonwealth of Australia (1999): *Parliament of Australia*. [Online] Available: http://www.aph.gov. au. Accessed April 2000. Last Updated 16/12/1999.

Commonwealth of Australia (2000a): *Australia Now - A Statistical Profile - Population*. [Online] Available: http/www.abs.gov.au/Ausstats. Accessed 03/07/00

Commonwealth of Australia (2000b): Federal Government Response to Specific Priorities from the Top End Local Consultations. Northern Australia Forum Report Water Infrastructure. [Online] Availabe:http://www.dotrs.gov.au/regional/northernforum/formalresponse/topend/water.html . Accessed 21/07/04. Modified 03/09/02.

Commonwealth of Australia (2001): *Australia State of the Environment Report 2001. Human Settlements Theme Report*. Lead Author: PW,Newton. CSIRO Publishing.

Commonwealth of Australia (2002): *The Value of Water*. Inquiry into Australia's Urban Water Management. Report of the Senate Environment, Communication, Information Technology and Arts References Committee December 2002. [Online] Available:http://www.aph.gov.au/senate/committee/ecitactte/water/report. Accessed 21/07/04.

Commonwealth of Australia (2004): *National Urban Water Efficiency. Urban Water Use Statistics in Australia.* Department of the Environment and Heritage. [Online] Available:http://www.deh.gov.au/water/urban/statistics.html Accessed 18/07/04.

Commonwealth of Australia (n.d.): Australia's Legal System [Online] Available:http://law.gov.au/auslegalsys/auslegalsys.htm. Accessed 16/10/99.

Competition Commissioner (1997): *Water and Sewerage Pricing for SA Water Corporation*. A pricing oversight investigation under the Government Business Enterprises (Competition) Act 1996. Final Report April 1997.

*Coober Pedy News* (2004) No. 61, 23 July 2004

*Coober Pedy Times* (1994a): Our water supply. Article by Carrie Adams appeared on 12 October 1994. 16.

*Coober Pedy Times* (1994b): Sewerage system now on line. Article appeared on 6 April 1994. 1&3

*Coober Pedy Times* (2001): Commissioning of the new water plant. Article appeared 20 December 2001, 1.

*Coober Pedy Times* (2001): Coober Pedy running out of water. Article appeared 25/10/2001 in the SA Regional Newspaper; 1.

Coombes,PJ; Kuczera,G; Kalma,JD (2002): Economic, water quantity and quality impacts from the use of a rainwater tank in the inner city. Paper presented to the Hydrology and Water Resources Symposium, Melbourne 2002 published in *Australian Journal of Water Resources*, Vol. 7, No. 2; 111-120.

Cooper,B; Crase,L; Dollery,B (2005): Using Choice Modelling to Reveal Wastewater Preferences in Regional Victoria. Paper in Proceedings of the *Integrated Concepts in Water Recycling* Conference, Woolongong, Australia, 2005; 142-153.

Cordery,I (1976): Potential Value of Treatment of Urban Stormwater. *Civil Engineering Transactions* 1976, 60-63.

Cordery,I; Cloke,PS (1992): An overview of the Value of Collecting Streamflow Data. *Transactions IEAust* Volume CE34 Number 3 September, 271-276.

Cordery,I (1999): The Need for Renewed Effort in Collection of Data on the Aquatic Environment. Paper presented at Water 99 Joint Congress - Brisbane Australia 6-8 July 1999.

Cortese,CF; Firth,L (1997): Systematically Integrating Public Participation into Planning Controversial Projects: A Case Study. *Interact* Volume 3 Number 1, 6-23.

Council of Australian Governments (1999): *Infrastructure Agreements and Reform Initiatives Chapter 3 Water Reforms.* [Online] Available:http://www.pc.gov.au/inquiry/compol/draftrep/supplementa/chapter3.pdf.
Accessed 16/10/99. Modified 22/06/99.

Cowen,PB; Cowen,T (1997?): Deregulated Water Supply: A Policy Option for Developing Countries. *CATO JOURNAL* Vol. 18 No.1 [Online] Available:http://www.cato.org/pubs/journal. Accessed 03/07/2004.

Cox,J; Fell,D; Thurstain-Goodwin,M (2002): Red Man, Green Man. RICS Foundation, London, UK.

Cox,P; Fisher,I; Kastil,G; Jegatheesan,V; Warnecke,M; Angles,M; Bustamante,H; Chiffings,T; Hawkins,PR (2003): Sydney 1998 - Lessons from a drinking water crisis. American *Water Works Association,* May 2003, 147-161.

Crockett,J; Carroll,L (1997): A quantum increase in water prices. *Water*, October 1997, 43-46.

Crook,J (1994): Water Reuse Evolution. *Water Environment & Technology* November 1994, 4.

*Crosscurrent* (1993): Recycled Water. Australian Water Association Newsletter, Vol. 4, No. 7, 18 August 1993; 1.

CSIRO (1999): Urban Water Program. A collaborative research effort. [Online] Available:www.dbce.csiro.au/urbanwater/index.htm. Accessed 16/11/2000. Updated 16/09/1999.

CSIRO (2000): Climate variability and climate change - the last 120 million years. *CSIRO Atmospheric Research Greenhouse Information Paper*. November 2000. [Online] Available:http://www.dar.csiro.ay/publications/greenhouse2000c.htm. Accessed 31/05/04. Modified 16/05/02.

CSIRO (2001): *Future of Adelaide's Water Supply*. Press Release 19 January; Ref 2001/22 reproduced in Built Environment Innovation & Construction Technology. Number 17 February 2001. [Online] Available:www.bdce.csiro.au/inno-web/0201/adelaide.htm. Accessed 27/02/01. Updated 23/02/01.

Cullen,P (2004): *Water Challenges for South Australia in the 21st Century*. Adelaide Thinker in Residence Final Draft July 2004. Adelaide, Australia.

Cummings,J (2003): Desalination scheme for Burrup Peninsula. *Engineers Australia Civil Edition* Volume 75 Number 10, 24-26.

Cunliffe,DA (1998): *Guidance on the use of rainwater tanks*. National Environmental Health Forum Monographs. Water Series No. 3, South Australian Health Commission, Adelaide.

**D**

Dale,M (1990): Woodlots Workshop. *Proceedings of a workshop held at Mildura*, 10-11 April 1990.

Dandy,G (1987): *A study of the factors which affect residential water consumption in Adelaide*. University of Adelaide, AWRAC Research Project 85/17, March.

Dandy,GC (1989): An Economic Approach to Water Restrictions Policy. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

Daniell,K; Kingsborough,A; Malovka,D; Sommerville,H (2004): *Assessment of the Sustainability of Housing Developments - Literature Review*. Assignment submitted to the University of Adelaide, School of Engineering May 2004.

Danzi,E (1999): Irrigation Water Reforms - Impact on horticulture farms in the Southern Murray Darling Basin. *ABARE Current Issues* 99.2, April 1999, 1-12.

Davis,C (1994): What is Water Business? *Water* Vol. 21, No. 5(October 1994), 3.

Davis,G (1996): *Consultation, Public Participation, and the Integration of Multiple Interests Into Policy Making.* Report prepared for the Organisation for Economic Cooperation and Development, Paris May 1996.

Davis,S; Roche,A (1998): Risk Management Strategies for Recoverable Resources. *Water* November/December, 38-40.

Davis,J; Iyer,P (2002): *Taking Sustainable Rural Water Supply Services to Scale: A Discussion Paper*. This report was funded by the Bank-Netherlands Water Partnership and the World Bank Water and Sanitation Program.

Day,DG; Formby,JR (1988): *The Introduction of User Pays Domestic Water Pricing in Newcastle: Public Reaction Government Response*. Australian Water Research Advisory Council Research Project 85/122 Final Report. Australian National University. March 1988.

deBono,E (2000): *Six Thinking Hats*. 3rd ed. Penguin, Great Briton.

Department of Agriculture South Australia (1987): *Far West Coast Alternative Water Supplies*. Report prepared by consulting engineers Roger Stokes & Associates. March 1987.

Department of Agriculture (1991): Irrigation Workshops for the Barossa Region. Presented by Tony Thomson, Irrigation Officer, Department of Agriculture, Adelaide. 22-25 July 1991 & 29 July - 1 August 1991.

Department for Environment Heritage and Aboriginal Affairs (1997): Water Affecting Activities - Farm Dams, Bores and the taking of water. A guide to Section 9 of the Water Resources Act 1997.

Department for Environment Heritage and Aboriginal Affairs (1999): *Who Owns Water*. An explanatory note to support the State Water Plan. [Online] Availabe:http://www.dehaa.sa.gov.au/water/plan.html. Accessed 30/12/99.

Department of Environment (1972): *People and planning*. A report of the Committee on Public Participation in Planning.

Department of Housing and Urban Development (1993): *Guide to Development Assessment.* An integrated planning and development assessment system.

Department of Natural Resources and Environment (1997a): *Improved Wastewater Management in Small Towns - A process for Community Involvement*. Water Agencies Branch. Water Quality Section Report No. WQ97.002. Victoria. May 1997.

Department of Natural Resources and Environment (1997b): *Guidelines for Alternative/Affordable Wastewater Management Options. Water Agencies Branch.* Water Quality Section. Report No. WQ97.003, Victoria. October 1997.

Department of Natural Resources (1998): *Queensland Wastewater Reuse Strategy*. Background paper prepared for Queensland Wastewater Reuse Strategy Steering Committee, Department of Natural Resources, Queensland Government. Edited by: Beavers,PD and Gibson,HE.

Department of Natural Resources (2000): *Draft Queensland Recycling Strategy*. Consultation document, November 2000. Queensland, Australia.

Department of Primary Industries and Energy (1988): *The Importance of Surface Water Resources Data to Australia*. Australian Water Resources Council Water Management Series No. 16, Australian Government Publishing Service, Canberra.

Department of Primary Industries and Energy (1989): *Guidelines for Low Cost Water Supplies for Small Communities.* Australian Water Resources Council Water Management Series No. 17. Australian Government Publishing Service, Canberra.

Department of Premier and Cabinet (1998): *Guidelines Paper for Agencies conducting a Legislation Review under the COAG Competition Principles Agreement*.

Department of Water, Land and Biodiversity Conservation (n.d.): *New Directions in Natural Resource Management in South Australia*. Fact Sheet 10 [Online] Available: http://www.dwlbc.sa.gov.au. Accessed 10/10/04.

Desmier,RE (1991): *Waikerie Septic Tank Effluent Disposal Scheme. Options for alternative design and management to reduce the potential for pollution of the River Murray*. Engineering and Water Supply Department. EWS Lib Ref. 91/32. Adelaide. November 1991.

Desmier,RE; Schrale,G (1992): *Concept Study of Irrigation Options for Bordertown Septic Tank Effluent.* Prepared by SA Department of Primary Industries (Adelaide) for Tatiara District Council (Bordertown) December 1992.

Desmier,RE (1995): Irrigating with Sewage Effluent Some Design Considerations. *Proceedings from a seminar on Re-Use of Sewage Effluent on 26 September 1995*, Australian Water and Wastewater Association.

Desmier,RE (1997): Reuse of Urban Stormwater. Hydrological Society of South Australia Seminar. *Proceedings of Stormwater in the next millennium: exportable innovations in stormwater management.* 23 October 1997.

Development Act (1993): South Australia

Diamant,BZ (1985): The urgent need for the reuse of sewage effluent in developing countries. *Reuse of Sewage Effluent Symposium.* Institution of Civil Engineers, London UK. 23-33.

Dillon,PJ; Martin,R (1999): Storage of Stormwater and Recycled Water in Aquifers: Impacts on Environmental and Health Risks in Water Reuse. *Proceedings of Australian Water and Wastewater Association 18th Federal Convention, Adelaide, Australia, 11-14 April 1999*.

Dillon,PJ; Pavelic,P (1996b): *Guidelines on the Quality of Stormwater and Treated Wastewater for Injection into Aquifers for Storage and Reuse*. Urban Water Research Association of Australia Research Report No. 109.

Dillon,PJ; Hickinbotham,MR; Pavelic,P (1996): Review of International Experience in Injecting Water into Aquifers for storage and Reuse. *Proceedings of Aquifer Storage and Recovery Seminar, Adelaide, October 1996*.

Dillon,PJ; Pavelic,P; Sibenaler,X; Gerges,N; Clark,R (1997): Aquifer Storage and Recovery of Stormwater Runoff. *Water* July/August 1997, 7-11.

Dillon,PJ (1999): ASR Economics. Course notes presented at the 2nd national short course on Aquifer Storage and Recovery, 27 - 29 October 1999, Adelaide, Australia.

Dillon,PJ; Toze,S; Pavelic,P; Ragusa,S; Wright,M; Peter,P; Martin,R; Gerges,N; Rinck-Pfeiffer,S (1999): Storing Recycled Wastewater in an Aquifer - Benefits and Risks. *Water* September/October 1999, 21-29.

Dillon,PJ (2002): Management of Aquifer Recharge for Sustainability. *Proceedings of the 4th International Symposium on Artificial Recharge of Groundwater, ISAR-4, Adelaide, South Australia* 22-26 September 2002.

Dodge,T (1999): Disseminating Water Information via CD-ROM: A Case Study. International Water Resources Association, *Water International*, Volume 24, Number 2, 168-171.

Dolnicar,S; Saunders,C (2005): Marketing Recycled Water; Review of past studies and research agenda. Paper in *Integrated Concepts in Water Recycling*, Wollongong, Australia;181-189.

Doorenbos,J; Pruitt,WO (1984): *Guidelines for Predicting Water Crop Requirements*. Irrigation and Drainage Paper 24. Food and Agriculture Organisation of the United Nations, Rome 1984.

Dortch,E (2005): Hypersaline water causes concern. Article appeared 20/05/05 in West Australian; 15.

Dragun,AK; Gleeson,V; Musgrave,WF (1986): *The economics of water use in the Hunter region*. Centre for Resource and Environmental Studies, Australian National University. CRES Monograph 13.

Dueker,L; Regli,P; Turnbull,J (1990): Goal Billing as a Water Conservation Tool. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990*, Phoenix, Arizona, 361-365.

Dugdale,M (1989): *A Community Consultation Strategy for Water Resources Planning and Management.* A report prepared for the Scientific Services Group of the Engineering and Water Supply Department of South Australia, September 1989.

Dugdale,M (1993): *Managing wastewater at Victor Harbour - community consultation program report*. Prepared for Engineering and Water Supply Department, January 1993.

Dugdale,M (1996): Community Ownership and Conflict Resolution in Planning. *Water* January/February, 8-9.

Dugdale,M; West,SF (1991): Public Participation in Natural Resources Planning and Management. *International Hydrology & Water Resources Symposium Perth 2-4 October 1991*.

Duncan,WR (1996): *A Guide to the Project Management Body of Knowledge (PMBOK).* Project Management Institute Standards Committee. 1996 edition.

## E

Earth Policy Institute (2002): *Water Deficits Growing in Many Countries*. Water Shortages May Cause Food Shortages. Article by Lester R Brown. [Online] Available:http://www.earth-policy.org/Updates/Update15.htm. Accessed 01/05/2004. Modified 06/08/2002.

Edwards,JA; Moore,SD; Schultz,GJ (1978?): *Storing water in farm dams*. Bulletin No 29/77 Department of Agriculture South Australia.

Einav,R (2003): Checking toady's brine discharges can help plan tomorrow's plants. *Desalination & Water Reuse* Volume 13 Number 1, 16-20.

Engineering and Water Supply Department (1987a): *Water Resources Inventory - Information on Water Availability and Use for the Water Resources Management Strategy, 1987*. EWS Lib. Ref. 86/35. Endorsed by the South Australian Water Resources Council.

Engineering and Water Supply Department (1987b): *Water Resources Development 1836-1986. The historical background to the water resources management strategy*.

Engineering and Water Supply Department (1989a): *Review of the Operation of the Hydrometric Data Collection Network*. Prepared by consulting engineers Lange, Dames and Campbell Australia. Adelaide. June 1989.

Engineering and Water Supply Department (1989b): *South Australia Water Futures - 21 Options for the 21st Century*. EWS Lib. Ref. 89/4, South Australia.

Engineering and Water Supply Department (1989c): *Water South Australia - Managing the resources into the next century*. EWS Lib. Ref. 86/36.

Engineering and Water Supply Department (1990): *Rainwater Tanks. For households without a mains water supply*. South Australia.

Engineering and Water Supply Department (1991a): *Options for Managing Adelaide Stormwater - A summary*. Document produced for public consultation. Adelaide. November 1991.

Engineering and Water Supply Department (1991b): *Towards Lower Cost Environmentally Sustainable Urban Water Systems*. EWS Lib. Ref 91/19. Adelaide.

Engineering and Water Supply Department (1992a): *Quorn-Hawker Water Supply Review*. A Ministerial task force was established to report on water supply development options for the towns of Hawker and Quorn.

Engineering and Water Supply Department (1992b): *Murray Bridge Wastewater Treatment Plant - Reduction of Pollution of the River Murray and the Use of Reclaimed Water for Irrigation and Wetland Habitat Creation*. Prepared by Eco Management Services. Adelaide. December 1992.

Engineering and Water Supply Department (1992c): *Water Planning & Design Manual*. Technical Practice No. 2 Annual Consumption. April 1992. Adelaide, Australia.

Engineering and Water Supply Department (n.d.): *Rainwater Tanks ... their selection, use and maintenance.* Public information booklet. Adelaide.

Environmental Consulting Australia (1991): *Metropolitan Adelaide Stormwater - Options for Management.* A discussion paper to assist community consultation.

Environmental Protection Agency (1992): *Small Community Water and Wastewater Treatment*. Science Applications International Corporation, Washington.

Environment Protection Act (1993): South Australia

Environment Protection Authority (1996): *South Australian Biosolids Guidelines for the Safe Handling, Reuse or Disposal of Biosolids*. Department of Environment and Natural Resources, Adelaide. December 1996.

Environment Protection Authority (1997a): *Development of an Environment Protection (Water Quality) Policy*. Discussion Paper February 1997.

Environment Protection Authority (1997b): *Stormwater Pollution Prevention - code of practice for local, state and federal government*. Prepared by John Botting & Associates and Kathryn Bellette. Department for Environment, Heritage and Aboriginal Affairs, Adelaide. November 1997.

Environment Protection Authority (2003): *The State of Our Environment Report for South Australia 2003*. November 2003 Adelaide, Australia. [Online] Available:http://www.environment.sa.gov.au/soe2003. Accessed 21/09/04.

Ernst,DA (1993): Leigh Creek Water Supply. The Electricity Trust of South Australia, Coal Production Department.

Essential Services Commission (2004): *Economic Regulation of the Victorian Water Sector*. Consultation Paper No 1. February 2004, Melbourne.

Essential Services Commission of South Australia (2004): *Inquiry into Urban Water Pricing Process*. Final Report April 2004, Adelaide.

ETSA (n.d.): *An Environment Guide to Leigh Creek*. Public information booklet published by the Electricity Trust of South Australia.

Evans,D (2000): The Australian Urban Water Industry - Where does it sit? *Water* May/June 2000.

## F

Feil,J (2003): *Observations on the National Competition Policy Water Reform Program*. Presentation at Urban Water 2003 Advancing Sustainable Development Quorum United Conference Melbourne, 30 October 2003.

Fierz,TR (1970): *Engineering aspects of evaporation reduction for small water storages*. Water Research Foundation of Australia. Report No. 30 April 1970.

Figueres,CM; Tortajada,C; Rockstrom,J (Eds.) (2003): *Rethinking Water Management; Innovative approaches to contemporary issues*. Earthscan Publications, UK and USA

Fiksel,J; McDaniel,J; Mendenhall,C (1999): Measuring Progress Towards Sustainability - Principles, process, and best practice. Paper in *1999 Greening of Industry Network Conference Best Practice Proceedings.*

Fink,W (1996): Recycling Water. *Engineering World* Dec 96/Jan 97. [Online] Available: http://members.australis.net.au/-engineer/ew/ewpotable12. Accessed 08/04/99

Fisher,AG; Clark,RDS (1989): *Urban Stormwater - A Resource for Adelaide*. Engineering and Water Supply Department, Report 89/16, South Australia.

Fitzgerald,J; Cunliffe,D; Rainow,S; Dodds,S; Hostetler,S; Jacobson,G (2000): *Groundwater Quality and Environmental Health Implications, Anangu Pitjantjatjara Lands, South Australia*. Bureau of Rural Sciences, Canberra.

Flack,JE (1982): *Urban Water Conservation - Increasing Efficiency-in-Use Residential Water Demand*. American Society of Civil Engineers, New York.

Flack,JE; Greenberg,J (1987): Public Attitudes Toward Water Conservation. *American Water Works Association* Volume 79 Number 3, 46-51.

Fleming,NS (1994): *An Investigation into Rainfall-Runoff Relationships*. Department of Civil and Environmental Engineering Research Report No. R119, September 1994. University of Adelaide.

Fleming,NS; Daniell,TM (1997): *Water Resources Management for Northern Adelaide Plains, SA. Information for the Assessment of Alternative Strategies using the Matrix for Evaluation of Sustainability Achievement (MESA).* The University of Adelaide, Department of Civil and Environmental Engineering. March 1997.

Fleming,NS (1999): Sustainability and Water Resources Management for the Northern Adelaide Plains, South Australia. Volume 1 of 2. Thesis submitted for the degree of Doctor of Philosophy in The University of Adelaide (Faculty of Engineering).

Foley,BA; Daniell,TM; Warner,RF (2003): What is sustainability and can it be measured? Paper presented at the National Environmental Conference 2003 and published in *Australian Journal of Multi-Disciplinary Engineering*, Volume GE27, 2003.

Forest Service US (2002): Monitoring Frameworks. Department of Agriculture Factsheet [Online] http://www.fs.fed.us/institute/monitoring/frameworkfactsheet.htm. Accessed 02/05/2005

Forward,P (2004): South Australia's River Murray Salt Interception Schemes - Successes so far and challenges for the future. Paper presented at the *9th Murray-Darling Basin Groundwater Workshop 2004.*

Freeze,RA; Cherry,JA (1979): *Groundwater*. Prentice-Hall, New Jersey.

French,J (1997): Go Green. *The Australian Women's Weekly*, May 1997.

Fuller,CO; Martin,TJ; Walters,RP (1981): *Quality aspects of water stored in domestic rainwater tanks*. A preliminary study by the Domestic Rainwater Tanks Working Party, March 1981. Adelaide, South Australia.

Furukawa,DH (1999): A New Approach for Mitigating Membrane Fouling. *Fouling Mitigation in Membrane Processes Workshop, Techion-Israel Institute of Technology, Hafia, Israel. 27-28 January 1999.*

## G

Gale,A (2000): The Need for a Water Industry Forum. *Water* July/August, 2.

Gardner,EA (2003): Some examples of water recycling in Australian urban environments: a step towards environmental sustainability. *Water Science and Technology: Water supply* Volume 3 Number 4, 21-31.

Garrett,P (1991): Destroying the bottled water fallacy at last. *Water Bulletin* Volume 489 20 Dec 1991, 22.

Geiger,WF (1993): Concepts for flood control in highly urbanised areas. *Integrated Stormwater Management*. (Eds: Field,R; O'Shea,ML; Chin,KK) Lewis Publishers, USA, 259-270.

Gerges,NZ; Dillon,PJ; Sibenaler,XP; Martin,RR; Pavelic,P; Howles,SR; Dennis,K (2002): South Australian experience in aquifer storage and recovery. *Proceedings of the 4th International Symposium on Artificial Recharge of Groundwater, ISAR-4, 22-26 September 2002, Adelaide, South Australia*. 453-458.

Gerges,NZ; Howles,SR; Dennis,K; Dillon,PJ; Barry,KE (2002a): Town water supply purification using aquifer storage and recovery in a saline aquifer. *Proceedings of the 4th International Symposium on Artificial Recharge of Groundwater, ISAR-4, 22-26 September 2002, Adelaide, South Australia*. 459-464.

Gesalman,CM (1994): Getting to Know the Neighbours. *Water Environment & Technology* February 1994, 64-68.

Gesellschaft fur Technische Zusammenarbeit (2001): *Water - a key to Sustainable Development. Ministerial Declaration, The Bonn Keys, Bonn Recommendations for Action from the International Conference on Freshwater, 3-7 December 2001, Bonn.* Convened by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry for Economic Cooperation and Development.

Gilbert,JB; Walter,JB; Weber,JA (1990): Reducing Water Demand During Drought Years. *Journal AWWA* Volume 82 Number 5, 34-39.

Glueckstern,P; Priel,M (2003): Comparative cost of UF vs conventional pretreatment for SWRO systems. *Desalination & Water Reuse* Volume 13 Number 1, 34-39.

Gomez-Ibanez,JA (2003): *Regulating Infrastructure: monopoly, contracts and discretion*. Harvard University, USA.

Government of South Australia (1993): *Guide to the Native Vegetation Act - how it affects rural landholders.* Prepared by SA Department of Environment and Land Management. Adelaide. Reprinted January 1993.

Government of South Australia (1996a): *Project Initiation Process*. Produced by Treasury and Finance/Services SA ed. Vol. Project No. 009. Government of South Australia.

Government of South Australia (1996b): *Community Service Obligations. Policy Framework.* South Australia. December 1996.

Government of South Australia (1999): *State Water Plan. Volume 1 Policies for a Sustainable Future.* Draft for consultation October 1999.

Government of South Australia (1999a): *State Water Plan. Volume 2 - South Australia's Water Resources.*

Government of South Australia (2002): *Guidelines for Urban Stormwater Management*. Produced by the Patawalonga Catchment Water Management Board, Torrens Catchment Water Management Board and Planning SA. August 2002. Adelaide, Australia.

Government of South Australia (2003): *Draft Natural Resources Management Bill 2003. Explanatory Document: Settled Draft Bill for Consideration*. December 2003. Adelaide, Australia.

Government of South Australia (2004): *Water Proofing Adelaide*. A discussion paper exploring the issues released in January 2004.

Graham,D; Scott,S (1997): Price Elasticity and Sustainable Water Prices: Policy Directions. *Proceedings of 26th Annual Conference of Economists, University of Tasmania, 30 September 1997.*

Gransbury,J (2000): The Willunga Basin Pipeline - Stage 1. *Water* September/October 2000, 27-31.

Grebbien,VL (1990): Reclaimed Water Use in Southern California: Metropolitan Water District's Role. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990, Phoenix, Arizona,* 167-170.

Griffin,B (1999): Creating a competitive edge through workforce planning. *Civil Engineers Australia* March 1999, 58.

Groom,J (1995): Maintenance Management in Australia. *Water* (September/October 1995), 29.

Gullick,RW; LeChevallier,MW (2000): Occurrence of MTBE in drinking water sources. *American Water Works Association* Volume 92 Issue 1, 10-113.

Gushiken,EC (1995): Water Reuse Through Subsurface Drip Irrigation. *Journal American Water Works Association Annual Conference Proceedings, Vol D, Water Quality*. [Online] Available:http://www.geoflow.com/wastewater/waterecg.htm. Accessed 21/10/2003.

## H

Ham,T (1990): Freeway Landscape Irrigation in San Diego County. *Water Reclamation - Here, Now...and How, Syposium III Oct 13-14, 1988*. (Ed: Price,B) Technomic Publishing Company, Pennsylvania, 127-132.

Hamilton,Cathryn M (1992): *Status of Guidelines for Sewage Effluent Disinfection. Results of a Survey of Major Urban Water Authorities and State EPAs in Australia.* Australian Centre for Water Quality Research, South Australia. December 1992.

Hamilton,Cathryn M (1993): *Methods for the Disinfection of Sewage Effluent - A Literature Review.* Australian Centre for Water Quality Research, South Australia, Final Draft February 1993.

Hammerton,M (1986): *Water South Australia. A History of the Engineering and Water Supply Department.* Wakefield Press, Adelaide. 319 pages.

Hamnett,S (2003): Adelaide as a Sustainable City: Water Management in the Broader Context of Sustainability. *Sustainable Cities Task Force, Shanghai Seminar Report*; 57-66.

Hansen,K (1999): Fresh Water From the Car. *Crosscurrent* 13 September 1999, 7.

Hardin,G (1974): Living on a lifeboat. [Online] http://www.mnforsustain.org/hardinglivingonalifeboat.htm. Access 24/05/05.

Harding,R (2005): Ecologically Sustainable Development: Origins, Implementation and Challenges. Paper in *Integrated Concepts in Water Recycling*, Wollongong, Australia, 2005; 239-250.

Hatton,T (2003): Engineering our way forward through Australia's salinity challenge. Keynote paper presented to the Hydrology and Water Resources Symposium, Melbourne 2002. Institute of Engineers Australia, *Journal of Water Resources*. Volume 7, Number 1, 13-21.

Hazeltine,B; Bull,C (2003): *Field Guide to Appropriate Technology*. Academic Press, United States of America.

Heath,LG (1992): Management of Rural Water Demand An Irrigator's Perspective. Australian Water Resources Council Conference Series No. 21. *Proceedings on the National Workshop on Rural Water Demand Management. Sydney 26-27 February 1992.*

Hemming,A (1997): Trials, tribulations and triumphs of a remote Council. *Local Government FOCUS,* May 1997. [Online] Available: http://www.loc-govfocus.aus.net/1997/may/trials.htm. Accessed 06/06/00

Hebert,HJ (1999): Bottled Water Not So Pure. *ABCNEWS Living* March,30,1999. [Online] Available: http//abcnews.go.com/sections/living/DailyNews/bottledwater990330.html

Heyworth,JS; Maynard,EJ; Cunliffe,D (1998): Who Drinks What? Potable Water Use in South Australia. *Water* January/February, 9-13.

Hickinbotham,M (1994): *A survey of water reclamation and reuse.* Hickinbotham Group January 1994. Adelaide, South Australia.

Hidell 3rd,HR (2000): Message in a Bottle - How the Revised Global Bottled Water Regulations will affect Asian and Australasian Bottlers. *Asia Pacific Bottled Water* Issue 3, 27-31.

Hill,AL; Nicholson,CJ (1989): *Water Conserving Design for Gardens and Open Space*. Water Authority of Western Australia, Report WP 89.

Hill,AL; Nicholson,CJ (1989a): Water Efficient Design for Australian Gardens and Open Space. Paper presented at *Urban Water Demand Management Conference*, 30-31 October 1989, Sydney.

Hills,M (1997): *Sub-surface Turf Irrigation*. [Online] Available:http://ARIDGARDNER:sub-surface turf irrigation. Accessed 21/10/2003.

*Hills Messenger* (1995): Plan to turn sewerage into pure water. Article appeared 9 August 1995.

Hilmer,FG (1993): *National Competition Policy*. Report by the Independent Committee of Inquiry. Commonwealth of Australia, Canberra. August 1993.

Hind,V; Foster,D (2003): *SA Water Wastewater Treatment Plants Valuation.* Report prepared Tonkin Consulting for the South Australian Water Corporation, Adelaide, June 2003.

Hitcock,D (1997): Transition to Sustainable Development: Is this about planning? [Online] http://www.asu.edu/caed/proceedings97/hitchcoc.html. Accessed 02/05/2005.

Hoad,M (2002): Water to the max. Article appeared 17/01/2002 in *Coober Pedy Times*, SA Regional Newspaper; 3.

Hoffrichter,K; Swift,DB; White,SJ (1999): Guidelines for the Assessment of Water Management Opportunities for Country Towns. Draft internal SA Water document.

Holler,S (2003): Decentralised Infrastructure: saves system costs, produces biogas energy. *Water & Wastewater Internationa*l May 2003, Volume 18, Issue 3, 28-29.

Holloway,J (2000): Going for Gold - Bottled Water in Australia. *Asia Pacific Bottled Water* Issue 3, 15-18.

Hudson,H (1990): *Review of EWS Water and Sewerage Charges.* For the Minister of Water Resources, Government of South Australia. Adelaide, July 1990.

Human Rights and Equal Opportunity Commission (2001): *Review of the Water Report*. Macmillan, Sydney.

Hunter,G (1995): Constructed Wetlands - Safety Issues. 'Wetlands for Water Quality Control' [Lecture] James Cook University Townville Queensland September 1995.

Hunter,GJ (1997): Structural Runoff Management Options. Paper presented at *Pipes Wagga Wagga* 15-17 October 1997.

Hunter,GJ (1998): Structural Source Controls. Paper in *Stormwater Management Source Control*, 24 September 1998, Merrylands, NSW.

Hunter,GJ (1998a): Evaluation of Some Readily Available Stormwater Quality Control Technologies. *Proceedings Stormwater the New Millennium Bug. 2nd Regional Stormwater Conference, Batemans Bay*, NSW, 27-28 April 1998.

Huppatz,N (1990): Greening the Lameroo Golf Course by Solving a Stormwater and Effluent Problem. Paper presented at the *Inaugral Asia Pacific Conference of the International Federation of Parks and Recreation*. October 1990.

Hurlimann,AC; McKay,JM (2005): What Attributes of Recycled Water Make it Fit for Residential Purposes? The Mawson Lakes Experience. Paper in *Integrated Concepts in Water Recycling*, Wollongong, Australia; 307-318.

Hydro Tasmania (2003): Wind Power. Frequently Asked Questions [Online] Available:http://www.hydro.com.au. Accessed 21/09/03.

**I**

IHD-WHO Working Group on the Quality of Water (1978): *Water quality surveys - A guide for the collection and interpretation of water quality data.* Sydenhams Printers, United Kingdom.

Independent Pricing and Regulatory Tribunal of NSW (2003): *Sydney Water Corporation Prices of Water Supply, Wastewater and Stormwater Services from 1 July 2003 to 30 June 2005.* Determination 4.

Industry Commission (1994): *Community Service Obligations - some definitional, costing and funding issues.* Prepared by the Steering Committee on National Performance Monitoring of Government Trading Enterprises. Canberra. April 1994.

Institution of Civil Engineers (1985): *Reuse of Sewage Effluent. Symposium* sponsored by the Institution of Civil Engineers, the International Commission on Irrigation and Drainage, and the Ross Institute of Tropical Hygiene. Great Briton.

Institution of Engineers Australia (1993): *At What Price Data?* National Committee on Coastal and Ocean Engineering. November 1993.

Institute for Sustainable Futures (2003): *Alice Springs Water Efficiency*. Study for Power and Water and the Department of Infrastructure, Planning and Environment, Alice Springs, Australia.

International Finance Corporation (1995): *IFC's collaboration with Private International Financial Institutions: Practices and Policies*. [Online} Available:http://www.ifc.org/PUBLICAT/BROCHURE/COLLAB.HTM. Accessed 23/06/99

International Water Resources Association (1999): Water on the Web Workshop: Report of Recommendations, Fort Lauderdale, Florida, USA October 23-24, 1998. *Water International*, Vol. 24, No. 2, 172-175. [Online] Available: http://www.iwra.siu.edu. Accessed 16/04/00

Irrigation Association of Australia (n.d.): *Useful and Interesting Irrigation Information*. [Online] Available:http://www.irrigation.org.au/irrigationinformation.html. Accessed 05/10/03.

Isaacson,M; Rauf Sayed,A; Hattingh,WHJ (1987): *Studies on the Health Aspects of Water Reclamation during 1974 to 1983 in Windhoek, Namibia*. Report prepared for the Water Research Commission by the South African Institute of Medical Research, Pretoria.

**J**

Jago,RA (1997): A new Screening Technology for the Environment. *Water,* May/June 1997.

James,LD; Lee,RR (1971): *Economics of Water Resources Planning*. McGraw-Hill, United States of America.

Jeppesen,Barry (1996): *Model Guidelines for Domestic Greywater Reuse for Australia*. Research Report No. 107 March 1996 ed. Urban Water Research Association of Australia, Brisbane.

Jermar,MK (1987): *Water resources and water management*. Elsevier, United States of America.

Jobling,P (1994): *Septic Tanks and Cesspools: A do-it-yourself guide*. Second ed. Great Briton.

Jones,K; Lewis,T; Aitken,K (1993): Waterwise Queensland - The Joint Venture. *Water* June 1993, 12-15.

**K**

Katko,TS (1991): Reselling and Vending Water. *American Water Works Association* Vol. 83 No. 6, 63-69.

Keating,J (1992): *The drought walked through - A history of water shortage in Victoria*. Gill Millar Press, Melbourne.

Keegan,JF (1994): Outsourcing facilities maintenance. *Maintenance* Vol. 7 No. 1, January 1994, 48-53.

Keen,M; Brown,VA; Dyball,R (2005): *Social Learning in Environmental Management*. Earthscan, London.

Kelly,J; Stevens,D (2000): From Problem to Profit: Wastewater Reclamation and Reuse on the Northern Adelaide Plains. *Water* September/October 2000), 37-41.

Kennedy,MF; MacDonald,PM; Maguire,JC (1985): *A Hydrological Investigation of the Penneshaw Water Supply*. Engineering and Water Supply Lib. Ref. 85/17. March 1985.

Kernich,AM (1984): *The Effect of the Birdguard on Class A Pan Evaporation in South Australia*. Department of Agriculture South Australia Technical Paper No. 10 July 1984.

Kerri,KD; Brady,J (1987): *Operation and Maintenance of Wastewater Collection Systems. Volume 1.* Field Study Training Program. US Environment Protection Agency and Office of Water Programs. Third Edition.

Kerri,KD; Brady,J (1987b): *Operation and Maintenance of Wastewater Collection System. Volume 2.* Field Study Training Program. US Environment Protection Agency and Office of Water Programs. Third Edition.

Khan,SJ; Gerrard,LE (2005): Stakeholder Communications for Successful Water Reuse Operations. Paper in *Integrated Concepts in Water Recycling,* Wollongong, Australia; 355-367.

Khan,SJ; Muston,MH; Schafer,AI (2005): *Integrated Concepts in Water Recycling*. Proceeding of an International Conference, University of Wollongong, Australia, 2005.

Kharbanda,OP; Stallworthy,EA (1985): *Effective Project Cost Control.* The Institution of Chemical Engineers, England.

Kibler,DF (Ed.) (1982): *Urban Stormwater Hydrology*. American Geophysical Union, Washington.

Kinzelbach,W; Kunstmann,H (1999): *Sustainable Management of Groundwater Resources*. [Online] Available:http//www/baug.ethz.ch/ihw/staff/kunstmann/stockholm.htm. Accessed 16/04/00. Modified 21/01/99.

Kirk,M; Rouch,G; Veitch,M (1999): What Happens in an Outbreak of Waterborne Disease? - An Historical Look at the Sunbury Gastroenteritis Outbreak. *Proceedings of Australian Water and Wastewater Association 18th Federal Convention, Adelaide, Australia, 11-14 April 1999*.

Klingberg,DJ; Schultz,TJ (1997): *Future Developments in Project Implementation*. Kinhill Pty Ltd. July 1997.

Knight,R (1994): Treatment wetlands Database Now Available. *Water Environment & Technology* February 1994, 31-33.

Knight,A; McGrath,D; Lawes,R (1998): *Low Rainfall Alley Farming Systems. A guide to alley farming in the 300mm-450mm rainfall zone of the Murray-Darling Basin*. Primary Industries and Resources South Australia, Adelaide.

**L**

Lacy,C (1999): Solar Powered Water Systems. *Crosscurrent* November, 7.

Lambert,T (1997): *Aldinga Wastewater Treatment Plant and Reuse Project*. Henry Walker Environmental Pty Ltd.

Lamm,FR (2002): Advantages and Disadvantages of Subsurface Irrigation. Paper presented at the International Meeting on Advances in Drip/Micro Irrigation, Puerto de La Cruz, Canary Islands, December 2-5, 2002.

Landline (2000a): 'Rainmain' targets niche market. Reporter: Rebecca Armstrong. First Published 7 May 2000. [Online] Available:http://www.abc.net.au/landline. Accessed 04/03/01

Landline (2000b): Great Western turns water into wine. Reporter: Pip Courtney. First published 30 April 2000. [Online] Available:http://www.abc.net.au/landline. Accessed 04/03/01.

Landline (2000c): Bottling the Basin. Item appeared on Landline shown on ABC Television at 1:00pm on 14 February 2000.

Lang,J; Allen,M; van der Well,B (2000?): *Good Alternative - Rainwater Tanks: Fact or Fiction*. Adelaide, Australia**.**

Langford,J (2003): Sustainability and WSAA's Five Year Forward Look. *Water* August 2003, 4-6.

Latham,M (1994): *Constructing the Team*. HMSO Final Report July 1994.

Law,IB (1999): Potable Reuse: Technologies and Trends. *Proceedings of Australian Water and Wastewater Association 18th Federal Convention, Adelaide, Australia, 11-14 April 1999*.

Law,IB (1993): Potable Reuse: Should It Not Be Considered More Fully? *Proceedings 15th Federal Convention of the Australian Water and Wastewater Association, Gold Coast*, 542 - 547.

Law,IB (1995): Non-Potable Reuse System - Why Not Consider Planned Indirect Potable Reuse Systems. *Proceedings Northern Engineering Conference, Institute of Engineers Australia, Mackay*.

Law,IB (1997): Domestic Non-Potable Reuse - Why Even Consider it? *Water* May/June, 9-13.

Law,IB (2003): Advanced Reuse - From Windehoek to NEWater and Beyond. *Desalination & Water Reuse* Volume 13 Number 1, 22-28.

Lawrence,G (1992): Rural Structure: Implications for Water Management in Australia. Australian Water Resources Council Conference Series No. 21. *Proceedings on the National Workshop on Rural Water Demand Management. Sydney 26-27 February 1992.*

*Leader* (1994): Huge cost of cleaning waterways. Article on 29 March 1995; 5.

Leahy,S (1998): *Total Water Cycle Approach to Management: A questionnaire and interview survey in South Australia*. Department of Environment Heritage and Aboriginal Affairs.

Leahy,S; McIntosh,G; van der Wel,B; Loan,L (1998): *Use of effluent and urban stormwater in South Australia 1998 - Total water cycle management*. South Australian Department for Environment, Heritage and Aboriginal Affairs.

Leake,M (2000): Small Water and Wastewater Systems. *Water* May/June, 44-45.

Liang,IAF (1981): *Evaluation of Small Catchment Surface Treatments*. Research Project No. 71/37A. Australian Water Resources Council Technical Paper No. 61, Canberra.

Liang,IAF (1985): Improved Catchments for Farm Dams. *Journal of Agriculture* Vol. 3, 67-69.

Liang,I (1998): *Rainwater Tanks*. Farmnote published by Agriculture Western Australia. [Online] Available:http://www.agric.wa.gov.au/agency/pubns/farmnote/1990/f08490.htm. Accessed 28/04/00.

Littlely,B (2001): Mining town has water rationed. Article appeared 16/10/2001 in the *The Advertiser*; 13.

Lloyd,L; Balla,S (1986): *Wetlands and Water Resources of South Australia*. Report by Conservation Project Branch, Department of Environment and Planning, January 1986.

Lloyd,SD (2001): Water Sensitive Urban Design in the Australian Context. *Synthesis of a conference held 30-31 August 2000, Melbourne, Australia*. Technical Report 01/7 September 2001.

Local Government Association (n.d.): *Septic Tank Effluent Drainage Scheme Design Criteria*. Human Services. Government of South Australia.

Local Government Association (1996a): Guidelines for establishing service charges and a council's contribution to a septic tank effluent disposal (STED) scheme.

Local Government Association (1996b): Need survey septic tank effluent disposal scheme guidelines and format for collection of data.

Local Government Association (2000): Local Government Association of South Australia. [Online] Available:http://www.lga.sa.gov.au Accessed 08/07/00. Modified 04/06/00.

Local Government Association; Planning SA (2000b): *Council Members' Guide to Planning - An overview of South Australia's Planning and Development Assessment System*. Prepared by QED Pty Ltd and Norman Waterhouse Lawyers, June 2000. [Online] Available:http://:www.lga.sa.gov.au/public/planning/members%20guide.htm. Accessed 06/09/00.

Local Government Association (2002): *Review of STEDS in South Australia*. Report by Tonkin Consulting in association with KATLYST 21 and Economic Research Consultants. Final Report December 2002.

Loh,M; Coglan,P (2003): *Domestic Water Use Study in Perth, Western Australia 1998-2001*. Water Corporation March 2003.

*Loxton News* (1995): Meetings follow water audit. Article appeared 30 August 1995, 3.

Ludlow,K (2005): Costello dips into water fight. Article appeared 20/05/05 in *Australian Financial Review*; 7.

## M

Makin,IW; Kidd,CHR (1979): *Urban Hydrology Project: Collection and archive of UK Hydrological Data*. Institute of Hydrology Report No 59, Wallington, Oxon.

Manigold,DB; Wentz,SJ (1988): *Coordination of Federal Water-use-data Collection and Dissemination*. Water-use Data for Water Resources Management, American Water Resources Association, August 1988.

Marks,J (2003?): The Sociology of 'Disgust' towards the use of Reclaimed Water. Paper by PhD candidate, Flinders University of South Australia, Adelaide.

Marks,JS (2005): Taking the Public Seriously: The case of potable and non-potable reuse. Paper in *Integrating Concepts in Water Recycling*, Wollongong, Australia; 417-426.

Marks,R (2002): Urban Water Recycling: A Developer's Perspective. Working on Water: New Trends in water resources management: Households to catchment. *Water Conservation Partnership Project, 23 October 2002, Hahndorf, South Australia*.

Markwick,G (1991): Drought strategies for the livestock producer. *The Australian Farm Manager* December 1991, 11-14.

Marohasy,J (2003): Myth & the Murray: Measuring the real state of the river environment. *IPA Backgrounder* December 2003, Volume 15, Number 5. Published by Institute of Public Affairs, Melbourne, Australia.

Matthews,D; Moore,SD (1993): *Water supplies for South Australia's pastoral zone*. Bulletin 5/92 Primary Industries South Australia.

Maywald,S (2000): *Consulting with your community. A guide to effective and equitable community consultation techniques for local government and associated organisations*.

McIntosh,GF; Pugh,SJ (1991): *A Preliminary Assessment of the Reuse Potential of Effluent and Urban Stormwater in South Australia*. October 1991.

McIntosh,G (1992): Reuse of Stormwater...An Overview. Paper in *Irrigation with Storm Water - The Emerging Technology, IAA Urban Irrigation Seminar 29 July 1992*. Adelaide, Australia.

McIntosh,G (1992?): *Wetland Systems in a Multi-objective Approach to the Management of Stormwater in Adelaide, South Australia*. Engineering and Water Supply Department, Adelaide.

McAulay,R (2005): Law of the land. Article appeared 19/05/05 in *Stock Journal*; 7.

McKenzie,B (1990): Self-reliance - an alternative for some small rural towns. *The Australian Farm Manager* December 1990, 4-7.

McLaren,N; Heath,D; Morias,A (1987): *Water Conservation for communities in arid areas of South Australia*. Engineering and Water Supply Department.

McLellon,WM (1991): Student water Use. *Journal AWWA* Vol. 83, No. 4, April 1991, 132-133.

McMahon,TA; Mein,RG (1986): *River and Reservoir Yield*. Water Resources Publications, USA.

McMahon,TA; Gan,KC (1989): A Survey of Australian Reservoir Yield Estimation Practice. *Proceedings of the National Workshop on Planning and Management of water Systems: Risk and Reliability. Adelaide, 23-25 November 1988*. GC Dandy and AR Simpson (Editors).

McMahon,TA; Nathon,RJ; Finlayson,BL; Haines,AT (1989): Reservoir System Performance and Climatic Factors. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

MFP Australia (1996): Virginia Pipeline Scheme Treated Water Study. Prepared by engineering consultants Kinhill Engineers, Adelaide. Final Report July 1996.

MFP Australia (n.d.): New Haven Village - A whole new way of living. Sales and Information brochures.

*Melbourne Age* (1995a): World conflicts loom over our scarce water resources. Article appeared 7 August 1995, 14.

*Melbourne Age* (1995b): Future holds Wars over water:study. Article appeared 8 August 1995, 8.

Melbourne Water (1992): *Total Catchment Management - A Solution to Urban Runoff?* Report by Dr Leon C Collett, Manager Bay and Catchment Strategy Division, Open Space, Waterways and Environment Directorate, Melbourne Water.

*Melbourne Water* (1993): *Hydraulic Servicing Proposed Concept and Implementation.* Prepared by Coomes Consulting Group.

*Melbourne Water* (2002): *Constructed Wetland Systems - Design guidelines for developers*. Publication produced in consultation with Cooperative Research Centre for Catchment Hydrology and the Association of Land Development Engineers. July 2002.

Meredith,D; Wong,K; Woodhead,R; Wortman,R (1985): *Design & Planning of Engineering Systems*. Second ed. Prentice-Hall Inc, United States of America.

Mersey River Basin (1999): WA Desalination Study. *Crosscurrent* November, 2.

Metcalf & Eddy (1991): *Wastewater Engineering - Treatment - Disposal - Reuse*. 3rd ed. McGraw Hill, United States of America.

Miller,GW (2005): Integrated Concepts in Water Reuse: Managing global water needs. Paper in *Integrated Concepts in Water Recycling*, Wollongong, Australia; 478-489.

Millis,NF (2003): Water quality relative to end use. Keynote paper presented at Hydrology and Water Resources Symposium, Melbourne 2002. Institute of Engineers Australia. *Journal of Water Resources* Volume 7, Number 1, 23-28.

Mineral Water Development (n.d.): Evaluation/ Albany Installation. Promotional video by GrahamTek PAL Ver. 2. Narration by David Furukawa (President, Separation Consultant Inc.) and Member of the International Desalination Association.

*Ministers Local Government Forum* (2003): Septic Tank Effluent Disposal Scheme. MLGF 17/03 July 2003.

Ministry of Education & Training Victoria (1991): *Doing Research Work in the Community. A handbook to help students get the most out of contacts with the community.* School Industry Liaison Officers, Ministry of Education & Training Victoria, and Department of Labour & Industry, Victoria. Published by the Ballarat Community Education Centre, Victoria.

Mitchell,G; Mein,R; McMahon,T (1999): *The Reuse Potential of Urban Stormwater and Wastewater*. Cooperative Research Centre for Catchment Hydrology Industry Report 99/14, December 1999.

Mitchell,VG; Shipton,RJ; Gray,SR (2002): Assessing innovative urban waters servicing options for a greenfield development site in Brisbane. Hydrology and Water Resources Symposium, Melbourne 2002. *Australian Journal of Water Resources*, Vol. 7, No. 2, 2002; 139-154.

Mitchell,VG; Mein,RG; McMahon,TA (2002a): Utilising Stormwater and Wastewater Resources in Urban Areas. *Journal of Water Resources*, Vol. 6, No. 1; 31-43.

Moore,J (1995): The Water Sell-Off - How it affects Country People. *The Southern Argus*. 5 Oct 1995, 14.

Moore,L (1997): From Public Involvement to Mediation: A Cautionary Tale. *Interac*t Volume 3 Number 1, 57-70.

Moore,SD; Cawthorne,JR (1974): *Water Harvesting and Runoff Inducement in Western Australia and South Australia.* Soil Conservation Branch, Department of Agriculture South Australia. S16/74.

Moore,SD (1990): The Exploitation of Stormwater Runoff in Rural Townships in South Australia: A Case History. Paper presented at the *Inaugral Asia Pacific Conference of the International Federation of Parks and Recreation*. October 1990.

Moore,SD (1992): *The Use of Engineered Catchments to Provide Water in the Semi-arid Pastoral Zone of SA*. Department of Agriculture South Australia Technical Paper No. 32, August 1992.

More,C (1995): Blatant water wastage. Letter from reader published in the *Transcontinental* 8 November 1995; 8.

Morenos,N (1992): Plant selection key to efficient water use. *Australian Horticulture* June, 55-57.

Morton,SD (1976): *Water Pollution - Causes and Cures*. Mimir Publishers Inc., Winconsin.

Moynahan,MD; Thornhill,EJ (1990): The Use of Financial Incentives to Encourage Implementation of Water Conservation Programs. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990, Phoenix, Arizona*, 355-359.

*Mt Barker Courier* (1994): Study goes underground to boost water. Article appeared 26/10/1994; 4.

Mudrakartha,S; Chopde,S (2002): Closing the Demand-Supply Gap through Rainwater Harvesting. A case study of Sargasan, Gujarat India. Paper submitted to *International Symposium on Artificial Recharge (ISAR-4) Adelaide, Australia, September 2002.*

Mullarkey,N; Hall,M (1990): Feasibility of Developing Dual Distribution Systems for Non-potable Reuse in Texas. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990, Phoenix, Arizona*, 59-63.

Murray-Darling Basin Commission (1990): *The Murray*. Inprint Limited, Brisbane.

Murray-Darling Basin Commission (1997): *Murray-Darling Basin Resource*. Material published on web site September 1998. [Online] Available:http://www.mdbc.gov.au. Accessed 16/10/99

Murray-Darling Basin Commission (2004): *The Impacts of Water Regulation and Storage on the Basin's Rivers*. Natural Resource Management and Education Centre. [Online] Available:http://www.mbc.gov.au. Accessed 03/07/04.

Murray-Leach,R (2003): Gardens and Water Conservation in Adelaide. Summary of Masters Thesis published in SA Water electronic newsletter *This Week* Number 497, 5-9 January 2004.

*Murray Pioneer* (1994): Effluent plant first of its type in Australia. Article by Rebecca Tilly appeared on 25th November 1994; 1.

*Murray Pioneer* (1995): Effluent plant approved. Article appeared 2 May 1995, 2.

*Murray Pioneer* (1997): Effluent system national first. Articled appeared 7 November 1997; 1-2.

*Murray Valley Standard* (1994): Country water users will pay more, says Shadow Minister. Article appeared 15/11/1994; 15.

*Murray Valley Standard* (1995): $20,000 saved on water bill. Article appeared 7 September 1995, 2.

Murrie,J (1994): Water may become 'a business'. Article by indutrial reporter appeared 10/05/1994 in *The Advertiser.*

Musgrave,WF; Alaouze,CM; Dudley,NJ (1989): Capacity Sharing and its Implications for System Reliability. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide, 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

Mussared,D; Bennett,B (1995): Storage goes underground. *ECOS*, Vol. 85 Spring 1995, 22-23.

## N

Nathan,RJ (1993): *Low flow atlas for Victorian streams*. Graeme Shaw Print Services, Melbourne.

National Academy of Science (1994): *Cultural Diversity and Early Education*. Report of a workshop edited by D Phillips and NA Crowell.

National Academy of Sciences. (1998): Water Systems Serving Small Communities are more Vulnerable to Contamination. Media release for 10 September 1996 from National Academy of Science published on website. [Online] Available: http://www2.nas.edu/whatsnew/2552.html. Accessed 18/06/99

National Competition Council (2001): 2002 *National Competition Policy Assessment Framework for Water Reform.* December 2001.

National Competition Council (2003): *National Competition Policy Water Reform Assessment Framework 2004.* December 2003.

National Health and Medical Research Council; Australian and New Zealand Environment Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand (1996): *Draft Guidelines for Sewerage Systems - Use of Reclaimed Water*. For public comment April 1996 to June 1996. Part of the National Water Quality Management Strategy.

National Heritage Trust (2004): *Report Card Review and Concept Development July 2004*. National Land & Water Resource Audit.

National Landcare Program (n.d.) *Setting Up for Success - A guide for designing, managing and evaluating projects.* [Online] Available:http://www .landcare.gov.au/pub/success.htm. Accessed 29/09/99. Modified 23/98/99.

National Water and Climate Centre (1998): Field Office Guide to Climatic Data. Accessed from the Internet: Modified 18/11/98.

Nelson,JO (1992): Water Audit Encourages Residents to Reduce consumption. *Journal AWWA* Vol. 84, No. 10, October 1992, 59-64.

Newman,P; Mourtiz,M (1992): The Urban/Geenfield and Rural Planning Context. *Managing Stormwater - The Untapped Resource Workshop Proceedings*. The Ramada Grand Hotel, Glenelg South Australia 23 October 1992, 20-42.

*News Review* (1994): Sewage trees ready for harvest test. Article appeared 20 April 2004; 15.

*News Review* (1995a): Water pipeline a big step closer. Article by Rebecca Tilly appeared 30 August 1995, 5.

*News Review* (1995b): Interest called for $40m pipe project. Article appeared 13 September 1995, 9.

Nicholson,BL; Clark,RDS (1992): *Nutrient Loads in the Onkaparinga River System*. Engineering and Water Supply Department. EWS Report No. 92/17. Prepared by Scientific Services Group. May 1992.

Nilsson,Å (1988): *Groundwater Dams for Small-scale Water Supply*. Intermediate Technology Publications, London.

Nix,SJ (1991): Applying Urban Runoff Models. *Water Environment & Technology* June 1991, 47-49.

Nordic Freshwater Initiative (1991): *Copenhagen Report: Implementation mechanisms for integrated water resources development and management. Report from Copenhagen Informal Consultation 11-14 November 1991*. Part of the Nordic Freshwater Initiative for the UN Conference on Environment and Development (Rio) 1992, and the International Conference on Water and the Environment (Dublin), 1992.

NSW Department of Land and Water Conservation (1997): *Small Town Sewerage - Guidelines on financial assistance and implementation of affordable systems*.

NSW Recycled Water Co-ordination Committee (1993): *NSW Guidelines for Urban and Residential Use of Reclaimed Water*. May 1993.

Nugent,RA; Wellman,KF; Gregory,R (1997): Assessing Stakeholder Values for Salmon Restoration in Willapa Bay, Washington. *Interact* Volume 3 Number 1, 39-55.

## O

O'Halloran,RJ; Pilkington,NH; Sexton,BA (1994): Continuous monitoring of sewage and industrial effluents. *Water* February 1994, 17-21.

Ohlsson,L (1999): *Environment Scarcity and Conflict*. G”teburg, Sweden: G”teburg University.

O'Loughlin,EM; Young,WJ; Molloy,JD (1992): *Urban Stormwater: Impacts on the Environment*. A report from CSIRO to the Minister for Arts, Sport, the Environment and Territories. Consultancy Report 92/29. 29 November 1992.

Overton,R (2002): *Feasibility Study Kit - Write your own feasibility study*. Sydney Business Centre. Martin Books.

Oyo,A (2002): *Creating Successful Private Sector Supply Chains.* A resource guide for rural water supply and sanitation practitioners. Part of the supply chains initiative led by the Water and Sanitation Program.

## P

Pacey,A; Cullis,A (1986): *Rainwater Harvesting. The collection of rainfall and runoff in rural areas*. Intermediate Technology Publications, London.

Palm,T; Qayum,A (1985): *Private and Public Investment Analysis*. South-Western Publishing Co., Cincinnati, Ohio.

Palmer,N; Lightbody,P; Fallowfield,H; Harvey,B (1999): Australia's Most Successful Alternative to Sewerage: South Australia's Septic Tank Effluent Disposal Schemes. *Proceedings of Australian Water and Wastewater Association, 18th Federal Convention, Adelaide, Australia, 11-14 April 1999*.

Pantell,SE (1993): *Seawater Desalination in California*. California Coastal Commission Publication, October 1993.

Parson,J; Cotner,S; Roberts,R; Finch,C; Welsh,D (n.d.): Efficient Use of Water in the Garden and Landscape. Texas Agricultural Extension Horticulture Information Resource. [Online] Available:http//aggie-horticulture.tamu.edu/extension/homelandscape/water/water.html. Accessed 04/06/99

Pavelic,P; Gerges,NZ; Dillon,PJ; Armstrong,D (1992): *The Potential for Storage and Reuse of Adelaide's Stormwater Runoff Using the Upper Quartenary Groundwater System*. Centre for Groundwater Studies Report No. 40. Adelaide. April 1992.

Pavellic,P; Dillon,P (1997): *Review of International Experience in Injecting Natural and Reclaimed Waters into Aquifers for Storage and Reuse*. Centre for Groundwater Studies Report No. 74, Adelaide. May 1997.

Pavelic,P; Dillon,PJ; Barry,KE; Herczeg,AL; Rattray,KJ; Hekmeijer,P; Gerges,NZ (1998): Well clogging effects determined from mass balances and hydraulic response at a stormwater ASR site. *Proceedings Third International Conference on Artificial Recharge of Groundwater 1998*.

Pavelic,P; Dillon,P; Martin,R (1999): Recovery Efficiency. Chapter 15 presented at the 2nd National Short Course on Aquifer Storage and Recovery, 27 - 29 October 1999, Adelaide, Australia.

Payne,JF (1993): Summary of Water Reuse Regulations and Guidelines in the United States. *Proceedings of the Water Environment Federation 66th Annual Conference and Exposition, Anaheim, California, USA. 3-7 October 1993*, 147-157.

Peacock,C (2003): South Australian Electricity Generation. [Online] Available:http://www.beyondlogic.org/southaustraliapower Accessed 21/09/03.

Pedersen,I (2000): Innovation needs willing purchasers. *Engineers Australia*, January, 3.

Pelekani,C (2004): Design and Operating Experience at the Penneshaw Desalination Plant. *Proceedings of the AWA SA Regional Conference, 18 August 2004*, Adelaide Australia.

Perterson,SM; Batley,GE (1992): *Road Runoff and its Impact on the Aquatic Environment: A Review*. CSIRO Investigation Report CET/LH/IR076. Prepared for the Roads and Traffic Authority of NSW.

Pescod,MB; Alka,U (1985): Urban effluent reuse for agriculture in arid and semi-arid zones. *Reuse of Sewage Effluent Symposium.* Institution of Civil Engineers, London, UK. 93-106.

Pettygrave,GS; Davenport,DC; Asano,T (1985): Introduction: California's Reclaimed Municipal Wastewater Resource. *Irrigation with Reclaimed Municipal Wastewater - A Guidance Manual*. (Eds: Pettygrove,GS; Asano,T) Lewis Publishers Inc., United States of America.

Phillips,WD (1977): Operational Experiences from Reuse Installations. Water Research Foundation of Australia, Report No. 51. *Reuse of Treated Wastewater Workshop*, July 1977, Sydney.

Pigram,JJJ (1986): *Issues in the Management of Australia's Water Resources*. Longman Cheshire, Melbourne.

Pilgrim,DH; Chapman,TG; Doran,DG (1988): Problems of rainfall-runoff modelling in arid and semi-arid regions. *Hydrological Sciences* Vol. 33, No. 4, 8/1988, 379-400.

Pitt,R; Field,R; Lalor,M; O'Shea,M (1993): U.S. EPA's manual of practice for the investigation and control of cross-connection pollution into storm drainage systems. *Integrated stormwater management*. (Eds: O'Shea,ML; Field,R; Chin,KK) Lewis publishers, USA, 355-368.

Planning SA (2001): *Development in Rural Areas. Preparing Development Plan policies for rural South Australia.* Planning Bulletin, July 2001. Adelaide, South Australia.

Planning SA (2002): *Wind Farms*. Development Act 1993 Advisory Notice 21 Draft for consultation.

Planning SA (2003): *Regional Open Space Enhancement Subsidy (ROSES) Program. Guidelines for Applications 2003-2004*. April 2003. Adelaide, South Australia.

Ploeser,JH; Pike,CW; Kobrick,JD (1992): Non-residential Water Conservation: A Good Investment. *Journal AWWA* Vol. 84 No. 10 October 1992, 65-73.

Polin,M (1977): *Re-Use of Treated Wastewater A Summary Statement*. Compiled for the Water Research Foundation of Australia from data provided by Gutteridge Haskins & Davey Pty Ltd. July 1977.

Population Action International (1993): *Sustaining Water: Population and the Future of Renewable Water Supplies*. National Council for Science and the Environment, 55. [Online] Available: http:\\www.cnie.org/pop/pai Accessed 01/05/04.

Porter,RB; Fisher,F (1985): Sewage effluent reuse - economic aspects in project appraisal. *Reuse of Sewage Effluent Symposium.* Institution of Civil Engineers. London UK. 267-283.

*Port Lincoln Times* (2001): Water savings made at Elliston. Article appeared 28/12/2001 in SA Regional Newspaper; 3.

Potter,M (1994): *Agricultural and Urban Integration within the Northern Adelaide Plains.* Prepared for Munno Para Arc Pilot Project Joint Committee. Sponsored by Hickinbotham Homes, Adelaide. January 1994.

Power,K (2000): Pathogens in Catchments. *Proceedings of Australian Water Association Catchment Management Seminar* 13 June 2000, Victorian Branch.

Praxis (1988): *Public Involvement: planning and implementing public involvement programs*. Calgary, Alberta

Price,B (Ed.) (1990): *Water Reclamation: Here, Now...and How: Symposium III Oct 13-14, 1988*. Technomic Publishing Company, Pennsylvania.

Price,D (1991): Increase Profits by changing cropping systems. *The Australian Farm Manager* December 1991, 7-8.

Primary Industries SA (n.d.): *Signs of Change*. National Landcare Program and Primary Industries SA. Australia. Report No. 8, AusInfo, Canberra.

Pritchard,C; Verbeek,V; Rahal,Z (2003): A Preliminary Design of a Direct Driven Wind Powered SWRO System. *Desalination & Water Reuse* Volume 13 Number 1, 29-33.

Productivity Commission (1999): Impact of Competition Policy Reforms on Rural and Regional

Productivity Commission (2000): *Arrangements for Setting Drinking Water Standards*. International Benchmarking, AusInfo, Canberra.

Productivity Commission (2000): Arrangements for Setting Drinking Water Standards: International Benchmarking Report. Edited Summary of Overview. *Water* July/August 2000, 49-54.

*Port Lincoln Times* (2005): Mining venture could offer desalination option for Eyre. Article appeared 17/05/05; 5.

*Port Pirie Recorder* (1995): Water resource group set up. Article appeared 10 August 1995, 3.

Public and Environmental Health Act (1987): South Australia.

Public Health Agency of Canada (2000): Waterborne Outbreak of Gastroenteritis Associated with a Contaminated Municipal Water Supply, Walkerton, Ontario, May-June 2000. *Canada Communicable Disease Report* Volume 26 Number 20, 15 October 2000. [On-line] Available:http://www.phac-aspc.gc.ca/publicat/ccdr-rmtc/00vol26/dr2620eb.html. Accessed 21/01/05

## Q

Queensland Government (2003): *Queensland Guidelines for the Safe Use of Recycled Water*. Public Consultation draft Guidelines. Environmental Protection Agency. Queensland, Australia

Quinn,P (2004): *The H20 pie - is there a slice for everyone?* Churchill Fellowship Report, October 2004.

## R

Rabone,FA; Fisher,AG (1994): Penneshaw Gauging Station Evaluation (Draft). Department of Environment and Natural Resources, Adelaide.

Rabone,FA (2004a): Benchmarking for Water Utilities. Paper submitted for Subject INFR8082 Managing Utilities 2. Master of Infrastructure Management, Australian National University. October 2004.

Rabone,FA (2004b): Review of the Impact of Water Pricing Reform on Residential Water Use in South Australia. Paper submitted for Subject INFR8082 Managing Utilities 2. Master of Infrastructure Management, Australian National University, October 2004.

Rabone,FA (2005a): Measuring Urban Water Sustainability – A Literature Review. Paper submitted for Subject EMDV8041 Sustainability. Master of Infrastructure Management, Australian National University, June 2005. Complete copy included in Appendix 1.

Rabone,FA (2005b): One Pipe or Two, Adelaide? Comparing alternative urban water supply approaches from a sustainability perspective. Paper submitted for Subject EMDV8041 Sustainability. Master of Infrastructure Management, Australian National University, August 2005.

Radcliffe,J (2004): *Water Recycling in Australia*. Review undertaken by the Australian Academy of Technological Sciences and Engineering.

Reeves,D (1994): Greens turn brown as Sydney's parks face an endless summer. Article appeared 16/11/1994 in *Sydney Morning Herald;* 4.

Reynolds,RG; Watson,WD; Collins,DJ (1983): *Water Resources Aspects of Drought in Australia*. Water 2000: Consultants Report No. 13. Department of Resources and Energy, Canberra.

*River News* (1995): Riverland Irrigators access to training. Article appeared 23 August 1995. p13.

Roche,R; Revels,C; Amies,M (2001): *Franchising in Small Town Water Supply*. [Online] Available: http;//www.wsp.org. Accessed 01/05/2004.

Roseberg,P (1994): Reducing demand for a limited supply. *Water & Wastewater International* February 1994, 38-42.

Rouse,MJ; Cranfield,RF (1988): An Overview of the Trends and Future Direction of information Technology in the Water Industry. *Water Science and Technology: Water supply* Vol. 21 No 10/11, 1129-1135.

Roxby Downs Council (2002): Water Page [Online] Available:http://www.roxbydowns.com.

Rowe,DR; Abdel-Magid,IM (1995): Handbook of Wastewater Reclamation and Reuse. Lewis Publishers . 550 pages.

Rural Water Corporation (1993a): What You Can Do to prevent Groundwater Pollution. *AQUA*, Autumn 1993, 4-5.

Rural Water Corporation (1993b): It Pays to Plan Your Dam. *AQUA*, Autumn 1993, 12-13.

## S

Sabburg,G; Simms,M; Paul,S; West,J (1993): Working with the Community - A Community Consultation Program. *Water*, June 1993, 30-33.

Saldinger,M (1992): *Small-scale Wastewater Treatment Technologies.* A quick guide to on-site domestic wastewater treatment technologies in Australia, October 1992, Western Australia.

Salkeld,M (1997): South Australia's Regional Water Treatment and Wastewater Treatment Projects. Paper presented to *Australian Infrastructure Investment Forum*, 29 August 1997.

Samra,S (1989): Survey of Security for Country Towns in Australia. *Proceedings of the National Workshop on Planning and Management of Water Systems: Risk and Reliability. Adelaide, 23-25 November 1988*. GC Dandy and AR Simpson (Editors).

Sarkissian,W; Perlgut,D; Ballard,E (1986): *The Community Participation Handbook.* Impacts Press, Sydney, Australia.

Sibenaler,Z; Clark,RDS (1999): How to initiate an ASR project. Course notes presented at the 2nd National Aquifer Storage and Recovery short course, 27 - 29 October 1999, Adelaide, Australia.

Sickerdick,L; Desmier,R (2000): Use of Reclaimed Water from SA Water's Wastewater Treatment Plants. *Proceedings of the First Water Recycling Forum Australia, Adelaide 19-20 October 2000*. CSIRO & AWA (PJ Dillon Ed).

South Australian Department of Mines and Energy (1991): *Groundwater in the Murray Mallee*. Information Sheet No. 11 issued by Information Services Branch of the South Australian Department of Mines and Energy (SADME).

South Australian Health Commission (1995): *Waste Control Systems. Standard for the Construction, Installation and Operation of Septic Tank Systems in South Australia.* Government of South Australia. March 1995, Adelaide.

South Australian Health Commission (1997): *South Australian Reclaimed Water Guidelines (Treat Effluent).* Prepared by the South Australian Health Commission (SAHC), the South Australian Water Corporation, Department of Primary Industries South Australia (PISA), Environment Protection Authority (EPA), Local Government Association (LGA) and United Water.

South Australian Health Commission (n.d.): Waste Control Systems - Standard for Connection to a Septic Tank Effluent Disposal Scheme. Draft. Adelaide.

SA Water (1995): Running water, responsibly. Explanation brochure included in water invoice.

SA Water (1996a): *A Review of South Australian Country Water Quality and the Development of a Strategy for a Quality Improvement Program*. Report prepared by Engineering Services Group. September 1996.

SA Water (1996b): *Annual Report 1996*. Adelaide, South Australia.

SA Water (1997): *Annual Report 1997*. Adelaide, South Australia.

SA Water (1999a): *Water Pricing in South Australia. December 1999, Discussion Paper*.

SA Water (1999b): *Off-Peak Transportation*. General Information based on the Barossa Scheme.

SA Water (1999c): *Annual Report 1999*. Adelaide, South Australia.

SA Water (1999d): *SA Water Corporation - Our Water System*. [Online] Available:http://www.sawater.com.au. Accessed 27/04/00

SA Water (1999e): *Penneshaw Water Supply - Concept Design Report Reticulation System Modifications.* Prepared by Roger Stokes & Associates. Adelaide. January 1999.

SA Water (2000): *Sewerage Pricing in South Australia Discussion Paper*. Government of South Australia. Adelaide. March 2000.

SA Water (2002): Environmental Policy. Explanation brochure March 2002. Adelaide.

SA Water (2003): *South Australian Permanent Water Conservation Measures*. [Online] Available: www.sawater.com.au/Restrictions/welcome/overview.html. Accessed 04/05/04. Modified 25/02/04.

SA Water (2005a): Sustainability Assessment Framework Background Summary and Suggested Way Forward for Optioneering of SA Water's Capital Projects. Draft Internal Discussion Paper.

SA Water (2005b): Business Rationale for Sustainability. Internal Discussion Paper.

SA Water (n.d.): *SA Water Facts*. Fact Sheet prepared by SA Water Corporate Communications.

SA Water (n.d.): *Where does our water come from and where does it go to?* Public information brochure produced by SA Water in collaboration with the Nursery & Landscape Industry Association of South Australia.

SA Water (n.d.): *Water Well - smart water use*. Public information brochure produced by SA Water in collaboration with the Nursery & Landscape Industry Association of South Australia.

SA Water (n.d.): *Water Well - wise plant selection*. Public information brochure prepared by SA Water in collaboration with the Nursery & Landscape Industry Association of South Australia.

Schlette,TC; Kemp,DC (1991): Setting Rates to Encourage Water Conservation. *Water Engineering & Management*, May 1991, 25 & 29.

Schoenfeldt,C (1999): Future of Water Resources for South Australia. Article published on Australian Academy of Technological Sciences and Engineering. *Focus* No. 111 Mar/Apr 2000 [Online] Available:http://www.atse.org.au/publications/focus. Accessed 29/12/00

Schulz,M (1998): Water bid starts pumping. *Guardian Messenger* Number 1702, 09/09/98, 1.

Securo,LA (1996): *Middle River Reservoir - Reservoir Reliability Study*. Edited by Dr P Crawley. Report for Water Supply Unit, Engineering Services, SA Water. Report 96/5. Adelaide. November 1996.

Sewell,WRD; Handmer,JW; Smith,DI (1985): *Water Planning in Australia: from myths to reality*. Highland Press, Canberra. 264 pages.

Shannon,JD; Derrington,B; Varma,A (1986): Multipurpose Wastewater Reuse. *Water Pollution Control Federation,* Number 58, 1039-1042.

Shaw,D (1984): *Towards Better Meetings*. Australian Rostrum Council.

Shepard,C (1995): Council Environmental Plans - local Agenda 21. *Aqua Australis*, Volume 1, Number 2, December 1995.

Shiklomanov,I (1999): *World Water Resources at the Beginning of the 21st Century*. Monograph UNESCO's intergovernmental scientific programme World Water Resources and Their Use website. [Online] Available: http://webworld.unesco.org/water/ihp/shiklomanov

Shivsu (Undated): *Reserve Osmosis*. Shivsu Group of Companies Website. [Online] Available: http://www.shivsu.com/html/osmosis. Accessed 18/06/99

Sidwell,AC (1990): Project Management: Dynamics and performance. *Construction Management and Economics*, 159-178.

Siemak,RC; Arber,RP; Asano,T; Crook,J (1990): National Guidelines for Water Reuse: Pros and Cons. *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990, Phoenix, Arizona*, 51-55.

Sloan,WN (1977): Changing Attitudes to Health Aspects. Water Research Foundation of Australia, Report No 51. *Reuse of Treated Wastewater Workshop*, July 1977, Sydney.

Sloan,WN; Langford,KJ; Lottkowitz,SN (1985): *Recycled Water in Victoria - Developing a Valuable Resource. Recycled Water: Marketing a Valuable Resource*. Papers for a seminar conducted by The Task Force on Recycled Water, Bendigo.

Smith,J; Renteria,L (1990): Golf Course Irrigation with Reclaimed Water. *Water Reclamation - Here, Now...and How, Symposium III Oct 13-14, 1988*. (Ed: Price,B) Technomic Publishing Company, Pennsylvania, 123-126.

Smith,VL (1996): Regulatory Reform in the Electric Power Industry. The Cato Review of Business & Government. *Regulation* 1996 Vol 19 No 1. [Online] Available:http://www.cato.org/pubs/regulation. Accessed 10/08/2004.

*Southern Argus* (1995): Feasibility study of Recycled water to Willunga Basin commences. Article appeared 3 August 1995, 5.

*Southern Times* (1995a): Effluent Idea for Subdivisions. Article appeared 21 June 1995, 6.

*Southern Times* (1995b): Wetlands project for Port Noarlunga. Article by Jeremy Pudney appeared 2 August 1995, 4.

*Southern Times* (1995c): Council looks at recycled sewage, stormwater to irrigate its reserves. Article by Jeremy Pudney appeared 6 September 1995, 3.

Southern Region Water Board (1991): *Outlook. Newsletter* Issue No. 9 edited by C. St Clair, December 1991. Sydney-Illawarra-Blue Mountains, NSW.

*Southern Times* (1995d): $1m computerised watering system for Noarlunga parks. Article by Jeremy Pudney appeared 6 September 1995, 3.

Southern Times (1995e): $1.2m water sprinkler okay for Noarlunga parklands. Article by Jeremy Pudney appeared 25 October 1995. p 16.

*Southern Times* (1995f): Recycled water plan for basin. Article by Sky Laris appeared 13 September 1995, 6.

*Southern Times* (1995g): User pays, if farmers want recycled water. Article by Scott Cowham appeared 20 September 1995, 8.

Stallworthy,OP; Kharbanda,EA (1986): *A Guide to Project Implementation.* The Institution of Chemical Engineers, England.

*Standard* (1995a): Cemetery plans to recycle wastewater to cut bills. Article by Lin Fong appeared 5 July 1995, 3.

*Standard* (1995b): Aquifer passes winter test. Article appeared 6 September 1995, 3.

Standards Australia (1994): *Disposal Systems for Effluent from Domestic Premises*. Australian Standard AS 1547-1994, Australia.

Starr,JR (1993): The Quest for Water from Biblical Times to the Present. *Environment, Science & Technology* Vol. 27, No. 7, 1264-1267.

State Rivers and Water Supply Commission (1970): *Farm Water Supplies*. Practical advice on making the most of available water. Victoria.

Staunton,J; Hunt,C (n.d.): *Impact of Capital Works on Rating for Smaller Country Local Councils.* Australian Water Research Advisory Council Research Project P87/22. Final Report. Department of Primary Industries and Energy.

Stewart,I (1993): What is Statistics? *Inside Science* Volume 61, 1-4.

Stiles,G (1996): *Demand-side Management, Conservation and Efficiency in the Use of Africa's Water Resources*. [Online] Available:http://www.idrc.ca/books/focus/804/chap1.html Accessed 18/06/99.

*Stock Journal* (1995): Lake Water on Stream for Langhorne Creek. Article appeared 28 Sep 1995, 15.

Stone,AW (1990): Water, Water Everywhere Have You Looked? *Proceedings of COSERV 90 The National Conference and Exposition Offering Water Supply Solutions for the 1990s, Aug 12-16, 1990, Phoenix, Arizona*, 571-575.

Stoneham,SM; Kidd,CHR (1977): *Prediction of runoff volume from fully sewered urban catchments*. Institute of Hydrology. Report Number 41, September 1977.

Strom,AG (1977): Current Position of Reuse in Australia. Water Research Foundation of Australia, Report No 51. *Reuse of Treated Wastewater Workshop,* July 1977, Sydney.

Strom,AG (1985): Reuse of sewage effluent in Australia. *Reuse of Sewage Effluent Symposium* Institution of Civil Engineers. London, UK. 35-44.

Stuyfzand,PJ (1999): Why ASR? International Experience. Paper presented at the 2nd National Short Course on Aquifer Storage and Recovery, 27 - 29 October 1999, Adelaide, Australia.

Subramaniam,V (1993): Privatisation of water supplies- the Malaysian experience. *AQUA* Vol. 42 No. 5, 310-313.

*Sunday Mail* (1995): Bring that old tank back to life. Article appeared 1 October 1995, 117.

Suppiah,R; Collins,D; Della-Marta,P (2001): *Observed Changes in Australian Climate*. Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology, Australia.

Sutherland,M (1992): Research is like Sex. *Marketing*, May 1992, 62-63.

Sweetman,K (1995): The green, green grass of Canberra gets a little help. *The Advertiser* 2 May 1995, 5.

*Sydney Morning Herald* (1995a): Invention stops rubbish going with the flow. Article by Gavin Gilchrist appeared 8 November 1995, 6.

*Sydney Morning Herald* (1995b): Adelaide flow. Article appeared 5 October 1995, 38.

Sydney Water (2001): *Rouse Hill Recycled Water Area Plumbing Guidelines*. Publication Number CSD37 July 2001. Sydney, Australia. [Online] Available:www.sydneywater.com.au. Accessed 30/07/04.

Sydney Water Board (1992): *Draft Guidelines for Stormwater Management Planning*. Prepared by Sinclair Knight, Sydney. March 1992.

Syme,GJ; Williams,KD; Nancarrow,BE (1989): Public Perception of Risk and Reliability in Relation to Household Water Supply. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide 23-25 November 1988*. GC Dandy and AR Simpson (Editors).

Sztajnbok,P (1999): Improving the quality of the injectant. Lecture from the 2nd National Short Course on Aquifer Storage and Recovery, Adelaide, October 1999.

## T

Tasman Asia Pacific (1997): *Third Party Access in the Water Industry. An assessment of the extent to which services provided by water facilities meet the criteria for declaration of access.* A final report prepared for the National Competition Council. September 1997.

Taylor,C; Yahner,J; Jones,D; Dunn,A (1997): Wastewater. Article in *Pipeline,* Fall 1997, Vol. 8 No. 4 adapted for use in Indiana by Purdue University.

Taylor,P (1993): Biological Sewage Treatment Facility. Presentation made by Pryme Wastewater Treatment to Engineering and Water Supply Department. Adelaide. 28 October 1993.

Telfer,AL (1997): Feasibility and Cost Analysis of Recycling Stormwater and Effluent for a City of 25,500 - Whyalla SA. *Seminar proceedings "Stormwater in the next millennium: exportable innovations in stormwater management" Hydrological Society of South Australia.* Held 23/10/97. 67-70.

Texas Water Development Board (1997): *Texas Guide to Rainwater Harvesting*. Second Edition. Written in cooperation with the Center for Maximum Potential Building Systems.

Thackray,P (1994): How to meet the challenge. *Management Accounting* July/August 1994.

*The Water Report* (1998): Various articles from the weekly newsletter for the water industry in Australia and New Zealand. Vol. 13, No. 5, 22 May 1998; 2,3,5 & 6.

*The Water Report* (1999): Various articles. Vol. 16, No. 14, 5 November 1999.

Thierot,RF (1994): Wetlands: A Challenge for Researchers. *Water Environment & Technology,* February 1994, 4.

Thomas,KD (1999): Critical analysis of the factors affecting the success of programs for the sustainable recycling and reuse of water. Honours Degree of Bachelor of Science Thesis, Flinders University of South Australia.

Thompson,M (2004): *Climate and Weather Atlas of Australia Guide*. [Online] Available:http://home.iprimus.com.au/ozthunder/oz.

Thompson,T (1996): *Irrigation in South Australia*. Report by the Department of Primary Industries South Australia.

Tomlinson,GW; Fisher,AG; Clark,RDS (1993): *Stormwater - A Community Resource - The Paddocks*. Report by Water Resources Branch (Hydrology Unit) of the Engineering and Water Supply Department. EWS Report No. 93/11. Adelaide.

Topp,V; McClintock,A (1998): Efficiency and Equity in Water Markets. *ANCID 1998 Conference 'Living with Limited Water' Sale, Victoria, 2-5 August 1998.*

Toset,H; Gleditsch,N (1999): Conflict and Shared Rivers. Paper in *40th Convention of the International Studies Association, Washington DC, USA February 16-20*.

Trauth,KM; Claborn,BJ; Urban,LV (1987): A Water Resource Audit for Small Communities. *American Water Works Association* Volume 79 Number 5, 48-51.

Turcotte,JW (1997): Review of Reuse of Reclaimed Water. The Florida Legislature Report No. 96-61 (March 1997) [Online] Available: http://www.oppaga.state.fl.us/reports/environ/r96-61s.html. Accessed 29/9/99

Turner,GK; Weinmann,PE (1989): Rural water Supply Systems in Victoria. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide, 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

## U

Uhlmann,JW (1989a): Risk and Reliability of Water Resources Commission Schemes: Queensland. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide 23-25 November 1988*. GC Dandy and AR Simpson (Editors).

Uhlmann,JW (1989b): Summary of Yield Estimation and Storage Operation for Major Irrigation Headworks in Australia. *Proceedings of the National Workshop on Planning and Management of Water Resource Systems: Risk and Reliability. Adelaide, 23-25 November 1988.* GC Dandy and AR Simpson (Editors).

UNESCO (2001): *Education - Key to a viable future*. [Online] Available:http:\\www.unesco.org/education/esd/english/education. Accessed 30/04/04.

UNESCO (2004): Meeting Basic Needs. Posted on the World Water Assessment Program for development, capacity building and the environment. [Online] Available:http:\\www.unesco.org/water/wwap/factsfigures/basicneeds. Accessed 30/04/04.

UNIDO (1996): *Guidelines for Infrastructure Development through Build-Operate-Transfer (BOT) Projects.* Prepared by the Investment and Technology Promotion Division of United Nations Industrial Development Organization, Vienna 1996.

United Nations Environment Programme (2002): *Source Book of Alternative Technologies for Freshwater Augmentation in Small Island Developing States. Part B - Technology Profiles, Water Conversation, Irrigation Systems*. Review Number SWR0004 Section B1.4.4. [Online] Available:http://www.siwin.org/reviews/swr0004/swr0004144.html. Accessed 01/05/2004. Modified 25/01/2002.

United States Environmental Protection Agency (1992): *Manual - Guidelines for Water Reuse*. U.S. Agency for International Development, Washington, DC.

United States Environmental Protection Agency (1998?): *Water Recycling and Reuse: The Environmental Benefits*. Water Division Region IX - EPA 909-F-98-001.

United Water (1998): *Economics of Wastewater Treatment - A Case Study of the Aldinga Wastewater Treatment Plant*. Presented by Brian Little as part of Water Pollution Control II subject to Indonesian students.

United Water (1999): *Bolivar DAFF Wastewater Recycling Project*. Submission by United Water for consideration as a candidate for a 1999 Engineering Excellence Award.

Unknown (1996): *Guidelines, Design Criteria and Standards for Septic Tank Effluent Disposal Schemes.* Amended July 1996.

*US Water News* (1996): Safety of water supplies in nation's small communities focus of NRC study. US Water News Online, December 1996. [Online] Available:http://www.uswaternews.com/archives/arcsupply/6safwat.html. Accessed 10/11/03.

UVTA (n.d.): *Water - A Precious Resource - The Gift of Life*. Sales brochure of Australia Designed and Manufactured Products from Ultraviolet Technology of Australia Pty Ltd. Adelaide.

**V**

van der Leeden,F; Troise,FL; Todd,DK (1990): *The Water Enclyopedia*. 2nd ed. Lewis Publishers Inc.

van der Merwe,B (1996): Water Reclamation for Potable Reuse in Windhoek, Namibia. *Proceedings of WaterTECH Conference, Sydney, May 1996*.

van der Wel,B; McIntosh,G (1996): *Integrated Water Management for Selected Rural Towns and Communities of South Australia.* Draft report for public discussion. Internal document of the South Australian Department of Environment and Natural Resources (Docket DENR 10083/94). March 1996.

Vecchio,G (2002): A History of Meteorology in South Australia to 2001. [Online] Available: http//www.bom.gov.au/weather/sa/inside/history. Accessed 26/04/04. Modified 19/02/02.

Vickers,A (1990): Water-Use Efficiency Standards for Plumbing Fixtures: Benefits of National Legislation. *Journal AWWA*, Vol. 82, No. 5, 51-54.

Vickers,A; Markus,EJ (1992): Creating Economic Incentives for Conservation. *Journal AWWA* Vol. 84, No. 10, 42-45.

Victorian Irrigation Research (1980): *Quality aspects of Farm Water Supplies.* Report of the Victorian Irrigation Research and Advisory Services Committee. Second Edition.

**W**

Wajon,J; Kenway,S; Maus,A (1999): Evaluation of Reuse of Wastewater in Perth for Irrigation of Parks, Gardens and Golf Courses. *Proceedings Australian Water and Wastewater Association 18th Federal Convention, Adelaide, Australia, 11-14 April 1999.*

Walton,R; Hunter,H (1999): Value for Money from Water Quality Studies. Paper in *Water 99 Joint Congress - Brisbane Australia 6-8 July 1999*.

Warren,R (2002): *The Purpose Driven Life*. Ministry ed. Zondervan, Michigan, USA.

Water and Sanitation Program (2002): *Willingness to Charge and Willingness to Pay: The World Bank-assisted China Rural Water Supply and Sanitation Program*. Field Note August 2002.

Water and Sanitation Program (2003): *Sustainability Planning and Monitoring in Community Water Supply and Sanitation. A Guide on the Methodology for Participatory Assessment (MPA) for Community-Driven Development Programs.* Edited by: Mukherjee,N and van Wijk,C.

Water Catchment Management Board (n.d.): *Septic Tank Information.* Pamphlet produced by Onkaparinga, Torrens, Northern Adelaide & Barossa Water Catchment Management Boards in conjunction with City of Onkaparinga, Adelaide Hills Council and Mount Barker District Council.

Water Data Services (1999): *Data Collection*. [Online] Available:http://www.waterdata.com.au/methods.html. Accessed 8/12/99. Modified 2/12/99.

Water Pollution Control Federation (1989): *Water Reuse - Manual of Practice*, 2nd ed. Prepared by Task Force on Water Reuse. USA.

Water Quality Program Committee (1996): *Small Community Wastewater Collection Systems*. Publication Number 448-405. [Online] Availablet:http://www.ext.vt.edu/pubs/waterquality/448-405/448-405.html. Accessed 18/06/99

*Water Recycling News* (1999): Various articles. Newsletter Vol. 1, No. 1, of the Water Recycling Forum; AWA Water Recycling Interest Group; 1-3.

Water Resources Act (1997): South Australia

Water Resources Commission of New South Wales (1986): *Water Pricing for Irrigation Areas and Districts*. December 1986.

Water Resource Solutions (n.d.): *Water Resource Solutions* [Online] Available:http://www.wrsolutions.com. Accessed 16/07/99

Water Resources Strategy for the Melbourne Area (2001): *Discussion Starter: Stage 1 in developing a Water Resources Strategy for the Greater Melbourne area*. June 2001. Victoria, Australia.

Water Reuse Association of California (n.d.): *Indirect Potable Reuse*. Fact Sheet [Online] Available:http://www.webcom.com/h2o/Pages/potable.html. Accessed 25/10/1999.

Waterose (1998?): The World's Water Supply - Is there enough? Written for Royal Roads University ES316 Environmental Hydrology and Soil Science Lecture Series. [Online] Available: http://www.geocities.com/waterosetest/sd11.html. Accessed 3/07/04.

Water Services Association of Australia (1995): *Environmental Management Guidelines for the Australian Water Industry*. Edited by Sue Mills. Water Services Association of Australia, Melbourne.

Water Services Association of Australia (1998): *Wise Water Management. A demand management manual for water utilities*. Water Services Association of Australia Research Report No. 86, November 1998.

Water Services Association of Australia (2002): *Dual Water Reticulation Systems*. Version 1.1. A Supplement to the Water Supply Code of Australia WSA 03-2002.

Water Services Association of Australia (2003): *House Environment Committee to Examine the Future Sustainability of Australian Cities Submission by Water Services Association of Australia*. November 2003.

WaterWeb (n.d.): The WaterWeb Consortium. [Online] Available:http://www.waterweb.org. Accessed 12/11/99

Waterworks SA (2000): Desalination Technology - A Showcase. Article appeared in the newsletter of the SA Branch of the Australian Water Association. Autumn 2000.

Watts,PJ; Hancock,NH (1984): Evaporation and Potential Evaporation - A Practical Approach for Agricultural Engineers. *Conference on Agriculture Engineering, Bundaberg, 27-39 August 1984*, 290-297.

Weeks,CV; Cole,TG; Badani,VM (1993): The Hazards of Golf Course Irrigation With Reclaimed Water - A tale of three districts. *Proceedings of the Water Environment Federation 66th Annual Conference and Exposition, Anaheim, California, USA. 3-7 October 1993*, 131-135.

*West Coast Sentinel* (1995): $300,000 water upgrade. Article appeared 23 November 1995, 1.

Western Australian Water Resources Council (1986): *Water Conservation through Good Design: A Guide for Planners, Architects, Engineers, Landscape Architects and Land Managers*. Perth.

Western Australian Water Resources Council (1990): *Water Sensitive Residential Design: An investigation into its purpose and potential in Perth Metropolitan Region*. Water Sensitive Urban Design Group. Perth. February 1990.

Western Mining Corporation (2000): *Olympic Dam Environmental Impact Statement*. [Online] Available:http://www.wmc.com/sustain/Olympic/. Accessed 27/06/2000.

Western Mining Corporation (1992): *Olympic Dam Operations & Roxby Downs Township*. Information brochure

*Whyalla News* (1994): Blevins supports tank plan. Article appeared 07/10/1995, SA Regional Newspaper; 5.

*Whyalla News* (1995a): Plan to recycle our waste water. Article appeared 9 June 199, 1.

*Whyalla News* (1995b): Council's efforts recognised. Article appeared 15/09/95, 4.

Wind Farm Developments (2003): *Frequently Asked Questions.* [Online] Available:http://www.windfarmdevelopments.co.nz. Accessed 14/09/03.

Winter,TC; Harvey,JW; Franke,OL; Alley,WM (2002): Ground Water and Surface Water - A single resource. US Department of the Interior, Geological Survey. [Online] Available:http//pubs.water.usgs.gov/circ1139 Accessed 25/04/04. Modified 20/06/02.

Wolf,AT (1998): Conflict and Cooperation along International Waterways". *Water Policy*. Volume 1. Number. 2.

Wolf,AT (1999): The Transboundary Freshwater Dispute Database Project. International Water Resources Association, *Water International*, Volume 24, Number 2, June 1999, 160-163. from [Online] Available: http://www.iwra.siu.edu. Accessed 16/04/00

Wolfe,P (2003): Alternative financial options widen Kyoto debate. *Water & Wastewater International*, April 2003, 3.

Wong,HF; Breen,PF; Somes,NLG; Lloyd,SD (1999): *Managing Urban Stormwater using Constructed Wetlands.* Cooperative Research Centres for Catchment Hydrology & Freshwater Ecology. Industry Report 98/7 Second Edition September 1999.

Wood,A (2003): Argument for regulation over price doesn't hold water. Article in *The Australian*, October 7, 2003.

Woolnough,P (2003): Government policy could make or break the wind industry. *Engineers Australia*, August 2003, 20-25.

World Bank (2003): *Water Resources Management*. [Online] Available:http//lnweb18.worldbank.org. Accessed 06/09/03.

World Health Organization (1987): *Technology for water supply and sanitation in developing countries.* Report of a WHO Study Group. Technical Report Series 742, Geneva 1987.

World Health Organisation (2003): Sustainability and optimisation of water supply and sanitation services. [Online] http://www.who.int/docstore/watersanitationhealth/wss. Accessed 02/05/2005.

World Health Organisation (2003): *The Right to Water*. February 2003, France. [Online] Available: http://www.who.int/watersanitationhealth/rightowater. Accessed 01/05/04.

## Y

Young,RA (1996): *Measuring economic benefits for water investments and policies.* World Bank Technical Paper No. WTP338. [Online] http://www-wds.worldbank.org/servlet. Accessed 19/05/2005. Last modified 22/10/2002.

Yuma Area Office (n.d.): *Yuma Desalting Plant. Bureau of Reclamation.* [Online] Available: http://www.yao.lc.usbr.gov. Accessed 18/06/99

## Z

Zwar,J (1985): Management of Dryland Landscapes. Paper in *Current Practices in Dryland Resources and Technology International Overviews, 1985*.

Zwar,J (1993): Water Efficient Plantings. *The Australian Garden Journal*. October/November 1993, 23-27.

# PART II SELECTED SOUTH AUSTRALIAN CASE STUDIES

**Figure 102 Leigh Creek (Climate Index 14) – Typical Street scape (Rabone 1993)**

# General Overview

## BACKGROUND

Many small South Australian towns and urban centres have developed non-potable water supplies through local water harvesting and reuse projects, using an array of practical technologies, with benefits to both the local community and environment. Over 30 years ago, some of the more progressive towns in South Australia recognised stormwater and treated effluent as an important community resource. In addition, every independent water source which is developed in South Australia reduces pressure on the State Government reticulated water supply system. However, no community wants to feel like a '*guinea pig*' for a new idea (Khan & Gerrard 2005). Therefore, implementation of early pioneering projects relied heavily on the strong commitment of motivated individuals and their ability to influence both local authorities and the community.

Early water harvesting and reuse schemes were inherently simple in form, often assembled with readily available materials and locally available construction expertise. Pioneering efforts have been a powerful endorsement by increasing awareness that certain communities practise water harvesting and reuse as a matter of choice. Other towns have subsequently been motivated to investigate opportunities to reduce their reliance on reticulated water supply for the irrigation of recreational areas; particularly, since the early 1990s, as consumption based water pricing has been progressively introduced in South Australia. At an institutional level, these success stories have been instrumental in generating widespread support and acceptance of community-driven projects to manage non-potable water supplies locally. Nonetheless, transforming these successes into water resource management initiatives with widespread adoption to benefit more South Australian towns remains elusive. The potential for local water harvesting and reuse will become more important with the application of permanent water use restrictions in 2003, the first for more than forty years.

Water harvesting and reuse is a sensible reality for the dry South Australian climate particularly when coupled with appropriate conservation and landscaping practices. The primary focus is harnessing stormwater runoff and treated effluent generated by normal township development to supplement higher quality public water for uses such as irrigation of public areas and sporting fields, both in urban and country areas. While many water harvesting and reuse projects operating in different socio-economic and environmental conditions have been documented, literature on small-scale initiatives is far more limited. A major obstacle to the research and development of small water harvesting and reuse projects has been the lack of data for the existing operational schemes to validate their social, economical, environmental, technological and institutional performance (ie. sustainability). Early pioneering schemes were not implemented with research in mind and often only minimal record keeping has occurred; hence, the difficulty in obtaining operational data, particularly, where outcomes were different to those expected.

## PRESENTATION OF INFORMATION

Part II provides a review of a selection of small-scale case studies from South Australia, in particular, those operating in country towns and regional areas. Critical examination of existing projects can offer information about how to facilitate more frequent development of water harvesting and reuse schemes in South Australia. These evaluations also provide an essential dissemination mechanism for improving understanding to ensure the implementation of more sustainable water strategies and policies. The aim of this part of the research is to present a basic picture of different schemes that have been implemented with the expectation that others may get ideas from these. For consistency, the available information for each case study has been separated into the following major categories (where relevant for the given case study);

| | |
|---|---|
| • General Statistics | Some statistics about the town such as location, population, average rainfall, average evaporation, and so on are provided. |
| • Water Supply | Information on the reticulated water supply available to residents, such as price, demand and consumption pattern. |
| • Stormwater Drainage | A brief description of the town's stormwater drainage system and method of disposal. |
| • Wastewater Management | A brief description of the wastewater system, treatment processes and method of disposal. |
| • Harvesting & Reuse | Information about the water harvesting or reuse scheme implemented including discussion of the factors to success and barriers encountered. |
| • Landscaping Practices | Any examples of water conserving landscaping that have been adopted for the beautification or to complement any reuse schemes have been noted. |

The information presented here has been gathered by researching literature about the schemes (where this exists), field visits, but mostly with the assistance of local operators and people from the community who were willing to share experiences. Given the non random selection of cases and informants, the experiences or findings related here should be considered illustrative rather than general.

Water harvesting and reuse has proven to be a beneficial strategy for addressing stormwater runoff and wastewater disposal problems and alleviating localised water supply problems for several South Australian towns and communities. The existing projects demonstrate both the strong community-based and innovative approach to water resources management in this state.

# Definition of 'Climate Index'

When trying to assess the viability of a region within South Australia to support a stormwater harvesting and reuse scheme, a key factor is the amount of stormwater that can be collected. The amount and reliability of stormwater is dependent upon the regions average rainfall and evaporation rate.

The prevailing climate of a location provides a summary of average atmospheric conditions over a long period of time as well as information about the natural variability and the likelihood of particular events. It also influences;

- the temporal pattern of water demand, particularly, in terms of volume used and seasonality of demand, and
- determines the probable volume of stormwater runoff, along with the extent of impervious surface cover (ie. degree of urbanisation), that can be harvested from a catchment.

There are a number of different ways for describing or classifying climates, but for towns that are interested in developing local water harvesting and reuse scheme, climate zones based on rainfall and evaporation rates will be most useful. A simple index herein called a "*Climate Index*" is proposed to describe the prevailing climate conditions of a town and to assist in making broad assessment of stormwater availability (for harvesting and use), as presented below:

$$\text{Climate Index (CI)} = \frac{\text{Average Annual Evaporation (mm)}}{\text{Average Annual Rainfall (mm)}}$$

Figure 103 below presents the application of the climate index and identifies four ranges for the state of South Australia. For much of South Australia, the average annual evaporation exceeds the annual average rainfall by a factor of ten. The climate index provides a method of categorising the prevailing climate of a region with respect to the potential for harvesting stormwater.

Low values of climate index correspond with a high potential for stormwater to be reliably harvested from impervious surfaces within the town. As the climate index increases (ie. region becomes more arid) the potential for harvesting reliable volumes of stormwater runoff is reduced. Typically, stormwater runoff projects are not viable for areas with a climate index greater than 15; however, localised water harvesting by diverting stormwater runoff into depressions at key points in the landscape may be practical.

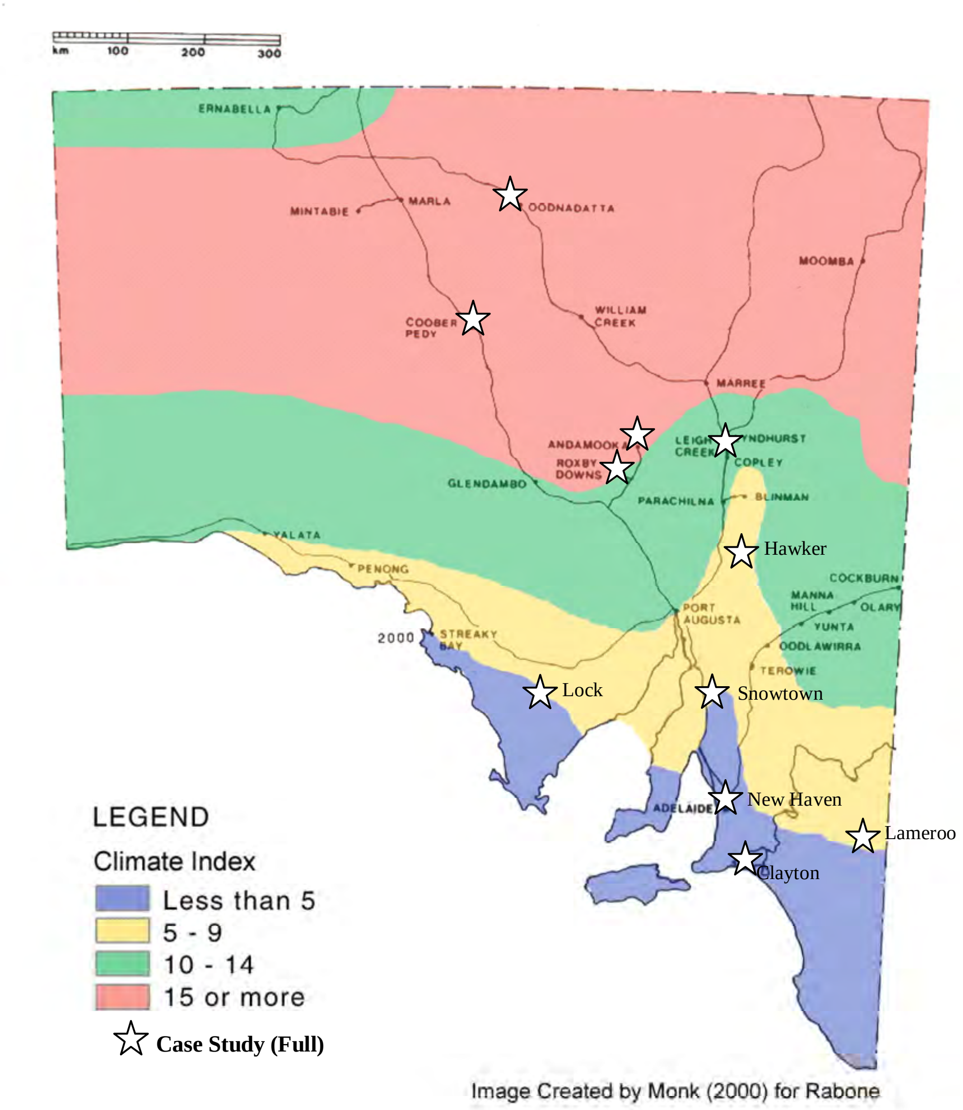


Image Created by Monk (2000) for Rabone

**Figure 103 Climate Index for Selected South Australian Case Studies**

The selected case studies dicussed in the remainder of this part come from a variety of climate indexes. The existence of successful non-potable water harvesting reuse projects in the more difficult regions of South Australia (ie. high climate index) suggest that opportunities to increase the use of low quality water in other urban and country areas can be pursued.

# Andamooka, Far North (Climate Index 15)

## GENERAL STATISTICS

Andamooka is a small opal mining community situated in the far north of South Australia within the Andamooka Station. It is located 600km north of Adelaide and lies between Roxby Downs 30km to the west and Lake Torrens (salt) 10km to the east. The opal field was discovered in the 1930 by two drovers from the station after a thunderstorm. The unique settlement sprawls either side of Opal creek along which some original cottages and semi-dugouts (circa 1931) can be found. Being outside the local government area services in the town are limited. Members of the Andamooka Progress and Opal Miners Association (APOMA) control town developments such as roads, water supply, and airstrip (Zwar 2004). Funding for improvements to services comes from the Outback Areas Community Development Trust. An obvious feature of the town is the lack of greenery.

**Figure 104 Andamooka – View of Town Area (Rabone 2000)**

The climate is arid with daytime temperatures in summer regularly topping 40 degrees Celsius and night temperatures in winter often dropping to zero or below.

**ANDAMOOKA – GENERAL STATISTICS**

| | | | |
|---|---|---|---|
| CLIMATE INDEX | 15 | | |
| REGION | Far North | | |
| POPULATION | 491 (Base) | 185% (Ultimate) | *ABS (2001) CENSUS* |
| URBAN FORM | Small isolated inland community - mining | | |
| AVE. ANN. RAINFALL | 207 mm | | *Burrows (1987)* |
| AVE. ANN. EVAP. | 3 020mm | | *Burrows (1987)* |
| NUMBER OF DWELLINGS | 251 (Occupied) | | *ABS (2001) CENSUS* |
| PERSONS PER DWELLING | 2.0 | | |

## WATER SUPPLY

There is no reticulated water supply making water precious in Andamooka. The quality, supply and cost of water to Andamooka has long been a problem. As has being able to achieve a secure and permanent water supply for residents.

### Early Water Supplies (1930s – 1987)

Water needs of the first settlers were met from small ephemeral dams near the town and by individuals harvesting and storing rainwater. There is no reticulated supply and all buildings have rainwater tanks to collect rainwater to meet requirements for drinking and cooking purposes (see Figure 105).

**Figure 105 Andamooka – Dwelling with Water Storage Tanks (Rabone 1993)**

Local water supplies come from two dams in the catchment of Opal Creek being Spencers Dam and Blue Dam (see Figure 106) being 3km and 16 km from town respectively (McLaren *et al.* 1987; Pat Katnich *pers. comm.* 2006). These are leased by the Andamooka Progress and Opal Mining Association (APOMA) which is responsible the administration. Water is carted by tanker from these dams and delivered into resident's storage tanks for household use but it is not safe to drink unless boiled (McLaren *et al*. 1987; Zwar *pers. comm.* 1993). The carted water is used for laundry, bathing and toilet flushing (where there a flush toilet has been installed).

**Blue Dam** **Storage Tanks at Blue Dam**

**Figure 106 Andamooka – Blue Dam & Storage Tanks (Katnich 2006)**

There have been many occasions when the Spencer and Blue Dams have dried up and water has had to be carted from Woomera about 120km away (McLaren *et al.* 1987). The water supplied to Woomera is transferred from the River Murray about 450km in major pipelines from Morgan. Water carted from Woomera was very expensive and consequently, to avoid the expense the residents of Andamooka have become adept at conserving water.

### Potable Water Supply (1987 – 2006)

In 1987, the APOMA with assistance of a grant from the Outback Areas Community and Development Trust purchased rights to 12ML of desalinated (drinking) water per year from Olympic Dam (Zwar *pers comm*. 1993; Pat Katnich *pers. comm.* 2006). Under the agreement the APOMA procures the desalinated water from BHP Billiton at the unit production cost and on-sell to residents. As part of the arrangement Andamooka paid for the installation of a standpipe in Roxby Downs where a local water carter collects desalinated water for delivery to households in Andamooka about 30km away (see Figure 107). It was a simple agreement with no fixed term and worked well. The APMOA pay BHP Billiton $1.21 per kL and charge residents $1.99 per kL.

**Private Water Tanker** **Typical Tank Residential Set-up**

**Figure 107 Andamooka – Water Tanker & Private Tanks (Katnich 2006)**

Many of Andamooka residents' (approx 80%) rely on potable water that is currently trucked to their homes from Olympic Dam by private contractors at a cost many times higher than the state-wide price. For example, resident's pay $65 per 1000 gallons of water delivered to their house, which is equivalent to $14.30/kL delivered plus compared to the state-wide price of $0.46/kL (ie. rate for less than 125kL reticulated water per year). Even in this arid climate, some residents about 50%) almost never buy water as they are self-sufficient and rely on rainwater (Pat Katnich *pers. comm*. 2006). Some residents prefer to continue to rely on water carted from the two local dams which is boiled prior to drinking.

For many years, a pipeline to supply desalinated water from Roxby Downs has been sought to provide a more reliable and affordable water supply for the community. During negotiations in 1989, the state water authority estimated the cost of the project to be of the order of $2 million (or $3 million escalated to 2006 dollars). The small unrated community (ie. outside local government area) was unable to raise the required 50% share for the project to proceed (Pat Katnich *pers. comm*. 2006). However, people living in Andamooka have a strong independent spirit and refused to give up this goal.

In 2001, BHP Billiton gave the Andamooka Progress and Opal Miners Associated (APOMA) an undertaking to provide an increased water supply of 30ML per year from Olympic Dam's desalination plant. By 2002, a pipeline route was surveyed (OACDT 2002). After more than a decade of lobbying, in May 2005 the State government agreed to contribute $400,000 towards the pipeline between the two outback towns (ABC Online 2005). The funding covered the purchase of the pipe, new storage tanks and UV disinfection facility for Andmooka. The community contribution was by way of in-kind voluteeer plant and labour estimated at a value of $200,000 to construct the pipeline (Pat Katnich *pers. comm*. 2006). While the pipeline and associated facilities were completed in early 2006, the operation of the new system has been delayed pending finalisation of the new agreement.

**New Storage Tank** **UV & Water Dispensing Facility**

**Figure 108 Andamooka – New Tank, UV & Dispensing Facility (Katnich 2006)**

When the pipeline is fully operational, water purchased from BHP Billiton will be piped to Andamooka and stored in the new storage tanks and following disinfection in the local UV plant residents will be able to be collect water from three dispensers in town. The cost of water is still to be determined but is expected to be significantly less than the cost of having water carted from Roxby Downs. A reduction in price and closer access may result in an increase in consumption in the town.

## ANDAMOOKA – WATER SUPPLY STATISTICS

*Pat Katnich (2006)*

| | |
|---|---|
| **ADMINISTRATION** | Outback Areas Community Development Trust (owner)<br>Andamooka Progress and Opal Miners Association (operator). |
| **WATER SOURCE** | 1. Local surface water from Spencers Dam (3km), and Blue Dam (16km).<br>2. Desalinated groundwater from Olympic Dam |
| **TREATMENT** | 1. Dam water boiled prior to use.<br>2. Reverse osmosis and chlorine disinfection at Roxby Downs before cartage. In 2006, desalinated water piped to Andamooka will receive UV disinfection before distribution. |

**DISTRIBUTION** Carted 32km from a standpipe in Roxby Downs.

In 2006, a water transfer pipeline between Roxby Downs and Andamooka will be commissioned. Potable water to be collected from dispensing units.

**RATING STRUCTURE** Pay for use; unit cost $1.99/kL plus cartage by private contractor.

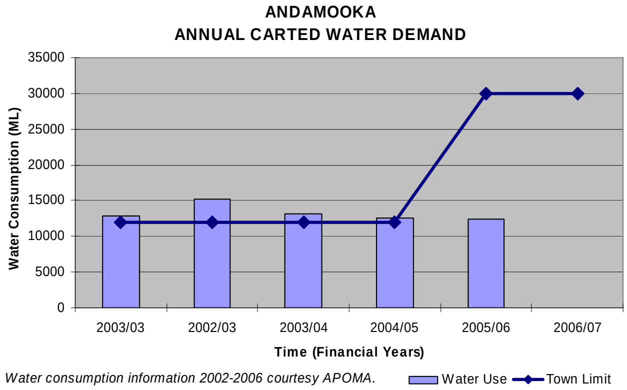
**RETAIL PRICE PAID** $1.99/kL from Roxby standpipe
$14.30/kL including water carting *Pat Katnich (2006)*

The unit price ($/kL) for water available at the dispenser in Andamooka and the cartage charge to deliver to households has yet to determined. *Pat Katnich (2006)*

**AVE. WATER USE** <100 kL/service/year *2002-2005 records APOMA (2006)*

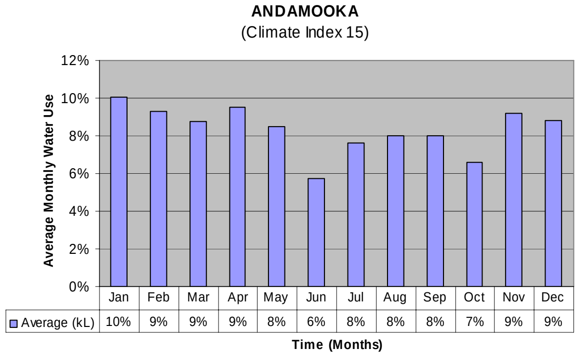
<100 kL/household/year

**AVE. ANN. DEMAND** 12 ML/year (town limit) increased to 30ML per year in 2005/06 *OACDT (2002)*



*Water consumption information 2002-2006 courtesy APOMA.*

**CONSUMPTION PATTERN** Uniform (indoor use only) at about 1 ML per month. Many residents leave from town for extended periods each year, particularly during the hottest months.



*Water consumption information 2002-2006 courtesy APOMA.*

There are no plans for providing reticulated water in Andamooka.

## STORMWATER DRAINAGE

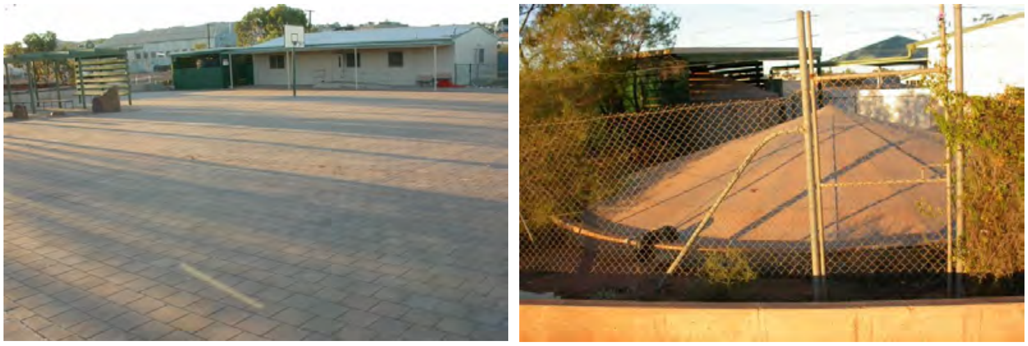
The main street is the only sealed road in town and without drainage causes localised flooding which then exposes residents to effluent. Other roads around the town become boggy in wet weather and access to the hospital is restricted (OACDT 2002). There is no kerbing in place. Stormwater runoff from the elevated areas drains into an ill defined creek that flows through the town after heavy rainfall events. Most of the runoff is likely to be from high intensity storms when the runoff coefficient of sealed and natural catchments is similar. With additional drainage, the stormwater could be harvested and used to beautify the town provided that covered storagae facilities were installed (ie. similar to those at the school). The extension of a sealed roads and addition of kerbs to harvest stormwater is unlikely to be economic in Andamooka due to the high variability in rainfall and high evaporation.

## WASTEWATER SYSTEM

Private septic tanks and long drops are used throughout the town with a result that there is some localised contamination of groundwater. Effluent running into streets was identified as a key environmental issue in the community plan (OACDT 2002). There are no plans to establish a STEDS for the township in the immediate future; consequently, effluent is not available for public plantings.

## NON-POTABLE WATER HARVESTING & REUSE

All buildings have rainwater tanks to collect rainwater for drinking and cooking purposes. Rainwater is also harvested from large school building roofs and paved areas and stored in large covered underground rainwater tanks (McLaren *et al.* 1987; Zwar *pers. com.* 1993). Figure 109 shows this water harvesting infrastructure.



**Paved School Yard** **School Runoff Storage**

**Figure 109 Andamooka – School Water Harvesting Scheme (Katnich 2006)**

## WATER SENSITIVE LANDSCAPING PRACTICES

There is little natural vegetation in the town, occasional shrubs and small trees can be found in low lying areas and local water courses (Figure 110). Residents have to pay to have water carted to their door from Roxby Downs and can not afford to beautify the landscape in the traditional manner.


**Low Lying Area** **Low Water Use Gardening**

**Figure 110 Andamooka - Low Water Landscaping (Katnich 2006)**

Plantings in Andamooka have been random, small scale and mainly undertaken by interested individuals (Zwar *pers. comm*. 1993; Zwar 2004). An increase in greening the town would create a positive impact on the appearance of the town; however, the harsh environment means that survival is restricted to a certain variety of plants (OACDT 2002). There are some old "*Athel Pines*" but more recent plantings are mainly of arid zone natives, many of which are thriving despite such harsh conditions (Zwar 2005). There are some surprisingly impressive home gardens, utilising wastewater, carted stormwater following heavy rains, and water harvesting techniques (Zwar 2005). For example, after storm events, '*Midnight Lenny*' goes out to collect water from low lying areas, ditches and puddles. He stores the water collected in an enormous array of water containers around his property. For his efforts, he is able to maintain a dense forest of native trees around his home.

Another resident, Caroline Christensen has access to a large private dam constructed when the property was established by her father. Although, water level in the dam drops quickly (and empties) in the hot months, she is often able to maintain a small irrigated vegetable garden and orchard of apricots, apples, oranges, pears, and grapefruit (see Figure 111).

**Figure 111 Andamooka – Private dam and fruit trees (Rabone 1993)**

## REFERENCES AND OTHER READING

Special thanks to Mr John Zwar for showing me around Andamooka.

Andamooka Progress and Opal Miners Association: Ms Patricia Katnich and Anne Budau who later provided additional information used to complete this study.

McLaren,N; Heath,D; Morias,A (1987) "*Water Conservation for Communities in Arid Areas of South Australia"* also provided useful facts on Andamookas water supply.

OACDT (2002); "*Andamooka Community Plan*" prepared by Collins Anderson Management, February 2002.

Zwar,JR (2004): "*Water sensitive Urban Design: a perspective from outback South Australia*". Paper presented at the International Conference on Water Sensitive Urban Design: Cities as Catchments, WSUD2004, Adelaide, 21-25 November 2004.

ABC Online (2005); "*Opal Town Gets Long Awaited Water Supply*". The World Today – Tuesday 23 August 2005. Reporter, Sally Dixon.

# Clayton, Murray-Darling Basin (SA) (Climate Index 4)

## GENERAL STATISTICS

Clayton is a holiday hamlet located on the shore of Lake Alexandrina about 80km southeast of Adelaide. Clayton is located on a small peninsula on the western side of Lake Alexandrina at the lower end of the River Murray system (Gerges *et. al*. 2002). Between Clayton and Hindmarsh Island, the River Murray narrows and the sheltered waters make an ideal location for all types of water sports. Most of the private dwellings in Clayton were 'holiday' type structures (EWS 1994); however, over the last few years there has been increased development of land within the town boundaries with most allotments now developed for housing (Alexandrina Council 2005). Clayton also features Australia's first aquifer storage and recovery (ASR) project established with the intention of potable water supply


**Typical House & Streetscape** **Hindmarsh Island**

**Figure 112 Clayton – Views around Town (Styan 2006)**

## CLAYTON – GENERAL STATISTICS

| | | |
|---|---|---|
| **CLIMATE INDEX** | 4 | |
| **REGION** | Murray-Darling Basin | |
| **POPULATION** | <200 (Base) | |
| **URBAN FORM** | Rural community/holiday hamlet | |
| **AVE. ANN. RAINFALL** | 422mm | *Narrung 85yr record BOM (2006)* |
| **AVE. ANN. EVAP.** | 1,536mm | *Hindmarsh Island (Mundoo) 20yr record BOM (2006)* |
| **NUMBER OF DWELLINGS** | NA (Occupied) | |
| **PERSONS PER DWELLING** | NA | |

## WATER SUPPLY

### Original Water Supply (1970s – 1996)

Clayton is one of the many towns in South Australia with an independent water system still reliant on locally available water resources. The water supply for Clayton consisted of pumping water from Lake Alexandrina directly to the elevated water tank (capacity 120kL). The lake water was disinfected with chlorine (with a residual of 5mg/L maintained) prior reticulation to customers. The existing Clayton water supply infrastructure is owned by the State Government. In June 1971 the council signed an indenture for the perpetual lease of the Clayton Water Scheme to operate and maintain the system. Residents of Clayton are rated for their water supply and use by the council and the council more or less breaks even on this scheme (EWS 1994).

**Figure 113 Clayton - Water Supply Original Tank & Pump Shed (Styan 2006)**

Although, the town water supply from the Lower River Murray is plentiful, it can suffer quality difficulties from occasional algal blooms in summer months. During the summer of 94/95 an outbreak of toxic blue green algae occurred in the lake for an extended period rendering the Clayton mains water unfit for human consumption (Alexandrina Council 2005). Records indicate that between 1958 and 1994 the lake experienced a total of 19 algal events (EWS 1994). Chlorination will kill the algae however the toxins remain in the water and cannot be removed by other than sophisticated and expensive filtration processes (Alexandrina Council 2005). The water cannot be used for drinking purposes, general washing or showering while the toxins are present.

The presence of toxic-blue green algae in the water supply from the lake caused problems for the residents of Clayton. An investigation into a range of options to ensure a safe water supply is available for residents of Clayton was undertaken in 1994 by the Engineering & Water Supply Department (now SA Water). Alternative supply or treatment strategies to provide a long term solution for Clayton included either using a separate water source (ie. groundwater or rainwater) with augmentation at times of peak demand or by treating the lake water to reduce toxins. In March 1994, the alternatives were discussed with the community at a public meeting and it was decided to investigate the suitability of a saline aquifer as a storage mechanism for lake water which could be accessed whenever there was an algal bloom in the lake (EWS 1994).

As very little information was available on groundwater in the Clayton area, the Department of Water, Land & Biodiversity Conservation (DWLBC) was commissioned to investigate feasibility of aquifer storage and recovery (ASR) to develop a summer emergency storage of 20ML for Clayton. The local groundwater was expected to have a salinity of 3000 mg/L (EWS 1994) but investigations revealed the salinity varied between 28,00mg/L and 37,000mg/L (Gerges *et al.* 2002a) far exceeding the guideline value of 1500mg/L for potable water. Despite this obstacle, the initial injection trial in July 1995 suggested that the aquifer capacity was adequate for ASR at the 20ML and further testing was warranted (Gerges *et al.* 2002a). Injection testing used unchlorinated lake water.

Full scale testing of the aquifer undertaken over the summer of 97/98 and 98/99 concluded that the aquifer could provide a drinking water supply for the township of Clayton (Alexandrina Council 2005). Investigations focussed on measures to reduce the rate of salinity increase as the plume of freshwater mixes within the aquifer during the storage and recovery period. The unconfined aquifer is situated at a depth of between 34-65m below ground and the fresh water lens sits in a saline aquifer of approximately 35,000mg/L salinity (Alexandrina Council 2005). The infrastructure was modified to enable injection of 300-500ML of unchlorinated lake water in order to form a 'sacrificial' lens that acts as a buffer and transition zone between fresh injectant and native groundwater (Gerges *et al.* 2002a). Clayton requires 40-70ML water each summer to meet demand. Within this lens a potable water supply with a salinity of 1000mg/L can be developed and maintained achieved by careful management of the aquifer.

### Current Potable Water Supply (1996 – 2005)

The current Clayton water supply system draws water out of Lake Alexandrina and uses aquifer storage and recovery (ASR) for treatment and storage with ultraviolet (UV) disinfection (see Figure 114). A large quantity of water (ie. around seven times the annual demand) is injected into the underlying aquifer to form a sacrificial lens in the aquifer. Year round recovered lake water is pumped from the aquifer into the original elevated tank and distributed to customers through the pipe network (Gerges *et al.* 2002; SA Water 2003). DWLBC designed and continue to operate the ASR system on behalf of the Alexandrina Council. As well as providing water free from algal toxins the aquifer also provides clear water at a turbidity of only 0.75NTU compared to the initially injected water at 44NTU (Alexandrina Council 2005). The low turbidity of the recovered water contributed to the viability of an ultraviolet (UV) disinfection.

**ASR Bores** **UV Facility**

**Figure 114 Clayton - Aquifer Storage and Recovery (Styan, 2006)**

The original pump and chlorination facility was incorporated into the ASR system to provide a safe backup supply should demand on the scheme exceed the rate at which the aquifer can provide water (Alexandrina Council 2005). However, residents of Clayton have become accustomed to the current water supply and when the system reverts to previous mode of operation complaints are received about, colour, cloudiness, taste and odour of the water (Gerges *et al.* 2002a). The ASR project to provide a potable water supply at Clayton has been operated by DWLBC since 1996 but over the longer term is it sustainable.

## CLAYTON – WATER SUPPLY STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | SA Water (owner),<br>Alexandrina Council (Lessee) and<br>DWLBC (contract operator). | | |
| **WATER SOURCE** | River Murray from Lake Alexandrina | | |
| **TREATMENT** | • Aquifer storage & recovery with UV disinfection or<br>• chlorine disinfection of raw River Murray water | | |
| **DISTRIBUTION** | Reticulated to residents from an elevated tank. The existing system is a low pressure supply with a maximum operating pressure of 10m head within the system (SA Water 2003). | | |
| **RATING STRUCTURE** | Two part tariff - pay for use with a minimum charge of $139 for access. | | |
| **RETAIL PRICE PAID** | 0 – 125 kL | $0.43/kL | *Alexandrina Rating Policy 2005/06* |
| | >126kL | $1.03/kL | *Alexandrina Rating Policy 2005/06* |
| **AVE. WATER USE** | NA kL/service/year | | *Neville Styan (2006)* |
| | NA kL/house/year | | |
| **AVE. ANN. DEMAND** | 29 ML/year (for 2004/05) | | *Neville Styan (2006)* |
| **CONSUMPTION PATTERN** | High seasonal difference in demand is expected in tourist/coastal areas, ie. low annual consumption but high peak demands (SA Water 2003). | | |

### Operation & Maintenance Matters

While the ASR project to provide a potable water supply at Clayton has been successfully implemented within a challenging hydrogeological environment; will it be sustainable over the longer term. Recovered water must be composed of at least 98% of lake water to be of an acceptable salinity for drinking water supply (Gerges *et al.* 2002a). Consequently, preparation to meet summer demand of between 40-70ML requires a significant volume of 200-300ML to be injected into the aquifer. The complex aquifer management and specialist expertise required has compelled the DWLBC continue to operate the system on behalf of the Alexandrina Council.

Historically, the salinity of Lake Alexandrina recorded at Milang has been between 300 and 900EC; however, limited data for Clayton between September 2002 and July 2003 indicated the salinity was between 1000EC and 2100EC which is well above acceptable limits for potable water (SA Water 2003). It is feared that over the next 10 years the salinity of the lake will further increase due to diminished environmental flows in the Murray, which will in turn degrade the township water quality even further (Alexandrina Council 2005).

## Future Water Supply

Although water resources at Clayton are plentiful, the water quality in Lake Alexandrina can be poor due to toxic blooms and unpalatable due to high salinity (ie. 1500–2000 mg/L TDS). The council would like to divest responsibility for operation of the water supply to SA Water because the limited number of connections means that the income generated is unable to fund the major capital upgrades required (Neville Styan *pers. comm.* 2006). The Counil sought legal opinion as to the validity of the perpetual lease (Alexandrina Council 2005). While it may be possible to relinquish the lease, the council decided not to proceed with this due to SA Waters reluctance to assume responsibility for the operation and maintenance of the infrastructure.

In 2003, SA Water investigated three options for supplying the township of Clayton with potable water. Two pipeline options to connect Clayton to Summit Water Filtration Plant (WFP) and the third was the installation of a local desalination plant. The investigation recommended connection of Clayton to Summit WFP and supply by boosting into storage at Clayton from Bremer Tank because it has a lower NPV and lower total capital cost of $4.9M (SA Water 2003). However, this will bring forward an upgrade to the Summit water filtration plant and transmission system between Littlehampton and Strathalbyn. The total capital cost of constructing a desalination plant is comparable to the pipeline options; however, the annual operating costs are higher (SA Water 2003). The existing system is a low pressure supply with a maximum operating pressure of 10m head within the system. The asbestos cement pipes have burst under existing head conditions. In order to supply Clayton's future requirements this pressure would need to be increased by around 10m to provide a minimum pressure of 20m head in the system and therefore may increase the burst frequency (SA Water 2003).

In August 2005, representatives from the council and the community meet to discuss the future of the Clayton water supply scheme. Based on the information available and the price that customers are willing to pay it was agreed to maintain a safe but non-potable water supply to the community.

## Tariff Setting

Water undertakings are usually required to raise all of their operating costs and to service all or some of the debt associated with their capital expenditure through revenue received. The price of a water service depends very much on the price of the inputs, like energy cost and financing infrastructure investments. This can present difficulties for small towns as the system components require replacement or additional infrastructure is required to meet treat varying water quality.

Residents of Clayton are rated for their water supply and use by the Alexandrina Council. The revenue collected by the council is used to finance operation and maintenance of the system. Based on water use and financial information for 2004/05, the calculated required tariff for the Clayton water supply system was $1.43/kL. This is comparable to the $1.34/kL charged under the state-wide price for 253kL (average water use in Adelaide). The calculation results in a tariff set to cover the costs of providing the water supply without the application of an access charge.

The Council needs security especially if it is to make long term investments because if the service is underpriced they can make losses. The challenge for the community is to implement an equitable system of charges which commands broad acceptance among consumers and acts to guarantee the long term sustainability of the town water supply scheme. At the same time, it must not impose large administrative costs on an ongoing basis unless there are clear gains to efficiency of resource use.

## STORMWATER DRAINAGE

No underground stormwater infrastructure is required to serve the township. Streets in Clayton are relatively wide and more than half of the roads are sealed which increases the volume of stormwater runoff. Most of the stormwater runoff from the township is diverted in surface drains and collects in several low points with natural swales before being discharged into Lake Alexandrina.

## CLAYTON – STORMWATER DRAINAGE

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Alexandrina Council | | |
| **CATCHMENT AREA** | Total | Not available | |
| | Urban | 50 ha | |
| **ROAD DATA** | Total length | 9.7km | *Alexandrina Council. 2006* |
| | Average width | 7.0 – 7.5m | *Alexandrina Council. 2006* |
| | Kerbed | 5% | *Alexandrina Council. 2006* |
| | Sealed | 59% | *Alexandrina Council. 2006* |
| **RAINFALL TO PRODUCE RUNOFF** | No observations made | | |
| **AVE. STORMWATER RUNOFF** | 65 ML/year (estimated) | | *Based on Fleming's Monthly Runoff Coefficients* |
| **TYPE OF DRAIN** | Surface diversion by open channel drains and some kerbing | | *Alexandrina Council. 2006* |
| **LEVEL OF TREATMENT** | Nil | | |
| **NUMBER OF DISCHARGE POINTS** | Several points | | *Alexandrina Council. 2006* |
| **DISPOSAL** | • Lake Alexandrina | | |

## WASTEWATER SYSTEM

The township of Clayton does not have a reticulated wastewater system. Sewage is treated in septic tanks and is disposed of in soakage trenches. The council does not have plans to seek funding to install a septic tank effluent disposal system (STEDS) to properties in the short- or medium-term.

### CLAYTON – WASTEWATER SYSTEM STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Property owner | | |
| **WASTEWATER SYSTEM** | Individual septic tanks and disposal trench for each property | | |
| **CONSTRUCTED** | Varies | | |
| **EST. POPULATION SERVED** | Not applicable | | |
| **RATING STRUCTURE** | No routine inspection or cleaning septic tank carried out by Council. No service charge applied. | | *Alexandrina Council (2006)* |
| **ANNUAL SEWAGE INFLOW** | Not applicable | | |
| **LEVEL OF TREATMENT** | • Primary (in septic tank) | | |
| **QUALITY TESTING** | Inflow | Not applicable | |
| | Effluent | Not applicable | |
| **AVE. EFFLUENT AVAILABLE** | Not applicable | | |
| **EFFLUENT DISPOSAL** | • Soakage trench | | |

## NON-POTABLE WATER HARVESTING & REUSE

No specific water harvesting or reuse projects for Clayton have been identified or implemented in Clayton. Local government, schools, sporting clubs and other community groups may decide to fundraise to implement simple, practical ideas that make a real difference to achieving environmentally sustainable water resource management.

## WATER SENSITIVE LANDSCAPING PRACTICES

No specific water sensitive landscaping practices have been implemented for public plantings.

## REFERENCES AND OTHER READING

*Alexandrina Council*: special thanks to Messer's Dennis Zanker and Neville Styan who provided information on the water, wastewater and stormwater infrastructure at Clayton.

Engineering & Water Supply Department (1994) *"Clayton Water Supply: Provision of a Safe Water Supply during a Toxic Algal Bloom in Lake Alexandrina."* Report prepared by Engineering Services Group. Lib. Ref No. 94/5, March 1994.

Gerges,NZ; Howles,SR; Dennis,K; Dillon,PJ; Barry,KE (2002a): *"Town water supply purification using aquifer storage and recovery in a saline aquifer."* Proceedings of the 4th International Symposium on Artificial Recharge of Groundwater, ISAR-4, 22-26 September 2002, Adelaide, South Australia p.459-464.

SA Water (2003) "*Clayton Water Supply System: Development of Options*." Report prepared Infrastructure Division, October 2003.

Alexandrina Council (2005) "*The Future of the Clayton Water Scheme*." Information prepared for a meeting between representatives of Clayton Community and the Alexandrina Council held on 28/08/05.

# Coober Pedy, Far North (Climate Index 22)

## GENERAL STATISTICS

Coober Pedy is one of the more remote communities in South Australia and is located approximately 800 kilometres north-west of Adelaide on the Stuart Highway between Port Augusta and Alice Springs. After the discovery of opal in 1915, a small population of miners (approx 150) moved into the area (Hyatt 1993). To escape the extremes of heat and cold in the surrounding desert, many residents have chosen to live in underground homes known as dugouts. Over the years the mine fields have surrounded the town extending 35km north, 50km south and 15km west. Today, Coober Pedy is reliant on tourism (over 200,000 visitors per year) and the opal mining industry to provide the community with employment.

**Figure 115 Coober Pedy – Aerial view of the town (Rabone 2003)**

| **COOBER PEDY – GENERAL STATISTICS** | | | |
|---|---|---|---|
| CLIMATE INDEX | 19 | | |
| REGION | Far North | | |
| POPULATION | 2 170 (Base) | 135% (Ultimate) | *ABS (2001) CENSUS* |
| URBAN FORM | Inland community - mining | | |
| AVE. ANN. RAINFALL | 157 mm | | *Burrows (1987)* |
| AVE. ANN. EVAP. | 3 000mm | | *Burrows (1987)* |
| NUMBER OF DWELLINGS | 974 (Occupied) | | *ABS (2001) CENSUS* |
| PERSONS PER DWELLING | 2.2 | | |

## WATER SUPPLY

### Early Water Supplies (1915 – 1984)

Since its inception in 1915, Coober Pedy has had difficulties with water shortage because surface water resources are almost non existent in the area. The first bore drilled in the town area in 1920 had salinities up to 20,000 mg/L (McLaren et al. 1987). In 1925, the State Government constructed an open surface catchment scheme (Hyatt 1993). The central feature was a 2.5ML underground concrete tank which received runoff from a 50 hectare water reserve. The highly variable nature of the rainfall meant that severe water shortages occurred regularly. Water was then rationed at 110 litres per person per week Problems of inadequate quantities and heavy sedimentation of the tank resulted in the use of salty bore water as the major supply. In later years, several station bores provided brackish water but they were some distance away (up to 100 miles) and water cartage was a significant cost to residents (Stokes 1983).

Demand for a reliable water supply led the State Government to begin desalination of bore water from the Great Artesian Basin using solar stills in 1966 (McLaren et al. 1987). High salinity water from the aquifer below the town was used to feed the solar still (Hyatt 1993). Desalinated water was distributed to residents from the depot by private and commercial carting. Solar still desalination did not perform to expectations, the maximum weekly production of 80kL per week in summer and 23kL per week in winter, fell far short of the town's demand (Stokes 1983). Operating problems, ie. windstorm damage and high costs, lead to the abandonment of the solar still in favour of reverse osmosis.

The first reverse osmosis plant with a capacity of approximately 90 kilolitres per day was installed in 1969. Desalinated water was delivered to homes by tanker at a cost approximately 26 times the State-wide rate at the time (Hyatt 1993). Despite the high cost of water, the reserve osmosis plant was soon taxed to the limit resulting in occasional water restrictions. However, the water shortages were alleviated with the arrival of a private contractor in the late 1970s. The company found it financially attractive to install an almost identical reverse osmosis plant with a capacity of 140kL/day at Cobber Pedy. The contractor sold desalinated water wholesale to the water carters and large consumers at rates about 25% less than the Government (Hyatt 1993). This resulted in the private plant being highly utilised and the government plant running below capacity thereby increasing the unit cost of water and maintaining a high price. Overall, the cost of water was around $12.50/kL and considered very high compared to Australian standards (Hyatt 1993).

In 1978, the State Government commissioned consultants to examine the feasibility of providing a reticulated water supply. The study estimated the average per capita consumption of 40 litres per day in Coober Pedy compared to per capita consumption (excluding garden watering) of 120 to 135 litres per day in Adelaide. The favoured scheme proposed pumping moderate salinity water (4500 mg/L TDS) to the township from a new bore 24 km away. This water would be reticulated for non-potable uses while a small proportion would be desalinated to potable quality and sold at the depot as before. However, the dual supply scheme was not pursued as capital cost of the scheme was prohibitive.

In the early 1980s, the Coober Pedy Progress and Miners Association (CPPMA) engaged consultants to review the viability a reticulated potable water supply. The study found that is was possible to provide reticulated potable water to residents for a unit cost of half the existing price by upgrading the desalination plant and adopting lower than normal standards for a reticulated water supply (Stokes 1983). The CPPMA successfully sought funding from Federal Government Community Employment Programme to install a new reverse osmosis plant and reticulation system based on the findings of feasibility study. The water supply project was funded as follows Federal 50%, State government 25% and local council 25% (Hyatt 1993). Without the substantial government funding obtained, the community would not have been able to afford the $3.5 million reticulated water supply scheme. The reticulated water supply was constructed between May 1984 and June 1985.

## Potable Reticulated Water Supply (1985 - 2005)

Since 1985 the reticulated water supply has been under the care and control of the Coober Pedy Council with some outlying dugouts being supplied by tanker. The works included;

- installation of a bore tapping into brackish water (4500 mg/L TDS) in the Great Artesian basin,
- construction of a 24 km of pumping main to bring the raw water bore to town for treatment,
- installation of a 800 kL per day treatment plant (consisting of pre-treatment, desalination, balancing storage and disinfection),
- construction of 40km of reticulation mains within the township, and
- installation of water meters on all services.

**Raw Water Bore** **Reverse Osmosis Plant**

**Figure 116 Coober Pedy - Raw Water Bore and RO Plant (Hunt 1993)**

Problems were encountered during commissioning and during the first six months of the treatment plant operation. Layson (n.d.) found problems where associated with the pre-treatment section and the oxidation of the iron and manganese. The problems were overcome by modifying the inlet pipework ensure that all raw water from the bore was fed from the raw water tanks and not straight into the plant. A review of the performance of desalination plant found the plant to be functioning well (with raw water rich in iron and manganese) producing water with TDS of 330ppm with salt rejection of 97% and recovery of around 77% (Layson n.d.). Good pre-treatment is the key to successful desalination by reverse osmosis.

It is usual for household water use to increase once reticulated water is available, primarily due the improved access and convenience. The extent of increase in water demand was difficult to predict, but the cost of the water was expected to be a major control (Stokes 1983). The council engaged a consultant to report to the Council on the water situation and alternatives for development of desired grassed recreational grounds (Coober Pedy Times 1994b). The report found that the capacity of the existing water supply would not support recreational uses at places such as those shown in Figure 117 below). The original $3.5 million water supply scheme was an investment that must be protected, consequently, treated wastewater seemed to offer more potential for the development of recreational grounds (discussed in more detail below).

**School Grounds** **Football Oval**

**Figure 117 Coober Pedy - Future Grassed Recreational Areas (Rabone 1993)**

The annual demand for water in Coober Pedy has tripled since 1986 when the water supply was reticulated. The average annual water use per service (including commercial) was 135kL in 1986/87 and nearly 185kL in 2003/04. Over the same 18 year period, the number of services (active) has doubled to present total of 1,672. Operational data shows an explosive surge in water demand since 2000/01, when the pricing policy was altered (tariff and water price is discussed in more detail below). The reduced unit rate of water and the dramatic change in water consumption in combination resulted in the desalination plant being unable to meet the peak demands. It was obvious by February/March 2001 that the town water supply would not last another summer (Hoad 2002).

The council successfully sought funding of $230,000 (33%) from the State Government, to be matched dollar for dollar by the Department of Industry and Trade's Regional Development Infrastructure Fund (33%), with the remaining 34% funded by the council (Coober Pedy Times 2001). By October 2001, the paper reported that people are using more water than the council can produce. While unable to monitor what the water is being used for, on the four September days when there was rain in Coober Pedy the water usage dropped (Coober Pedy Times 2001). This would suggest that people are using water on gardens although there is no real proof of this around the town. The situation means that the town has to be careful with its water usage and accept that water may be cut off for a couple hours a day.

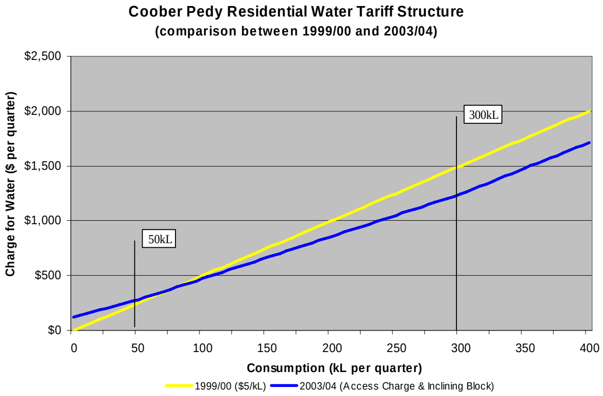
The water was so critical that the Council maintained a 24-hour watch on the storages and desalination plant to prevent the town from running out of water (Hoad 2002). In fact, there was only 10 hours water supply left in the storage tank when the first litre of water was processed by the new reverse osmosis plant

(Hoad 2002). The $700,000 upgrade to the water supply increased the capacity of the reverse osmosis plant from 800 to 1,400 kilolitres per day. On 10 December 2001, the Premier commissioned the new reverse osmosis plant, after which residents were invited to inspect the plant and enjoy refreshments (Coober Pedy Times 2001).

In July 2004, it was revealed that water valued at $250,000 dollars (ie equivalent to about 70ML of desalinated water) had been stolen from the Council (Coober Pedy News 2004). The council resolved to install meters in the feeder lines for an estimated cost of $50,000 to determine the point of illegal extraction and to prosecute any identified 'water thieves'.

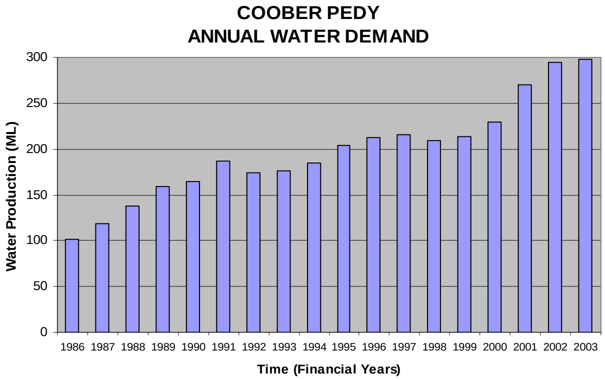
## COOBER PEDY – POTABLE WATER SUPPLY STATS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Coober Pedy Council | | |
| **WATER SOURCE** | Brackish groundwater bore, 25km from town. | | |
| **TREATMENT** | Desalination | | |
| **QUALITY TESTING** | Source | Quarterly | |
| | Product | Monthly | |
| **DISTRIBUTION** | Reticulated in township | | |
| **SERVICES** | 1,672 | | *In 2004* |
| **RETAIL PRICE PAID** | Access Charge | $125/.year | *Residential 2003/04* |
| Use | 0 – 50 kL | $3.10/kL | *Residential 2003/04* |
| | 51-300kL | $3.85/kL | *Residential 2003/04* |
| | > 300kL | $4.70/kL | *Residential 2003/04* |



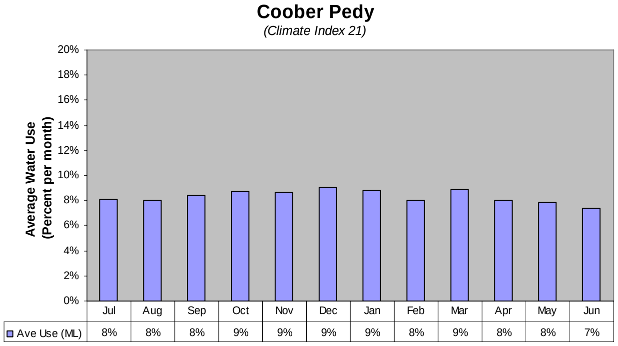
*Water tariff information courtesy of Coober Pedy Council (2005)*

| | | |
|---|---|---|
| **AVE. WATER USE** | 185 kL/service/year | *Calculated from data* |
| **AVE. ANN. DEMAND** | 300 ML/year | *Les Hoad (2001)* |



### CONSUMPTION PATTERN

The monthly demand is relatively constant at about 18 - 20 ML throughout the year; this is consistent with in-house water use and limited water gardening.



Although the substantial government funding was required for capital works, the water supply has been run on a full cost recovery basis for nearly 20 years with sufficient revenue to allow for maintenance and replacement costs. It is a success story and a credit to the people who operate it.

## Water Price & Water Demand

It is widely accepted that water use in households tends to increase once reticulated water is available, primarily due the improved access and convenience. The Coober Pedy Council does not receive a subsidy from the South Australian Government under the state-wide water pricing policy for the operation and maintenance of the town's water supply in the same way as SA Water. Consequently, the Coober Pedy reticulated water supply offers an opportunity to study the regulating affect of water price on water use not often presented in South Australia. This is possible because the Coober Pedy Council has collected and maintained a significant amount of operational and financial information.

Figure 118 sets out the historical annual demand trend for water in Coober Pedy for the 18 year period between July 1986 and June 2003. The number of services doubled over this period while the annual demand tripled. The demand for water surged after the introduction of a two-part tariff with an access charge and a lower presiding unit rate in 2000/01 can be clearly observed in Figure 118. The average annual water use per service (including commercial) was 135kL in 1986/87 and nearly 185kL in 2003/04.

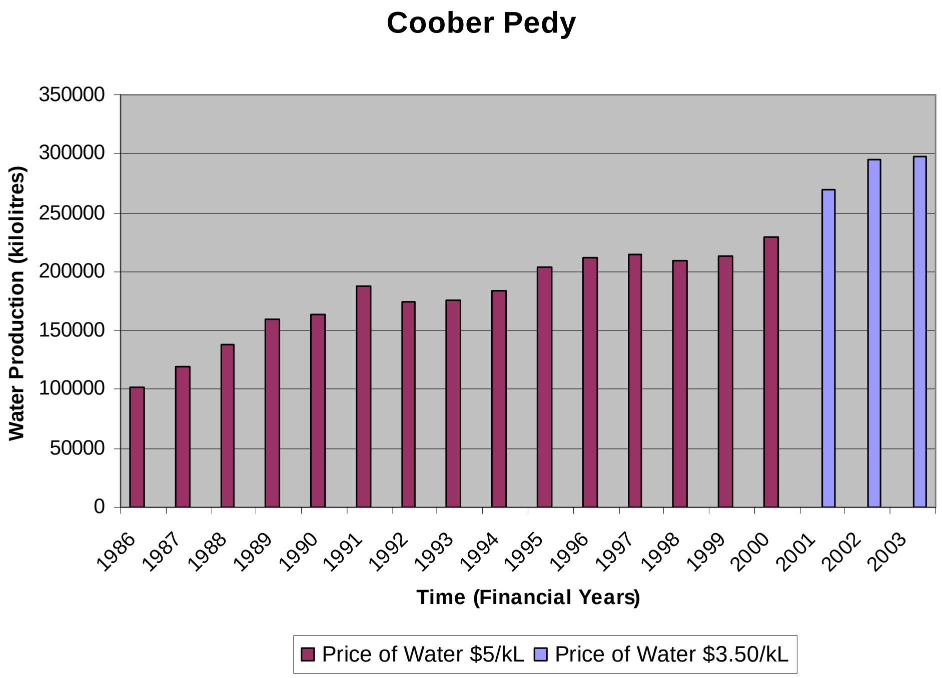


**Figure 118 Coober Pedy - Historical Annual Water Demand**

In 1986/87, the price of reticulated water was $4.85 per kilolitre on a pay for use basis (ie. no access or minimum charge) and increased to $5.00 per kilolitre in 1992/93. Outlying dugouts paid the same unit rate for carted water, plus a delivery fee. In 2000/01, the Council converted the water price structure to a two part tariff which consisted of an access charge and water use charges. This change is consistent with the 1994 COAG water reform principles. To discourage excessive water use, the variable water use component was subjected to a three block inclining tariff being; $3.00 per kilolitre for the first 50kL, $3.50 per kilolitre up to 300kL, and $4.10 per kilolitre above 300kL. The limit set for each tariff block appears generous given the average water consumption in South Australia is 350 per kilolitre per service (based on data for 1991/92 to 2002/03 from SA Water), which supports a high percentage of external water use. The internal water use component for South Australia is generally considered to be of the order of 175kL per household.

## Tariff Setting

Tariff calculation is comprehensive and includes the cost of electricity, salaries, water source fee, depreciation, debt servicing, and overheads (WSP 2002). A tariff calculation using the method recommended by the World Bank (WSP 2002) was carried out using historical financial information provided by the Coober Pedy Council for the years 1999/00 and 2003/04. The World Bank calculation results in a tariff set to cover the costs of providing water supply without the application of an access charge; this type of pricing structure existed in Coober Pedy in 1999/000. The results of the analysis are set out in Table 51 below.

**Table 51 Review of Potable Water Supply Tariff for Coober Pedy**

**COOBER PEDY - Water Tariff Calculation**

| | **2003/2004** | **1999/2000** |
|---|---|---|
| **System Information** | | |
| Number of Connections | 1,672 | 1,612 |
| Annual Water Production (kL) | 297,226 | 229,928 |
| **Annual Cost (1)** | | |
| • Electricity | $ 143,714.00 | $ 72,633.00 |
| • Water source fee (2) | $ 160,000.00 | $ 106,398.00 |
| • Maintenance - RO Plant | $ 68,854.00 | $ 43,906.00 |
| • Maintenance - Network | $ 61,359.00 | $ 46,523.00 |
| • Depreciation | $ 256,000.00 (3) | $ 246,520.00 |
| • Chemicals | $ 65,890.00 | $ 26,291.00 |
| • Loan Repayment Amount | $ - | $ - |
| • Interest | $ - | $ - |
| • Salaries | INC. OVERHEADS | $ 164,520.00 |
| **Overheads** | | |
| • Office, Training | $ 320,000.00 | $ 318,460.00 |
| • WQ Monitoring & Testing | $ 7,856.00 | $ 3,562.00 |
| **Total Annual Operating Cost** | **$ 1,083,673.00** | **$ 1,028,813.00** |
| **Water Tariff Required (4)** | **$ 3.65 per kL** | **$ 4.47 per kL** |
| Actual Tariff Levied ($/kL) (5) | $ 3.50 per kL (5) | $ 5.00 per kL |

(1) *Operation and financial information courtesy of Les Hoad and Damien Clark, Coober Pedy Council (2004) respectively.*
(2) *The source water fee is the annual cost for operation of the bore and pipeline to bring the raw water 24km to the desalination plant in Coober Pedy.*
(3) *The depreciation value for the 2003/04 includes the reverse osmosis plant capacity increase (ie. 1,400kL/day) commissioned in December 2001.*
(4) *The tariff calculation is based on World Bank example presented in WSP (2002) which assumes no wastewater access fee is applied.*
(5) *The water pricing structure was modified from a 'pay for use' in 2000/01 into a 'two part tariff' with an access fee and a use component.*

The unit cost of producing the water may drop if production is increased however as the reticulation system ages the operation and maintenance costs can be expected to increase. The cost of running the water treatment plant and reticulated water supply system in Coober Pedy has been met from user collections for nearly 20 years. Naturally, the increased water consumption has produced increased effluent.

## STORMWATER DRAINAGE

Some streets are paved but only parts have kerbing, however, the reasonable slope allows stormwater runoff from the elevated areas drains into low lying areas. Some small-scale water harvesting schemes have been developed with trees in depressions receiving runoff (ie. locations where water ponds after rains). Since 1986, around 3,000 native trees have been planted in natural depressions around Coober Pedy. The trees were drip irrigated with potable water until they were established. Diversion of stormwater runoff to depressions planted with native trees should be further considered when extending sealed roads or adding kerbs in the future.

## WASTEWATER SYSTEM

In addition to the water supply, the Coober Pedy Council also operates and maintains the wastewater treatment plant and sewerage system which serves the central business centre and tourist facilities. The wastewater project was proposed by the Council in response to the frequently reported objectionable odours in the Main Street area by the late 1980s. In August 1990, engineering consultants were engaged to review the situation. Moderate size commercial establishments, particularly those providing accommodation to tourists, were generating too much effluent for onsite disposal by means of deep soakage shafts. The soakage shafts serving these premises were backing up with sewage, producing gas and odours, and required new larger shafts to be drilled (Stokes 1990). Outside the business centre, toilet and sullage wastes are generally disposed of in onsite down deep shafts and often extracted from the shafts to irrigate a small amount of vegetation on the allotment.

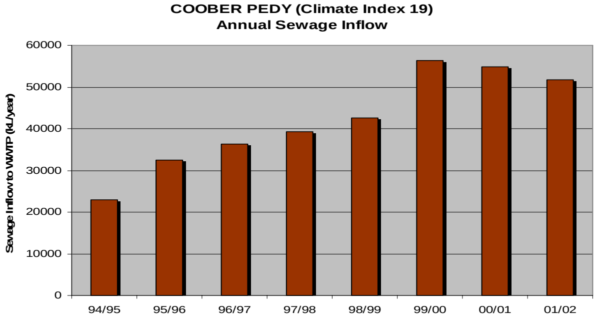
The consultant’s report also confirmed that the cost of STEDS is significantly less than the cost of full wastewater scheme, where septic tanks are already installed on allotments (Stokes 1990). However, in the case of Coober Pedy the cost difference is not likely to be a significant factor in the decision for two reasons. Firstly, the installation of a large number of septic tanks, many of considerable size to accommodate flows from commercial and tourist facilities is required (Stokes 1990). Secondly, a wastewater scheme could be installed, without a pumping station, owing to the slope down Main Street leading to the suitable site at the northern end of town (Stokes 1990). A comprehensive wastewater system with appropriate treatment and disinfection would provide effluent suitable for development grassed recreation facilities.

Two projects proposed for Coober Pedy by the State Government in 1992 presented the council with an opportunity to seek support for the installation of a comprehensive wastewater scheme. The projects were a new TAFE with a capacity for up to 100 students, and a new recreational complex comprising a gymnasium and a swimming pool at the school. Each facility was to be provided with mini sewage treatment works with the intention of using the treated effluent to irrigate the part of the school oval (probably about a sixth of the oval). In addition to the limited quantity of effluent available, the mini treatment works were expected to have a high capital cost and ongoing requirements for specialist operation. If funds allocated to the two mini treatment plants could be diverted towards the comprehensive wastewater scheme then potentially there would be enough reclaimed water to irrigate the whole oval. The council successfully sought for the redirection of the funding for the two projects and with financial assistance from the State Government STEDS Subsidy Fund and the wastewater treatment plant and network was constructed in 1994.

The system began receiving wastewater from the Desert Cave on 18th February and from the Opal Inn on 26th February (Coober Pedy Times 1994b). Other landholders required to connect to the scheme received notice from the council, outlining costs and connection date, with all connections completed by end of September 1994. The Council sought training for operators in Adelaide. Up to this time the treatment plant equipment has performed well (Les Hoad *pers. comm*. 2004)

## COOBER PEDY – WASTEWATER SYSTEM STATISTICS

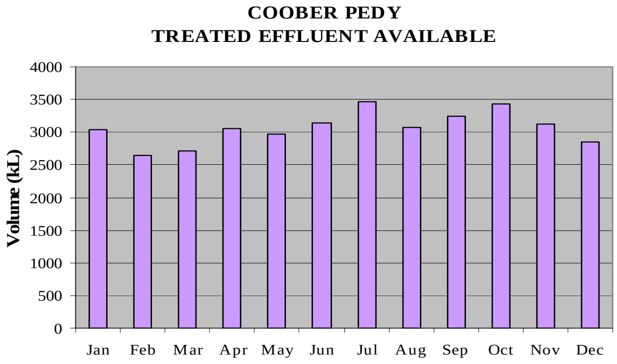
| | | |
|---|---|---|
| **ADMINISTRATION** | Coober Pedy Council | |
| **WASTEWATER SYSTEM** | Full wastewater system serving central business and tourist area. | |
| **CONSTRUCTED** | 1994 | *Local Government Association (2000)* |
| **EST. POPULATION SERVED** | 2,000 EP Tourist Impact | *Local Government Association (2000)* |
| **CONNECTIONS** | 85<br>(includes estimated extra 30 connected to the Umoona Aboriginal Community system) | *Les Hoad pers. comm.. 2006* |
| **RATING STRUCTURE** | Annual Fee | |
| **ANNUAL SEWAGE INFLOW** | Approx. 50 ML/year | *Average calculated from 97/98 to 02/03 data* |



*Operational data courtesy Les Hoad (Coober Pedy Council)*
*Reticulated water supply commissioned in 1985.*
*Sewerage system commissioned in 1994 to replace effluent disposal by deep shaft*

| | | |
|---|---|---|
| **LEVEL OF TREATMENT** | • Secondary Treatment<br>• Disinfection | |
| **QUALITY TESTING** | Inflow | Quarterly |
| | Effluent | Monthly |

|  |  |  |
|---|---|---|
| **AVE. EFFLUENT AVAILABLE** | 42 ML/year | *Average calculated from 98/99-03/04 data* |



**EFFLUENT DISPOSAL**

- Reuse Irrigation System
- Evaporation

## NON-POTABLE WATER HARVESTING & REUSE

Coober Pedy residents identified a grassed oval as their most important priority in order to give the young people a recreational outlet (Hemming 1997). The Coober Pedy wastewater reuse scheme has been operational since 1995 following the commissioning of the 250kL per day wastewater treatment plant. The plant receives wastewater from the main business area (shops, restaurants, hotels, public offices, school etc). The Council ensures that oil and grease traps installed at restaurants and shops are regularly maintained. The original objective of the wastewater reuse project was to return treated and disinfected effluent to the school grounds and create a recreational asset for the community.

The non-potable water supply system comprised of 136kL effluent balancing tank at the treatment works, pumping station adjacent to this tank with two pumps, 2.5km of 80mm diameter rising main laid in a common trench with the sewer to the school and 22kL tank with level controls at the school. Treated effluent for reuse is pumped from the wastewater treatment plant to the irrigation tank at the school (see Figure 119). Any emergency wastewater overflows or reclaimed water surplus to requirements is pumped to an evaporation basin at the plant.

**Wastewater Treatment Plant** **School Oval**

**Figure 119 Coober Pedy – WWTP & School Development (Rabone 1993)**

In 1994, the school embarked on a project to install subsurface irrigation immediately below the grassed surface of the oval. This arrangement eliminates possible exposure risks for children associated with reuse of wastewater through inhalation of aerosols, contact with spray residues or surface runoff. There is no contract of the treated effluent with the atmosphere or the grass other than at root level. The non-potable water supply also incorporates a chlorination unit which helps to prevent any algae or bacteriological build up in the reuse pumping and distribution system. The non-potable water reuse system was extended to irrigate the hospital grounds, Umoona Aboriginal Community (UAC) and the town oval after estsablishing the quantities of water available.

| Location | Year | Irrigation Method | Volume |
|---|---|---|---|
| School Oval | June 1995 | 0.6ha turf by sub-surface dripper systems | 7ML/yr |
| Treatment works | June 1995 | Trees and shrubs by above ground drippers | when available |
| Hospital Grounds | Nov 1995 (ceased 2002) | Trees and shrubs by above ground drippers | 0.5ML/yr |
| Umoona Aboriginal Community | Sept 2000 | Trees and shrubs by below ground drippers | 1ML/yr |
| Town Oval | Nov 2000 | 2ha turf by subsurface dripper system, a mix of treated effluent and high salinity (TDS 4200mg/L) bore water. | 22ML/yr |

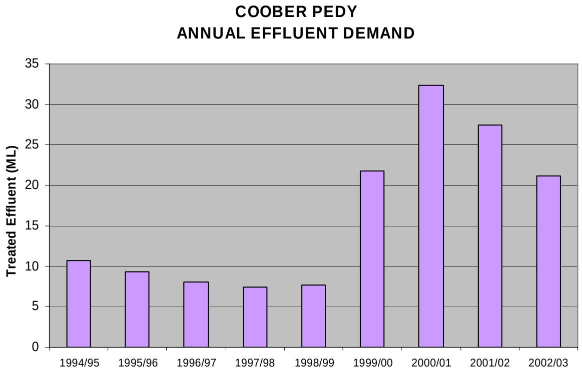
The UAC commissioned a private sewerage collection system, which serves a population of around 200, before discharging into the council wastewater system. A percentage of the flow from Umoona is returned as treated effluent for irrigation. The Town Oval development involved laying 700m of drainage pipes, 48,000m of subsurface irrigation and planting the entire oval with runners of saltwater couch imported from Alice Spring (Hemming 1997).

**School Oval** **Town Oval**

**Figure 120 Coober Pedy – School & Town Oval Development (Rabone 2000)**

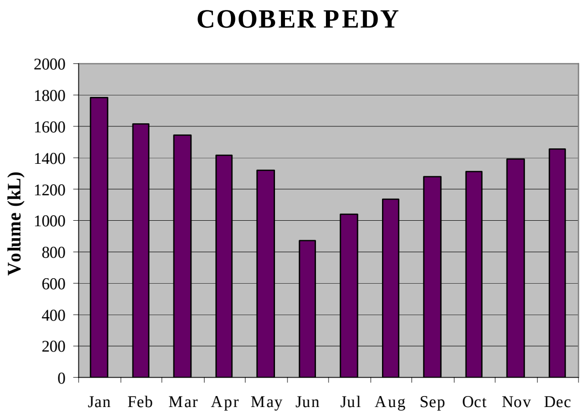
# COOBER PEDY – NON-POTABLE WATER SUPPLY

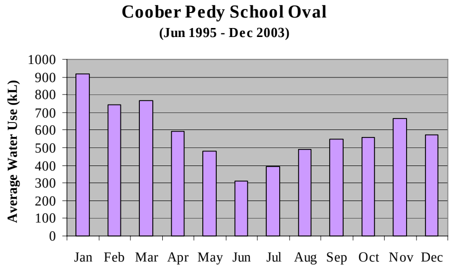
| | | |
|---|---|---|
| **ADMINISTRATION** | Coober Pedy Council | |
| **WATER SOURCE** | Treated Effluent (Class C) | |
| **DISTRIBUTION** | Piped to customers (limited) | |
| **COMMISSIONED** | 1995 | |
| **SERVICES** | 4 | |
| **QUALITY TESTING** | Monthly | |
| **RATING STRUCTURE** | Pay for use | |
| **RETAIL PRICE PAID** | $1.50 /kL | *Coober Pedy Council* |
| **AVERAGE USE** | 25 ML/year | *Average calculated from 99/00-02/03 data* |
| **LEVEL OF REUSE** | 100% | |

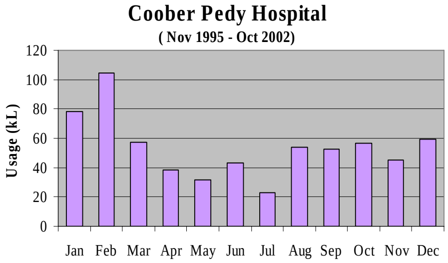


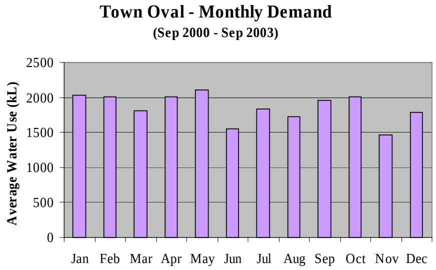
Note: Town oval was developed in during the 2000/01 financial year.

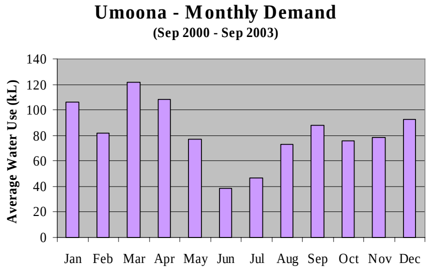
| | |
|---|---|
| **CONSUMPTION PATTERN** | The monthly demand varies depending on the customers needs. |



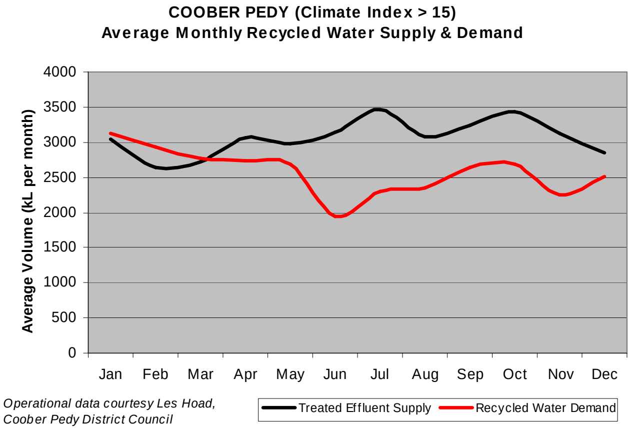








**SUPPLY & DEMAND MATCH** Generally, the average monthly demand can be met.



*Operational data courtesy Les Hoad,*
*Coober Pedy District Council*

Reuse of the treated effluent for commercial enterprises could not originally considered as the quantities required to irrigate the two ovals was known well enough. Hemming (1997) reported that sufficient effluent is not available to keep the grass in summer and will cost the council 10% of its revenue. However, based on the average supply-demand match (especially without the Hospital) determined from operational information it appears there is an opportunity for the Council to sell some of the treated effluent water to other users. Commercial enterprises and interested residents could collect it from a metered standpipe at the wastewater treatment plant. This would require a new tank for '*effluent to waste*' that would normally overflow into the lagoons for disposal by evaporation. The tariff calculation recommended by the World Bank (WSP 2002) for the non-potable water reuse scheme in Coober Pedy is set out in Table 52. The cost of making the treated effluent available at the standpipe is around $2.20/kL.

## Table 52 Review of Non-Potable Water Tariff at Coober Pedy

**COOBER PEDY - Water Reuse Tariff Calculation**

| **System Information** | | **2003/2004** |
|---|---|---|
| Number of Sewer Connections | | NA |
| Wastewater Treated (kL/year) | | 54,300 (1) |
| Annual Water Sales (kL) | | 43,560 (2) |
| **Annual Cost (3)** | | |
| • Electricity | $ | 24,941.00 |
| • Water source fee | | NA |
| • Maintenance - WWTP | $ | 32,427.00 |
| • Maintenance - Network | $ | 22,003.00 |
| • Depreciation | $ | 14,616.00 |
| • Chemicals | | INC. IN WWTP |
| • Loan Repayment Amount | $ | - |
| • Interest | $ | 2,234.00 |
| • Salaries | | INC. IN OVERHEADS |
| **Overheads** | | |
| • Office, Training | $ | 21,560.00 |
| • WQ Monitoring & Testing | $ | 1,034.00 |
| **Total Annual Operating Cost** | **$** | **118,815.00** |
| **Wastewater Tariff Required (4)** | **$** | **2.19 per kL** |
| **Actual Reuse Tariff Levied** | **$** | **1.50 per kL** |

*(1) Estimated from three years of recorded inflow.*
*(2) Total volume of water recorded through the water reuse meters.*
*(3) Operation costs available courtesy of Les Hoad and Damian, Coober Pedy Council (2004)*
*(4) The World Bank (2002) tariff calculation assumes no wastewater access fee is applied.*

## WATER SENSITIVE LANDSCAPING PRACTICES

The harsh environment has never made for easy living. Lack of water has always a problem and it often had to be recycled before being discarded. Coober Pedy residents are aware of the value and scarcity of water. Plantings have been random, small scale and mainly undertaken by interested individuals. With the exception of the grassed school and town ovals, courtesy of the availability of treated effluent from the town centre, public landscaping is limited.

### Local Water Harvesting

The Coober Pedy Hospital is an excellent example of water harvesting where attractive native gardens were established in about 1983 using rainwater tank overflow and stormwater runoff from the car park and site (see Figure 121).

**Figure 121 Coober Pedy - Water Harvesting at the Hospital (Rabone 1993)**

Rainwater collected from roofs (where these exist!) is used by individuals. Most above-ground houses have rainwater tanks, and some dugouts have downpipes to tanks from verandahs and outbuildings. However, because of the low and erratic rainfall, rainwater collection can not be expected to supply more than supplementary water for the average family (McLaren *et al.* 1987).

### Private Reuse of Sullage (Pre 1994)

Sullage generated on residential allotments (ie. a result of local conditions and high cost of water) has long been used untreated to irrigate a small amount of vegetation from the deep shafts. An example is the garden established by Rosie Sutherland using septic tank effluent that is carted from the Desert Cave which until 1994 (ie. the sewage system was commissioned) was reliant on a septic tank system is unable to cope with the flows.

**1991** **1993**

**Figure 122 Coober Pedy - Rosie Sutherland's Garden (Sutherland 1993)**

Another example is the private planting of around 100 trees and 50 shrubs established by Sid & Del Harris in 1989 (see Figure 123). The main reason cited for establishing the trees was to provide shade, attract a variety of bird life and shelter against the wind and dust.

**Shelterbelt of trees** **Vegetable patch under shadecloth**

**Figure 123 Coober Pedy - Sid & Del's Garden (Rabone 1993)**

Sid admitted they would not have attempted to establish the garden without access to the sullage from the Desert Cave (his place of employment). In 1993, there was concern that they would be prevented access to the sullage once the treated effluent is diverted to the school oval. The owners of these gardens hoped that residents would be allowed to purchase excess treated effluent from the council and expressed a willingness to collect and cart treated effluent from the wastewater treatment plant for maintaining their gardens as they have for the last five years. However, these gardens did not survive when access to the sullage effluent ceased when the reuse water supply system came on line.

## REFERNCES AND OTHER READING

The information presented here would not have been possible except for the good records maintained by the water and wastewater operations staff and their kindness in sharing the raw data with me over the years. Special thanks to Les Hoad who answered many enquiries over several years.

Engineering & Water Supply (1978): *Alternatives for Upgrading Coober Pedy Water Supply*. Report prepared by Kinnaird Hill deRohan and Young Consulting Engineers, Adelaide, August 1978.

Stokes,R (1983): *Feasibility Study for the Upgrading of the Coober Pedy Water Supply*. Report prepared for the Coober Pedy Progress and Miners Association, December 1983.

Layson (n.d.): *Reverse Osmosis Applied to a Potable Water Supply – Coober Pedy*. Report by NEI John Thompson Australia

District Council of Coober Pedy (1992): *Proposed Sewearge Scheme for Coober Pedy*. Paper for Council Meeting 22 July 1992.

Hyatt, N (1993): Coober Pedy Water Supply. Paper for AWWA Seminar on *Drinking Water Quality: Technical & Management Issues for the 1990s*, Adelaide 12 October 1993.

Hemming,A (1997): Trials, tribulations and triumphs of a remote Council. *Local Government FOCUS,* May 1997. [Online] Available: http://www.loc-govfocus.aus.net/1997/may/trials.htm. Accessed 06/06/00.

*Coober Pedy Times* (1994a): Our water supply. Article by Carrie Adams appeared on 12 October 1994. 16.

*Coober Pedy Times* (1994b): Sewerage system now on line. Article appeared on 6 April 1994. 1&3

*Coober Pedy Times* (2001): Commissioning of the new water plant. Article appeared 20 December 2001, 1.

*Coober Pedy Times* (2001): Coober Pedy running out of water. Article appeared 25/10/2001 in the SA Regional Newspaper; 1.

Hoad,M (2002): Water to the max. Article appeared 17/01/2002 in *Coober Pedy Times*, SA Regional Newspaper; 3.

*Coober Pedy News* (2004) No. 61, 23 July 2004

# Hawker, Mid North (Climate Index 9)

## GENERAL STATISTICS

Hawker is a small outback town located in the Flinders Ranges about 400km north of Adelaide (see location marked in red below). Throughout the 1880s, the town was the hub for the wheat farming in the area; however, the success of wheat farming was always on a knife edge due to lack of reliable rainfall. Hawker was also an important town on the Ghan railway line to Alice Springs until 1956 when the line upgrade moved the route further west. The most important industries in the area are tourism and pastoral runs of sheep to grow wool and increasingly beef cattle. Due to the arid environment, stocking rates are low at one sheep per 3 or 4 hectares. Today, tourism is playing a more important role in the local economy and Hawker is a stopover and base for tourists to the central Flinders Ranges.

**Typical House & Streetscape (Rabone 1994)**

**Location of Hawker**
*(http://en.wikipedia.org/wiki/Hawker)*

Like the strong, uncompromising landscape, residents in arid areas are more attuned to the principles and need for water conservation (McLaren *et. al*. 1987). Residents of Hawker have adapted their lifestyle to suit the environment; most homes feature a large rainwater tank and either no lawn or only a small one.

## HAWKER – GENERAL STATISTICS

| | | | |
|---|---|---|---|
| **CLIMATE INDEX** | 9 | | |
| **REGION** | Mid North – Flinders Ranges | | |
| **POPULATION** | 287 (Base) | 126% (Ultimate) | *ABS (2001) CENSUS* |
| **URBAN FORM** | Inland rural community | | |
| **AVE. ANN. RAINFALL** | 306mm | | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 2 715mm | | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 141 (Occupied) | | *ABS (2001) CENSUS* |
| **PERSONS PER DWELLING** | 2.0 | | |

## WATER SUPPLY

### Early Water Supplies (1880s - 1963)

Government agencies provided water services for smaller more isolated groups but these efforts where not always successful. In 1881, plans for the construction of an open water storage and stepped weir spillway to the south-east of the town were drawn up. The *Public Works Report* 1885-86 recorded that these works were successfully completed in 1885, the new reservoir was filled with water (carted by rail) and the interest on the cost was to be guaranteed by leading residents in the township. However, the water supply was poor, being turbid, of high salinity, and unreliable frequently requiring water to be carted by rail at drought rates (Hammerton 1986). Difficulties with the water supply upset guarantors at Hawker and they refused to sign the lease or pay the interest costs. The government was compelled to take over the water supply system and rate the town to recover costs. In 1900, a second larger dam was excavated south of the first dam which improved the supply to the town.

The two dams were eventually abandoned because of unreliable yields and poor water quality (SA Water 1998). The extensive array of contour drains, storage dams, weirs and pumping systems that formed part of the previous Hawker water supply are no longer operational (van der Wel & McIntosh 1998).

### Potable Reticulated Water Supply (1964 – 2005)

Hawker is still one of the many towns in South Australia with an independent water system reliant on locally available water resources. Water was supplied to the township through two bores drilled to 110m and 93m in 1963 and 1972 respectively. The town water supply is drawn from the reliable groundwater resources of marginal quality in the vicinity. Although plentiful, the groundwater is unpalatable due to high salinity (ie. 1500–2000 mg/L TDS) and high mineral content. The minerals have resulted in common and unsightly occurrences of calcium deposits on taps, fittings, and basins for example. A majority of residents have established private rainwater systems as an alternative for drinking and in-house uses as this source of water is low in salinity; however, this source of water is not disinfected before use.

Since 2000, groundwater for the reticulated water supply has been treated to remove iron and disinfected with chlorination prior to distribution, but the salinity level continues to render it unpalatable and suitable for only watering salt tolerant plants. It is widely accepted that saline water causes corrosion of water pipes which can increase the maintenance cost and reduce the useful operating life of private and public infrastructure. A reverse osmosis desalination plant is being considered for Hawker (SA Water 1998; Geoff Kilmore *pers. comm*. 2005).

## HAWKER – WATER SUPPLY STATISTICS

**ADMINISTRATION** SA Water

**WATER SOURCE** Local groundwater from two bores located about 4km out of town. Bore No. 1 is 90m deep and supplies the majority of the flow and Bore No. 2 is 80m deep and contributes about 1/3 of the supply (SA Water 1998). The groundwater has a high salinity and mineral content.

**TREATMENT** Iron Removal (since 2000) by
oxidation (chlorine) & filtration
Disinfection

**DISTRIBUTION** Reticulated to residents from an elevated tank. Water pressure within the town was noticeably below standard and calcium deposits that reduce the diameter of the pipes in the reticulation system, parts of which are approaching 100 years and nearing the end of their life.

**RATING STRUCTURE** Statewide pricing policy administered by the State government - pay for use with a minimum charge. .

**RETAIL PRICE PAID**

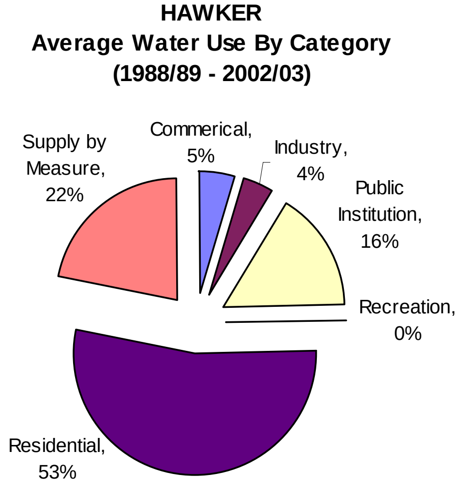
| | | |
|---|---|---|
| 0 – 125 kL | $0.46/kL | *Residential 2005/06* |
| >126kL | $1.06/kL | *Residential 2005/06* |

**AVE. WATER USE**

262 kL/service/year
228 kL/house/year

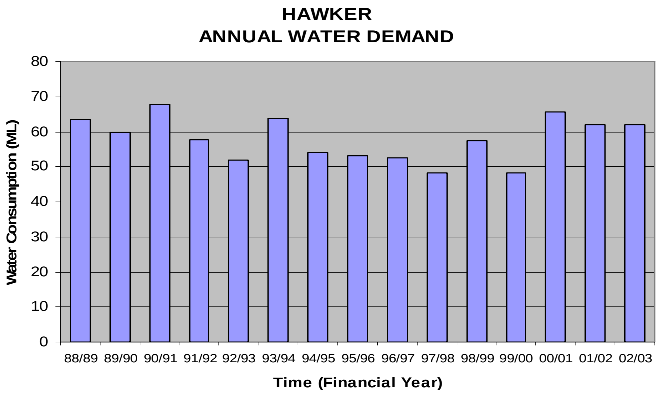
*Average 88/89 -02/03 Water Consumption Statistics*

Nearly half of the water used in Hawker is for non-residential purposes and no reticulated water is used for community recreation facilities.



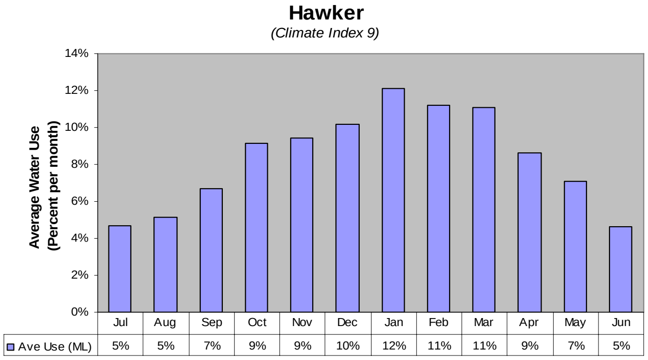
**AVE. ANN. DEMAND** 58.5 ML/year

*Water Consumption Statistics SA Water (1989-2003)*



*SA Water (1989 - 2003) Water Consumption Statistics - Table 10 Independent Schemes Northern Region*

**CONSUMPTION PATTERN** Despite the salinity levels in the town water supply a seasonal water usage pattern is observed from looking at the water consumption information collected by SA Water. van der Wel & McIntosh (1998) found a general decrease in water consumption with increasing rainfall and concluded some use of reticulated water on the garden.



*Source: SA Water (1989 - 2003) Water Consumption Statistics - Table 10 Independent Schemes Northern Region*

## STORMWATER DRAINAGE

No underground stormwater infrastructure is required to serve the township. Streets in Hawker are relatively wide (ie. 20 to 30m) and sealed between kerbs. Most of the stormwater runoff from the township is diverted in surface drains and collects in a low point in the northwest corner of the town. Figure 124 shows the point where stormwater runoff crosses the street in a large spoon drain near the hotel leaving the township and discharges into a small settling basin (ie. gross pollutant trap). The stormwater settling basin is successful in removing turbidity (ie. water leaving the stormwater basin is clear) prior to storage in the community stormwater dam.

**Stormwater Drainage Discharge** **Stormwater Settling Basin**

**Figure 124 Hawker – Stormwater Discharge & Stilling Basin (Rabone 1996)**

During intense rainfall events, instances of localised flooding of the hotel basement have occurred, primarily when flow through the settling basin and into the dam is impeded. The Council manages this risk through routine reed and debris removal from the settling basin every 3 or 4 years.

## HAWKER – STORMWATER DRAINAGE

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Flinders Ranges Council | | |
| **CATCHMENT AREA** | Total | 100 ha | *Van der Wel & McIntosh (1998) Figure 5.5* |
| | Urban | 30 ha | |
| **ROAD DATA** | Total length | 4.7km | *Mr Terry Barnes pers. comm. Jan 2001* |
| | Average width | 20 – 30m | |
| | Kerbed | 99% | |
| | Sealed | 98% (ie. 10 ha) | |
| **RAINFALL TO PRODUCE RUNOFF** | 10-15mm (from bitumen roads) | | *Mr David Smith pers. comm. 2005.* |
| **AVE. STORMWATER RUNOFF** | 55 ML/year (estimated) | | *Based on Fleming's Monthly Runoff Coefficients* |
| **TYPE OF DRAIN** | Surface diversion by kerbing and open spoon drains | | |
| **LEVEL OF TREATMENT** | Primary (Sedimentation) | | |
| **NUMBER OF DISCHARGE POINTS** | Two | | |
| **DISPOSAL** | • Old Railway Dam for Reuse | | |

## WASTEWATER SYSTEM

The council operates and maintains the septic tank effluent disposal system (STEDS) to all properties in Hawker. It was constructed in 1982, with financial assistance from the State Government STED subsidy scheme, when it was common practice to provide secondary treatment of the effluent in a lagoon and disposal by evaporation. The effluent lagoons are located in the parklands about 700m west of the north-west corner of the town.

## HAWKER – WASTEWATER SYSTEM STATISTICS

| | | |
|---|---|---|
| **ADMINISTRATION** | Flinders Ranges Council | |
| **WASTEWATER SYSTEM** | STEDS<br>(established with a subsidy grant) | |
| **CONSTRUCTED** | 1982 | |
| **EST. POPULATION SERVED** | 300 EP (not licensed) | |
| **CONNECTIONS** | 154 | |
| **RATING STRUCTURE** | Service Charge<br>$60pa for occupied properties<br>$40pa for vacant land | *Flinders Ranges Council Rating Policy (2003)* |
| **ANNUAL SEWAGE INFLOW** | Not recorded | *Mr David Smith pers. comm. 2005.* |
| **LEVEL OF TREATMENT** | • Secondary (Lagoon) | |
| **QUALITY TESTING** | Inflow Not required<br>Effluent Not required | |
| **AVE. EFFLUENT AVAILABLE** | Not recorded | *Mr David Smith pers. comm. 2005.* |
| **EFFLUENT DISPOSAL** | • Evaporation | |

The caravan park is adjacent to these lagoons and the owner expressed an interest in the effluent for use in a drip irrigation system. However, the treated effluent is not used as the salinity levels (ie. between 2,500-5,000mg/L) can only be tolerated by the hardiest grasses (van der Wel & McIntosh 1998). The elevated salinity of the effluent is a combination of the high salinity in the reticulated water supply and concentration by evaporation from the common effluent lagoons. Salinity, particularly sodium, affects soil structure; therefore, use of high salinity effluent requires careful management. The salinity could be reduced by the blending treated effluent with stormwater, which also increases the quantity of non-potable water available.

## Operation & Maintenance Matters

The high salinity level in Hawker's reticulated water supply also has a detrimental effect on the structural integrity of concrete components in the septic tank effluent drainage system (STEDS). Concrete corrosion has lead to spalling of concrete manholes and failure of septic tanks in the collection system, increased maintenance costs and reduced useful operating life of these components. The failure of septic tanks could result in potential environmental and health problems in the community. To minimise the risk, septic tanks are regularly inspected and cleaned by the Council as follows; once every three years for each household and annually for the commercial properties. If the condition of the septic is found to be poor the Council's places an order on the property owner to replace the septic tank.

One method of protection concrete components is by installation of a protective lining or coating; nevertheless, experience shows coatings often delaminate over time. In 1994, the Council commenced a trial to line a number of concrete manholes with fibreglass to investigate if such an approach will alleviate some of the problems and reduce ongoing maintenance costs (Terry Barnes *pers. comm.* 1993). Progressively, at a rate of 4 or 5 per year all the manholes in the Hawker septic tank collection system were lined with fibreglass. Mr David Smith (*pers. comm*. 2005) confirmed that while the lining itself appears to be holding up well, the concrete wall behind the lining is continues to fret and decay.

## Tariff Setting

Since 1972, the provision of STEDS has been a partnership between the State Government and Local Government. The level of assistance (subsidy) is dependent on the estimated cost of construction and operation and rate revenue from serviced allotments. The subsidy means the tariff charged by Councils is lower or equivalent to SA Water's sewerage charges. However, operation and maintenance, upgrading of the reticulation systems and treatment plants (for effluent reuse) must be financed by Councils from revenue raised by service fees (Neil Palmer *et al*. 1999; Lightbody & Endley 2002). This prerequisite may present difficulties for small towns like Hawker as the components approach the end of their expected life and replacement of the existing scheme is required. The challenge for the community is to undertake tariff reform which will guarantee the long term sustainability and cost effectiveness of the STEDS in Hawker.

## NON-POTABLE WATER HARVESTING & REUSE

On the northwest corner of town, a dam collects stormwater runoff from the streets and some rural catchment (see Figure 125 below). This dam was originally constructed in the 1890s, along with an elevated tank, to provide for the water needs of steam trains but was later abandoned and lay idle for many years. In the late 1970s, Mr Bernie Matthews, a resident of Hawker, initiated a community project to return the abandoned railway dam infrastructure to service. In conjunction with the Council, Mr Matthews arranged for the dam to be cleaned and enlarged to maximise the storage capacity of stormwater, a source of low salinity water suitable for garden watering, collected from the roads. The reliability of the supply is dominated by drought (van der Wel & McIntosh 1998).

## HAWKER – NON-POTABLE WATER SUPPLY

| | | |
|---|---|---|
| **ADMINISTRATION** | Flinders Ranges Council | |
| **WATER SOURCE** | Urban stormwater | |
| **DISTRIBUTION** | Private carting | |
| **COMMISSIONED** | 1970s (old dam rehabilitated) | *Mr David Smith pers. comm. 2005.* |
| **SERVICES** | Single standpipe;<br>20 residents use regularly and 15 others more occasionally. | *Mr David Smith pers. comm. 2005.* |
| **QUALITY TESTING** | Nil | *Mr David Smith pers. comm. 2005.* |
| **RATING STRUCTURE** | Voluntary service fee of $50pa: unlimited consumption until dam runs dry | |
| **RETAIL PRICE PAID** | $/kL depends on quantity used. | |
| **AVERAGE USE** | Not recorded | |
| **LEVEL OF REUSE** | NA | |
| **CONSUMPTION PATTERN** | The monthly demand varies depending on weather conditions and individual residents needs | |
| **SUPPLY & DEMAND MATCH** | The average monthly irrigation demand can generally be met until the stormwater dam runs dry (often around January). | |

The rainfall at Hawker is variable and high intensities can be expected in any month. The quality of the runoff is improved (ie. sediment removal) during its passage through the stormwater settling basin before the water enters the dam (see Figure 124 above). However, no water quality testing is carried out by the Council and signs have been erected advising that the water is not suitable for drinking. The water is not chlorinated.

**Figure 125 Hawker Community Stormwater Dam (Rabone 1996)**

The community dam is a small excavated earth tank (unlined dam) with a storage capacity of 12.5ML. The maximum volume of stormwater that can be stored in the dam was estimated based on the dimensions at full supply; being 6m deep and 96m wide and 44m long with a constant side slope of 1:3. Not all of the stormwater stored is useable; some is lost to evaporation before the dam is emptied each year.

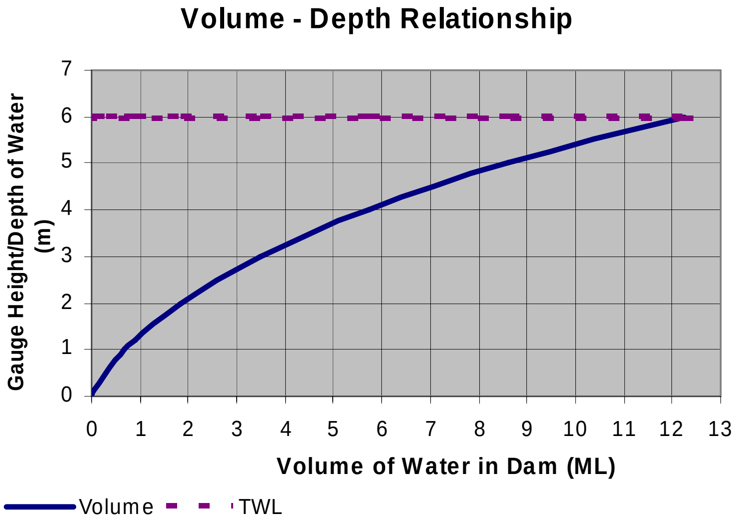


**Figure 126 Hawker – Dam Depth/Volume Relationship**

Water from the stormwater dam is not reticulated and residents must cart water to irrigate their gardens; direct pumping from the dam to private properties is not permitted. The Council operate and maintain the pumping units used to lift water to an elevated storage (old railway tank) with a capacity of 100kL. The stormwater is made available through a standpipe at the base of the tank to keen gardeners (see Figure 127). These residents have private water carts to collect this stormwater for irrigating their gardens. Approximately 45 to 50 residents, with 20 regulars, draw water from the dam for gardening purposes because the salinity is lower than the reticulated supply (SA Water 1998; David Smith *pers. comm.* 2005).

**Elevated Tank & Standpipe** **Private water cart**

**Figure 127 Hawker – Water Distribution by Private Carting (Rabone 1994)**

## Operational Matters

When the water level in the dam drops to 1.5m, Council pumping from the stormwater dam to the overhead tank ceases and the hose is removed from the standpipe. The elevated tank is keep full with water from the reticulated town supply for emergency fire fighting purposes, yet a number of residents continue to take water to maintain their gardens (David Smith *pers. comm*. 2005). Pumping of stormwater is resumed by Council when the water level reaches 2.5m. However, individuals can bring their own pumps and can pump directly from the dam into their water carting facilities until the dam is empty. For the last five years, the stormwater dam has run dry by January and is generally well on its way to being full by June or July; sometimes earlier if there are heavy autumn rains (David Smith *pers. comm*. 2005). There are no records of water level in the dam (ie. when Council is pumping) and no records of extractions from the dam by Council or individuals. Water from the dam is currently used by one resident to irrigate a piece of land (around 1ha) planted with vines; sometimes requiring several loads in a day during summer (David Smith *pers. comm*. 2005). When people in a community share a water supply they should be aware of how their water use could restrict others' use or the life of the resource. The shift towards volumetric pricing can be interpreted as a shift towards a more equitable allocation of costs because it better reflects actual consumption by individual users.

## Tariff Setting

Theoretically, the cost of operating the stormwater system in Hawker is met from users. The Council includes an allowance of $3,000 per annum in the budget for operation and maintenance of the dam; this excludes power costs associated with the pumping. The community agreed that user's make a voluntary contribution of $50 per year to Council to maintain the dam and the pump facilities. However, the Council has actually received very few voluntary payments to help defray costs from the residents benefiting from the supply. Water undertakings are usually required to raise all of their operating costs and to service all or some of the debt associated with their capital expenditure through revenue received. The revenue requirement can be meet from a number of sources including expected sales, subsidies and other forms of government support.

A tariff calculation using the method recommended by the World Bank (WSP 2002) for the Hawker stormwater system was made based on Council budget information, an assumed power cost of $1,000 per year and an estimated volume of water available for sale. While there is about 12.5ML of water stored in the dam, on average 2ML of water will be lost to evaporation and 2.5ML of water stored below 1.5m depth will not be pumped by council to elevated tank. Hence, an average volume of 8ML of water per year would be available for sale by the Council; provided measures are in place to achieve volumetric control of water extraction and recovery of charges. The price of a water service depends very much on the price of the inputs, like energy cost and financing infrastructure investments. The World Bank calculation results in a tariff set to cover the costs of providing the non-potable water supply without the application of an access charge. The results of the analysis are set out in Table 53 below along with an estimation of the tariff required to recover costs associated to service loans of various amounts to introduce access and volumetric controls.

## Table 53 Hawker Stormwater Reuse Tariff Calculation

**HAWKER - Stormwater Reuse Tariff Calculation**

| | **Current Budget 2005/06** (1) | **Including Loan Repayments @ 7.5% interest** | | | |
|---|---|---|---|---|---|
| | | **$25,000 in 15yrs** | **$50,000 in 20yrs** | **$75,000 in 25yrs** | **$100,000 in 25 yrs** |
| **System Information** | | | | | |
| No. of Connections (2) | Nil | Nil | Nil | Nil | Nil |
| Annual Water Sales (3) | 8,000 kL | 8,000 kL | 8,000 kL | 8,000 kL | 8,000 kL |
| **Annual Costs** | | | | | |
| • Electricity (4) | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 |
| • Water source fee | $ - | $ - | $ - | $ - | $ - |
| • Maintain – Dam | $ 2,000 | $ 2,000 | $ 2,000 | $ 2,000 | $ 2,000 |
| • Maintain - Network | $ - | $ - | $ - | $ - | $ - |
| • Depreciation (5) | $ - | $ - | $ - | $ - | $ - |
| • Chemicals | $ - | $ - | $ - | $ - | $ - |
| • Loan Repayment | $ - | $ 906 | $ 1,084 | $ 1,026 | $ 1,368 |
| • Interest | $ - | $ 1,875 | $ 3,750 | $ 5,625 | $ 7,500 |
| • Salaries | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 | $ 1,000 |
| **Overheads** | | | | | |
| • Office, Training | Inc O&M | Inc O&M | Inc O&M | Inc O&M | Inc O&M |
| • WQ Monitoring | $ - | $ - | $ - | $ - | $ - |
| **Total Annual Cost** | **$ 4,000** | **$ 10,435** | **$ 11,547** | **$ 12,764** | **$ 15,685** |
| **Tariff Required** | $0.54/kL(6) | $0.92/kL(7) | $1.19/kL(7) | $1.44/kL(7) | $1.74/kL(7) |

*(6) Budgeted operation costs courtesy of Mr David Smith, Flinders Ranges Council (2005)*
*(7) All water is collected by individuals from the standpipe at the base of the elevated tank.*
*(8) Average annual volume of water for sale, ie. above the 1.5m water level and after evaporation losses.*
*(9) Estimation of power costs as pumping station is not separately metered.*
*(10) Council financial accounts do not include a depreciation value for the asset; a combination of the age of the stormwater dam (ie. fully depreciated), its long life span and there has been no recent investment*
*(11) The tariff required for existing operation assuming no access fee is applied.*
*(12) The tariff required to recover costs and make loan repayments for improvements. This calculation assumes no access fee is applied*

Discussions indicate the dam water usage, which can be high in dry periods, would be reduced if a potable water supply is provided due to the costs associated with water carting (SA Water 1998). However, at $0.54/kL the required tariff for this service is very favourable in comparison to the current $1.06/kL unit cost of reticulated water supply above 125kL (note: in Hawker average residential water use is 262kL). The unit cost of making the stormwater available may also increase if less water is used as a result of introducing a volumetric pricing policy or when low salinity reticulated water from the proposed desalination plant becomes available. The Council needs security especially if it is to make long term investments because if the service is underpriced they can make losses.

The challenge for the community is to implement an equitable system of charges which commands broad acceptance among consumers and acts to guarantee the long term sustainability of the stormwater scheme. At the same time, it must not impose large administrative costs on a ongoing basis unless there are clear gains to efficiency of resource use.

## WATER SENSITIVE LANDSCAPING PRACTICES

In arid areas like Hawker the proportion of water used outside is much less than Adelaide due to smaller lawns and garden areas. While climate, soil types, and availability of water affect the development of parklands and community recreation facilities (ie. swimming pools, golf courses and ovals), in Hawker, water quality also limits outdoor water use. Local experience indicates that within 3 years of watering gardens with saline groundwater (ie. town water supply) the soil is damaged and plantings die-off (David Smith *pers. comm.* 2005). Consequently, development of irrigated community recreation facilities within the township has been minimal. Yet, while the golf course is not irrigated and putting surfaces are scrapes, some tree plantings have been established along the fairways (refer Figure 128).

**Plantings along fairway** **Putting Scrapes**

**Figure 128 Hawker Golf Course (Rabone 1994)**

## REFERENCES AND OTHER READING

*Flinders Ranges Council*: special thanks to Mr Terry Barnes for showing me around Hawker and its water, wastewater and stormwater infrastructure; and Mr David Smith who later provided additional information.

SA Water (1998) "*Hawker, Blinman, Marree and Oodnadatta Water Supplies: Report on Adequacy and Options for Desalination.*" Consultants Roger Stokes & Associates in association with Gutterridge Haskins & Davey were engaged to carry out this investigation.

van der Well & McIntosh (1998) "*Integrated Water Management for Selected Towns of South Australia*" gives examples of six towns, Hawker was one of these, where economic development can be enhanced by the use of alternative water sources.

# Lameroo, Murray-Darling Basin (SA) (Climate Index 5)

## GENERAL STATISTICS

The rural town of Lameroo is located 210 km east of Adelaide in the Southern Mallee region. The district was first farmed in the late 1800's; however, it was not until 1906, that viable farming activities came into existence due to the introduction of rail services. Originally, the land was used almost exclusively for wheat; but sheep were introduced in the 1920s. Between 1935 and 1950 there was a change from wheat to barley (Southern Mallee District Council). The township of Lameroo grew rapidly in the post-war period due to the decline of other small towns along the railway (Southern Mallee District Council). Today, Lameroo is surrounded by mixed farming and has been developed to service a large area. For a region that typically receives less than 400mm of rain per year, the township is unexpectedly green and attractive.

**(Broughill 2006)** **Irrigated Golf Course (Rabone 1994)**

**Figure 129 Lameroo – A Green & Attractive Town: Typical Views**

## LAMEROO – GENERAL STATISTICS

| | | |
|---|---|---|
| **CLIMATE INDEX** | 5 | |
| **REGION** | Murray-Darling Basin (SA) | |
| **POPULATION** | 459 (Base)   124% (Ultimate) | *ABS (2001) CENSUS* |
| **URBAN FORM** | Inland community | |
| **AVE. ANN. RAINFALL** | 391 mm | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 1 919 mm | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 212 (Occupied) | *ABS (2001) CENSUS* |
| **PERSONS PER DWELLING** | 2.2 | |

## WATER SUPPLY

There is no shortage of low salinity groundwater (ie. less than 1,000mg/L) groundwater around Lameroo. The watertable is approximately 40-60m below the surface and flows from the Grampians and Great Diving Range to the Murray River at a rate of half a metre per year (DME 1990). However, the groundwater is subject to elevated naturally occurring chemical contaminants such as iron (Scott 2004).

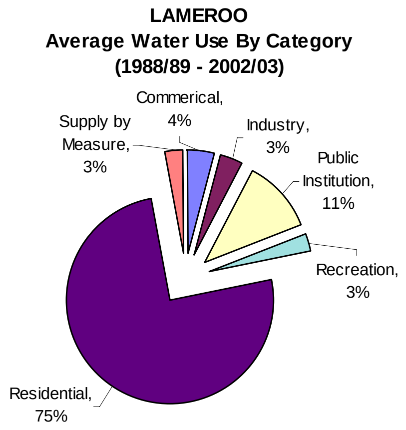
### Reticulated Water Supply (1963-2005)

Water was supplied to the township of Lameroo through three bores that were progressively constructed in 1963, 1984 and 1998 (Scott 2004). Originally, the bores provided water directly into the distribution system or to the elevated water storage tanks without any form of treatment.

In 2001, each bore was fitted with a sodium hypochlorite dosing facility to provide a disinfectant residual within the distribution system to maintain the microbiological safety of the reticulated water supply (Scott 2004). In 2003, the Lameroo water treatment plant with a capacity of 16L/s (1.4 ML/d) was commissioned to reduce the concentrations of iron below the Australian Drinking Water Guideline values.

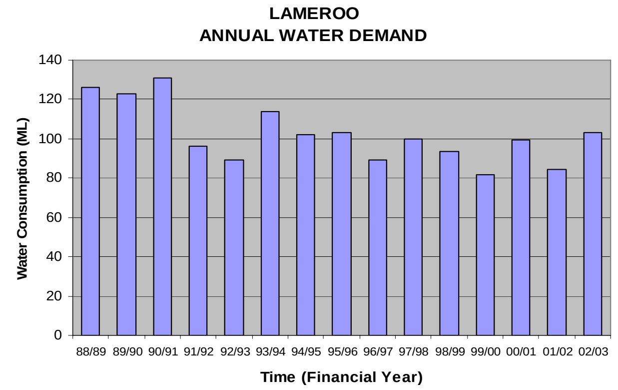
## LAMEROO – WATER SUPPLY STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | SA Water | | |
| **WATER SOURCE** | Local groundwater. The groundwater has elevated levels of naturally occurring chemical contaminants including iron (aesthetic). | | |
| **TREATMENT** | Iron Removal (since 2003) by oxidation (chlorine) & filtration<br>Disinfection | | |
| **DISTRIBUTION** | Reticulated to residents directly into the distribution system or from an elevated storage. | | |
| **RATING STRUCTURE** | Statewide pricing policy administered by the State government - pay for use with a minimum charge. . | | |
| **RETAIL PRICE PAID** | 0 – 125 kL | $0.42/kL | *Residential 2003/04* |
| | >126kL | $1.00/kL | *Residential 2003/04* |
| **AVE. WATER USE** | 300 kL/service/year | | *Average 88/89 -02/03 Water Consumption Statistics* |
| | 321 kL/house/year | | |
| | Three quarters of the reticulated water supply in Lameroo is used for residential purposes. | | |



**AVE. ANN. DEMAND** 100 ML/year

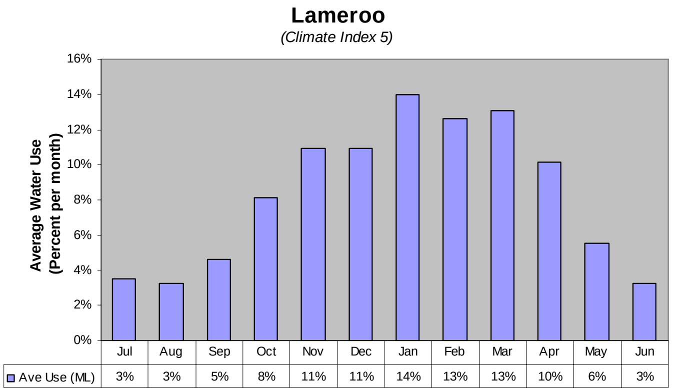
*Water Consumption Statistics SA Water (1989-2003)*



*SA Water (1989 - 2003) Water Consumption Statistics - Table 12 Independent Schemes Murray Mallee Region*

**CONSUMPTION PATTERN**

A strongly seasonal water usage pattern is observed. During the winter period (May to September) the monthly demand is less than 6ML and almost doubles during the summer. This pattern is consistent with normal household and garden use.



*Source: SA Water (1989 - 1996) Water Consumption Statistics - Table 12 Independent Schemes Murray Mallee Region*

## STORMWATER DRAINAGE

The town of Lameroo is built within a shallow basin with sandy rises and clay depressions; consequently, stormwater runoff accumulates in the low lying areas on the eastern side of the town. During the 1960s and 1970s, significant development occurred in Lameroo with the construction of many new public buildings and sealing of streets (Huppatz 1990). As the broad streets in the town were fully sealed and kerbed an increasing amount of stormwater runoff occurred. Low areas of the township were inundated (ie. flooded) following intense rainfall events in the summers of 1969 and 1974. The Council installation of the stormwater drainage system was a gradual process over many years with little financial assistance from the State government.

Today, stormwater runoff collected from a 78ha urban catchment area, equivalent to 80% of total stormwater runoff from the town, flows through the underground drainage and is discharged into the pumping pond (see Figure 130). The pumping pond has a concrete floor in the base to allow easy access to remove material which accumulates in the pond. The Council cleans the pumping pond every few years. Two pumps with a combined duty of 175L/s at 5m head (around 15ML/day), transfer runoff from the pumping pond to the stormwater lagoon (adjacent the STEDS lagoon) on the northern side of the golf course (Huppatz 1990).

**Discharge to Pumping Pond (80%)** **Stormwater Pumping Pond**

**Figure 130 Lameroo Stormwater Discharge & Pumping Pond (Rabone 1994)**

In a heavy downpour of rain, or in the event of a power failure, the level in the pumping pond can rise above (ie. drown) the stormwater discharge pipe. The consequent temporary build-up of water stored in the relatively flat drainage system, ie. pipe with falls of only 0.11 to 0.20, can cause localised flooding (Huppatz 1990). In the early 1990s, the council commenced a cleaning effort to remove silt build up within the drainage system. Street sweeping is carried out on a regular basis to prevent rubbish being washed into the stormwater system. When the pumps can not keep up the stormwater flows over a spillway into an adjacent low lying area (ie. known as the Stormwater Lake).

In addition to acting as an emergency collection area for overflow from the pumping pond, around 20% of the town's stormwater runs directly into the Stormwater Lake (see Figure 131). Since 1994, the area around the Stormwater Lake has been developed for recreational purposes. Council is currently seeking funds for infrastructure to intercept this flow and divert it to the stormwater pumping pond (Mr Peter Broughill *pers. comm*. 2006).

**Figure 131 Lameroo - Stormwater Lake & Emergency Storage (Broughill)**

Water can be drained back into the Stormwater Lake from the stormwater storage lagoon; however, this facility has not been used in this way since the early 1990s as an odour problem can result. Instead, the lake is topped up with groundwater from a Council bore to maintain a constant level for aesthetic purposes.

## LAMEROO – STORMWATER DRAINAGE

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Southern Mallee District Council | | |
| **CATCHMENT AREA** | Total | 78 ha | |
| | Urban | 78 ha | *Huppatz (1990)* |
| **ROAD DATA** | Total length | NA km | |
| | Average width | NA | |
| | Kerbed | 99% | |
| | Sealed | 99% | |
| **RAINFALL TO PRODUCE RUNOFF** | 10-15mm (from bitumen roads) | | *Huppatz (1990)* |
| **AVE. STORMWATER RUNOFF** | 85 ML/year (estimated) | | *Based on Fleming's Monthly Runoff Coefficients* |
| **TYPE OF DRAIN** | Underground stormwater drainage | | |
| **LEVEL OF TREATMENT** | Primary (Lagoon) | | |
| **NUMBER OF DISCHARGE POINTS** | Two (approx. 80:20% split) | | *Mr Peter Broughill pers. comm. 2006* |
| **DISPOSAL** | • Irrigation System (80%)<br>• Stormwater Lake (20% & Pumping Pond Overflow) | | |

## WASTEWATER SYSTEM

Prior to the construction of the septic tank effluent drainage system (STEDS), the town effluent disposal was individual septic tanks with soakage trenches. In general, septic tanks are simple to operate and maintain and can be relied upon to function as designed. In Lameroo, some residents experienced problems with the downstream soil adsorption system (ie. soakage trenches) due to the clay soils and septic tanks and trenches had to be pumped out regularly and the effluent disposed of outside of the town (Huppatz 1990). Unreliable performance of septic tanks can present a risk to health and the environment.

In 1975, the Lameroo STEDS was installed with the aid of a State Government grant. Effluent is treated in a two lagoon system by sunlight and natural bacterial processes before disposal by evaporation. This method was commonly used for small towns in South Australia when the Lameroo STEDS was constructed. Where acceptable climatic conditions exist (ie. net evaporation is significant) disposal by evaporation is cost-effective. In winter, after a decent downpour, the level of the effluent lagoons can rise significantly and cause the effluent lagoons to overflow (Huppatz 1990). This suggests that some households have connected rainfall to the septic system rather than the stormwater drainage system. This operational problem is overcome by transferring excess effluent in winter to the adjacent stormwater lagoon.

## LAMEROO – WASTEWATER SYSTEM STATISTICS

| | | |
|---|---|---|
| **ADMINISTRATION** | Southern Mallee District Council | |
| **WASTEWATER SYSTEM** | STEDS<br>(established with a subsidy grant) | |
| **CONSTRUCTED** | 1975 | |
| **EST. POPULATION SERVED** | 500 EP | |
| **CONNECTIONS** | 287 | |
| **RATING STRUCTURE** | Annual Service Fee<br>$150pa for occupied properties<br>$150pa for vacant land | *Southern Mallee District Council Rating Policy (2006)* |
| **ANNUAL SEWAGE INFLOW** | >30 ML | *Mr Peter Boughill pers. comm. 2005.* |
| **LEVEL OF TREATMENT** | • Secondary (Lagoon) | |
| **QUALITY TESTING** | Inflow NA<br>Effluent NA | |
| **AVE. EFFLUENT AVAILABLE** | Not Recorded | *Mr Peter Boughill pers. comm. 2005.* |
| **EFFLUENT DISPOSAL** | • Irrigation system<br>• Evaporation | |

## NON-POTABLE WATER HARVESTING & REUSE

### Community Spirit & Pride

During the 1960s, the positive community spirit was successfully harnessed and used to stimulate interest in the development of attractive parklands and community recreation facilities around Lameroo. For example, by using underground water, the median strips and public areas are always green, providing an oasis in the dry mallee area. Sporting bodies also voluntarily made use of the plentiful underground water to improve their facilities (Huppatz 1990). Nevertheless, development of the independent water supplies has been a long slow process and its success is the result of the work of dedicated members of the community and Council.

### Golf Course Development

The golf course is on a 32ha recreation reserve under the care, control and management of the Council. In 1966, despite considerable opposition, local resident and businessman Mr Des Pahl convinced the golf club to establish three greens using the reticulated town water supply (Border Times 1991). After that, Des actively researched the costs associated installing and equipping a private bore to achieve a completely independent water supply. The club has used groundwater extracted from a depth of 76m to irrigate the golf course since 1968. This was followed by the establishment of more greens and by 1972 (ie. within 8 years) the club boasted 18 greens (Border Times 1991). The next improvement was the turfing of the fairways and the planting of thousands of trees. Today, around 18ha (ie. around 50%) of the recreation reserve is irrigated and the beautiful golf course seen in Figure 132 is a credit to Lameroo.

**Figure 132 Lameroo – Golf Course with Established Plantings (Rabone 1994)**

Since 1975, part of the irrigation demand has been met from a blend of stormwater and treated effluent. Access to this supply of surface water supply has reduced the annual irrigation costs by about $4,000 (Huppatz *pers. comm*. 1994). Between the mid 1980s and mid 1990s, an underground and automatic irrigation system was gradually installed to water all fairways and greens. Council provided some assistance in the form of plant and equipment for installation works.

## The 'Idea' to Meet Needs

The catalyst for the most important water harvesting and reuse initiative by this small community was the need to solve the towns increasing stormwater and septic tank effluent disposal difficulties in the mid 1970s. The Council engaged a consulting firm (Lang, Dames and Campbell) to provide assistance with the design of an appropriate solution. Figure 133 presents a schematic overview of the adopted solution to the stormwater and wastewater problems. A significant aspect is that the local water harvesting and reuse system is accepted by the local community as the normal course of events (Huppatz 1990).

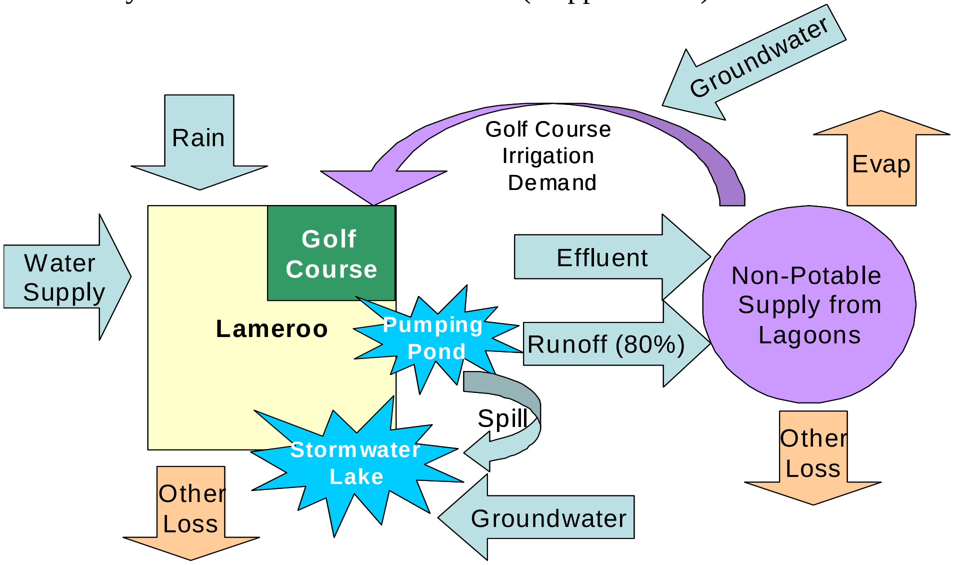


**Figure 133 Lameroo - Schematic of Local Water Harvesting & Reuse System**

Part of the town stormwater runs directly into the ornamental stormwater lake while the majority runs into the pumping pond and is transferred to a specifically constructed 63.5ML stormwater storage lagoon (see Figure 134). The stormwater storage lagoon is conveniently located adjacent to the effluent lagoons and the golf course. The golf club can pump from either the stormwater storage or the effluent lagoons; however, in winter excess effluent is stored in the stormwater storage. A shandy of stormwater and treated effluent is pumped to the golf course for irrigation purposes. The blend in stormwater storage lagoon is managed to not exceed more than 20% effluent at any one time (Huppatz 1990).

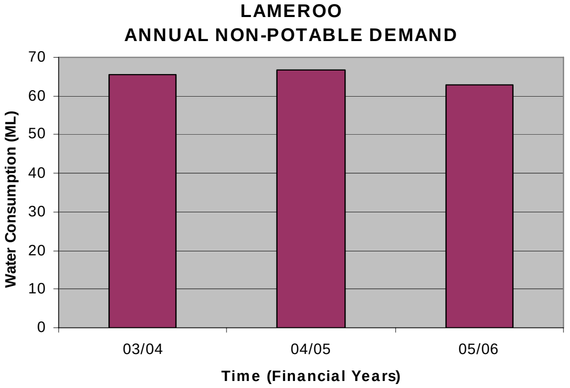
**Effluent Storage Lagoon** **Irrigation Pumps (Rabone 1994)**

**Figure 134 Lameroo –Storage Lagoon & Irrigation Pumps**

The stormwater storage lagoon measures 160m long by 125m wide by 3.5m deep and is owned by the Council as part of Lameroo's stormwater drainage infrastructure. While the storage lagoon has not overflowed, excess water could be pumped onto the golf course (Huppatz 1990). The large surface area of 20ha means losses due to evaporation are significant in summer; in fact, the lagoon could dry out even if no water was extracted to irrigate the golf course (Huppatz *pers. comm.* 1994). Nevertheless, water from the stormwater storage usually meets the 25mm per week irrigation demand of the golf course for the three months between October and December each year. Naturally, this is dependent on rainfall and other weather conditions. Water from the golf club bore is used for the remaining months of the irrigation period. Because the bore water has to be pumped from a depth of 76m vast savings in electricity costs are made by the club by using the stormwater/treated effluent blend.

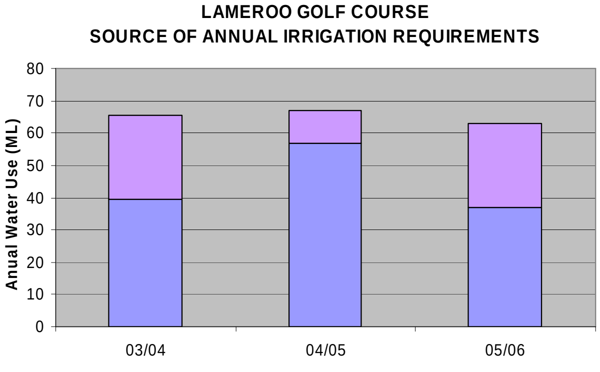
## LAMEROO – NON-POTABLE WATER SUPPLY

| | | |
|---|---|---|
| **ADMINISTRATION** | Southern Mallee District Council | |
| **WATER SOURCE(S)** | • Low salinity groundwater (710mg/L TDS)<br>• Blend of urban stormwater runoff with treated STEDS effluent | |
| **DISTRIBUTION** | Dedicated pipe to point of use | |
| **COMMISSIONED** | 1968 (groundwater) &<br>1975 (stormwater/effluent) | *Mr Noel Huppatz pers. comm. 1994.* |
| **SERVICES** | One (Golf Club) | *Mr Noel Huppatz pers. comm. 1994.* |
| **QUALITY TESTING** | Nil | |
| **RATING STRUCTURE** | Cost sharing arrangement | |
| **RETAIL PRICE PAID** | $/kL depends on quantity used. | |
| **AVERAGE USE** | 65ML per year (Estimated)<br>Water used from golf club bore is metered. Stromwater/effluent use is not recorded | *David Crispy (2006)* |



*Source: David Crispy, Lameroo (2006)*

| | |
|---|---|
| **LEVEL OF REUSE** | 25% of treated effluent |
| **CONSUMPTION PATTERN** | The monthly demand varies depending on weather conditions and irrigation needs. |
| **SUPPLY & DEMAND MATCH** | The average monthly irrigation demand by the golf club can be met from the stormwater lagoon between October and December (ie. lagoon empty). The remainder of the irrigation demand usually to April is met from more expensive groundwater extracted from a depth of 76m. |



*Source: David Crispy, Lameroo (2006)*

The small community of Lameroo has demonstrated that a country town can solve its own problems in the area of effluent and stormwater management and at the same time improve the quality of life for residents.

## Operational Matters

For 38 years, the golf club has maintained independence from the town's reticulated water supply using groundwater from its private bore. This supply has been supplemented for over 30 years with stormwater and effluent from the small town of Lameroo. The main operational problems encountered with respect to the irrigation system are related to the bore water and the outlet from the stormwater pond. The water extracted from the bore causes the foliage of native pines to die if sprayed onto the leaves; however, other trees are not affected (Huppatz 1990). Algae develops in the dam and each year it is dispersed with copper sulphate to prevent blocking of the inlet to the irrigation pump. Also, the outlet from the stormwater storage lagoon can be clogged with water weeds which may be overcome by relocating the outlet nearer the middle of the dam.

The costs of operating the non-potable water supply in Lameroo are met jointly by the Council and the golf club being the entities that benefit from the system. The Council pays for the maintenance of the stormwater drainage system. The Council pays the electricity costs associated with pumping the stormwater to the stormwater storage lagoon. The Council pays the electricity cost of irrigating the golf course from the lagoons. The costs associated with algal management are shared equally between the Council and the Golf Club. From January to April, water is pumped from the golf course bore pump which is 76m deep. The cost of doing this is around $1,200 to $1,500 per month for electricity.

Regrettably, despite the sustained operation of this pioneering local water supply initiative, lack of historical operational data has prevented a critical review of the scheme's overall performance. Neither the council nor the golf club monitors the volume of water stored in the stormwater storage lagoon or the hours the irrigation pumps run. Likewise, the effluent flow into the evaporation ponds and the amount transferred between the various lagoons is not measured. Similarly, the amount of water (say mm/month) used on the golf course over the years is not known either; however, it may be possible to estimate this more accurately now that irrigation system is automatic. Because the system was not designed with research no accurate rainfall – runoff data is available to facilitate yield predictions from similar area.

## WATER SENSITIVE LANDSCAPING PRACTICES

No specific water sensitive landscaping practices were observed.

## REFERENCES AND OTHER READING

*Southern Mallee District Council*: special thanks to Mr Noel Huppatz for showing me around Lameroo and its wastewater, stormwater and reuse infrastructure; and for Mr Peter Broughill who later provided additional information.

Huppatz,N (1990) "*Greening the Lameroo Golf Course by Solving a Stormwater and Effluent Problem"* also provided useful facts on the water harvesting and reuse scheme. This paper was presented at the inaugural Asia Pacific Conference of the International Federation of Parks and Recreation.

# Leigh Creek, Far North (Climate Index 14)

## GENERAL STATISTICS

Leigh Creek is a company town located 550km north of Adelaide in the hot arid zone of South Australia's Flinders Rangers. The current town is 13km south of the original town after it was moved in 1980 to allow the expansion of the mine. The purpose of the town is to supply services and housing for the Leigh Creek Coalfield initially run by the Electricity Trust of South Australia (ETSA) and under operational control of NRG Flinders since 2002. It is a modern township with a series of neat modern roads and small, attractive plots of land on which standard modern houses have been built to house the workers and their families who provide the labour force for the nearby coal mine. Leigh Creek is a closed town with nearly all facilities owned and managed by the mine operator which acts as a local council for the community.

**Aerial View (walkabout.com 1999)**

**From the Outskirts (Rabone 1993)**

The town is set in an imposing arid landscape enclosed on three sides by hills with views of the Flinders.

## LEIGH CREEK SOUTH – GENERAL STATISTICS

| | | | |
|---|---|---|---|
| **CLIMATE INDEX** | 14 | | |
| **REGION** | Far North | | |
| **POPULATION** | 585 (Base) | 191% (Ultimate) | *ABS (2001) CENSUS* |
| **URBAN FORM** | Inland community – mining | | |
| **AVE. ANN. RAINFALL** | 208 mm | | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 2 940mm | | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 227 (Occupied) | | *ABS (2001) CENSUS* |
| **PERSONS PER DWELLING** | 2.6 | | |

## TOWN PLANNING & DEVELOPMENT

### Original Town of Leigh Creek (1945 – 1980)

The area around Leigh Creek was first settled in 1856. Coal was discovered and mined in small quantities from 1888. However, it was not until 1943 that coal was mined commercially in an effort to make South Australia more self sufficient for it energy needs (www.wikipedia.org). The reasons for the late development of the mines are twofold. Firstly, early mining was thwarted by mine shafts being filled with water. Secondly, by the early 1940s South Australia was totally dependent on New South Wales for its coal supply. Thomas Playford, the SA Premier at the time, successfully argued that the state needed to be self-supporting in energy.

The original township of Leigh Creek was built following a traditional development pattern following the Second World War. The 133 square kilometre lease, covering the coalfield and township was, administered by ETSA which provided and funded all services. In 1946, the coalfield town of Leigh Creek was the first small country town in South Australia to be served by a full sewerage scheme (see Figure 135).

**Figure 135 Leigh Creek – Wastewater Treatment Plant 1946 (SA Water)**

The natural environment is a harsh one, with high summer temperatures, low erratic rainfall and poor quality soils. Natural vegetation is sparse except in good seasons and in the creek beds where large stands of River Red Gum thrive. The soil and subsoil in Leigh Creek is alkaline and saline. Consequently, many plants commonly grown in more temperate climates and depend on acid soils are unsuited to Leigh Creek. Public plantings and private gardens were established and high water usage resulted in the development of a perched and highly saline water table (Zwar 2004). Excessive watering increases the risk of salinisation (ie. excessive salt build up in the soil) that reduces plant growth, causes foliage damage or even kills plants (ETSA n.d.). In the original township, tree deaths occurred through waterlogging and salinity (Zwar 2004). In 1976, ETSA decided to move the town to accommodate expansion of the Leigh Creek Coalfield mining operation.

## New Town of Leigh Creek South

The new town of Leigh Creek was rebuilt where it is today and expanded from a capacity of 1100 to 2500 people. The site at Windy Creek and landscaping was established in 1977, construction commenced in 1979 and the first houses were occupied in 1980 (Zwar 2004). The natural vegetation cover prior to development consisted of low open mallee woodland on the hills with open shrub land of saltbush and bluebush as the major groundcover (ETSA n.d.). The prevailing climate and relative isolation required sensitive town planning and house design, and had a major influence on subdivision layouts, design and orientation of housing, and policies for maintenance of existing vegetation.

Housing was designed to feature outdoor shaded areas, carports, rainwater tanks, insulation, underground water reticulation and sewerage services (ETSA n.d.). In accordance with normal practice in Australia, independent systems for the collection and disposal of stormwater and wastewater were planned. All wastewater effluent is treated and chlorinated for irrigation purposes on Leigh Creek's two sports ovals and tree plantings. ETSA committed to a high standard of town development for Leigh Creek South and created a cool, shady environment, with some 250,000 trees, shrubs, groundcover and climbing plants being established. The new Leigh Creek, a company town on the edge of the desert, is set in an imposing arid landscape enclosed on three sides by hills with views of the Flinders.

In an arid township like Leigh Creek a secure reliable water supply is essential and the new town was designed to minimise the use of water and to maximise the use of rainwater runoff. This town has incorporated water conservation principles and installed water conservation devices, for example, rainwater tanks are installed at every house and 'low water use' gardening actively encouraged. Water use records for new township of Leigh Creek point to a reduction of 47% in water use per service per year (ie. 530kL in 1985/86) compared to the old town where average annual consumption was around 1000kL per service (McLaren *et al* 1987). This reduction in consumption has been achieved by recycling effluent water for the irrigation of playing fields and tree planting, a reduction in domestic lawn areas, widespread use of drip irrigation, mulching and selection of suitable arid-zone plant species. The township demonstrates that water consumption can be significantly reduced by careful town planning and water conservation.

## WATER SUPPLY

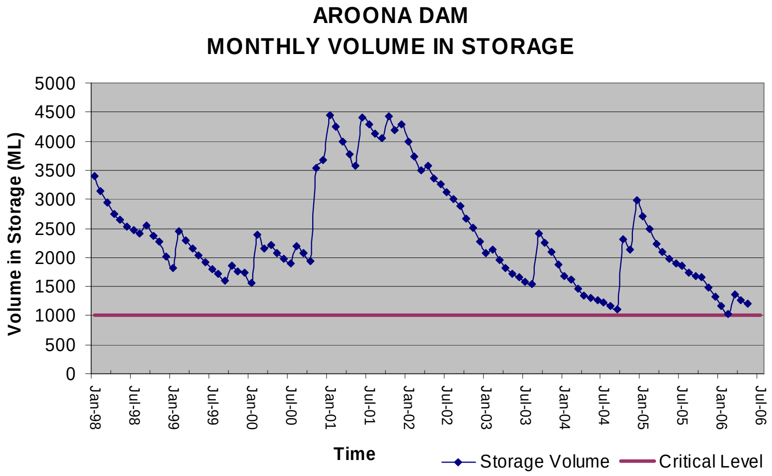
Aroona Reservoir is built on Myrtle Spring station has been the primary source of potable water for the townships of Leigh Creek, Copley and Lyndhurst since 1955. Most arid area streams are turbid through natural processes. Due to the nature of its catchment and local rainfall patterns Aroona dam was not a reliable source of water. At the time of construction, the dam's capacity was 7500ML but has progressively reduced by nearly 1/3rd through silting (Ernst 1993). The lack of security of supply from Aroona is further exacerbated by significant loss of water stored; through seepage from the dam (estimated to be 25%), evaporation from the water surface (between 30% and 50%); and because the last 10% stored in the dam is poor quality. Thus on average only about 30% of the water collected is available for potable water supply (for Leigh Creek, Copley and Lyndhurst).

Nevertheless Leigh Creek was entirely dependent on Aroona Dam shown in Figure 136 for potable water until 1982.

**Aroona Reservoir(Eckerman 1992)** **Aroona Dam (ETSA 1993)**

**Figure 136 Leigh Creek – Views of Aroona Reservoir & Dam**

With the increase in population in the late 1970s and the dam not being a reliable source, a backup water supply was needed (ETSA n.d.). Figure 137 shows the volume of water in the Aroona Reservoir at the beginning/end of each month since January 1998. The critical level represents between 3 to 4 months supply left in the dam and triggers the next level of water conservation measures.



*Operational data courtesy of Dion Robins, NRG Flinders 2006*

**Figure 137 Leigh Creek – Historical Record of Volume in Aroona Reservoir**

A bore field producing water of salinities ranging from 600ppm to 3500ppm was developed. A reverse osmosis (RO) desalination plant has been built to serve as a backup during times of drought to enable use of saline and brackish groundwater resources. The RO desalination facility (see Figure 138) was commissioned in four stages between 1982 and 1986. In 1987, the pre-treatment sections of the Stage 1 & 2 reserve osmosis plants were modified to treat turbid low salinity water from Aroona Dam. The capacity of the existing RO plant to produce potable water is 3.4ML/day. The brine (reject water) has a TDS of approximately 18,000mg/L and is piped to the mine for disposal at the coalfield.

**Desalination Facility (ETSA 1993)** **Operations Library (Rabone 2005)**

**Figure 138 Leigh Creek – Reverse Osmosis & Water Treatment Facility**

Aroona water remains the cheapest source and while it is of suitable quality it is used exclusively with desalinated bore water only being introduced when necessary (Beal 1991, Dion Robins *pers comm*. 2005). Aroona dam water can be pumped directly into the 9ML tank and gravity fed into town after chlorine disinfection. If the water quality of the dam deteriorates (ie. increased turbidity due to creeks flowing or seasonal conditions) raw water is diverted through the modified Plants 1 & 2 for clarification and filtration (now the normal mode of operation). All potable water pumped to the township is filtered and chlorinated. Water quality testing for chlorine levels, salinity, turbidity and pH is carried out daily at the on site laboratory (Dion Robins *pers comm*. 2005). On a weekly basis, samples are sent to the Australian Water Quality Centre (AWQC) in Adelaide to test other parameters mainly bacteriological. Good records of operational matters are maintained in the on site laboratory (see Figure 138).

## LEIGH CREEK – WATER SUPPLY STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | NRG Flinders | | |
| **WATER SOURCE** | • Aroona Dam water<br>• Blend of Aroona water and better quality bore water<br>• Brackish bore water | | *Dean Ernst (1993)* |
| **TREATMENT** | • Chlorinated Aroona water, or<br>• Clarified and chlorinated Aroona water (when turbid),<br>• Desalinated and chlorinated brackish groundwater | | *Dean Ernst (1993)* |
| **QUALITY TESTING** | Source | Physical tests daily onsite<br>Biological tests monthly by AWQC | *Dion Robins (2005)* |
| | Product | As above | |
| **DISTRIBUTION** | Reticulated in township | | |
| **SERVICES** | 250 (with around 230 residential) | | *Dion Robins (2006)* |

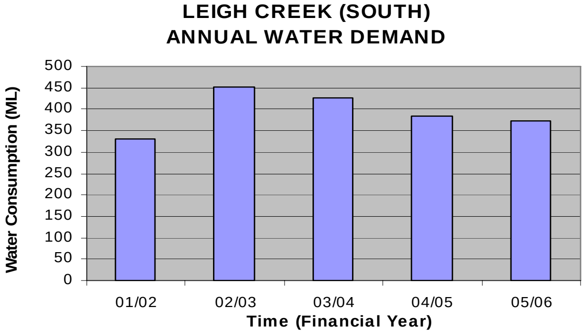
**RATING STRUCTURE** Free of charge for residents of Leigh Creek South. Residents of Copley, Lyndhurst & pastoral properties pay $0.97/kL of water used.

**AVE. WATER USE** 1297 kL/service/year *Dion Robins (2006)*

300 kL/house/year (estimate based on monthly meter reading program that commenced in March 2006)

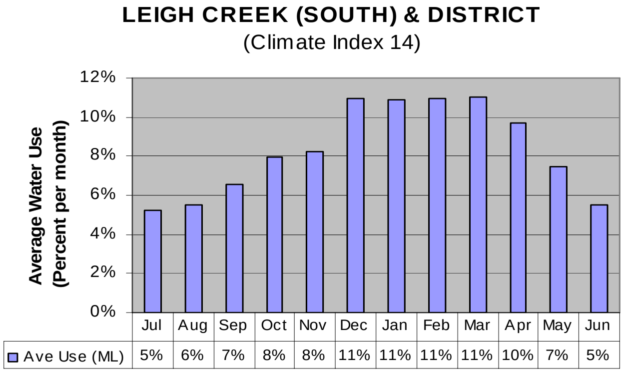
**AVE. ANN. DEMAND** 398 ML/year *Average calculated from 2000-06 data*

The average annual demand includes potable water used for irrigation of public plantings. This amounted to nearly 20% of the total use in 2004.



*Source: Data courtesy Dion Robins, NRG Flinders (2006)*

**CONSUMPTION PATTERN** Seasonal water usage pattern consistent with normal household and garden use.



*Source: Data courtesy Dion Robins, NRG Flinders (2005)*

Potable water is a limited and expensive commodity to provide nevertheless filtered and chlorinated water is provided free of charge to residents of Leigh Creek and provided at an affordable tariff to nearby communities. In 2004, the cost of delivering dam water to Leigh Creek was $0.25/kL, around $0.90/kL for clarified dam water through Stage 1 & 2 plant, and $1.00/kL for desalinated bore water (Dion Robins *pers. comm.* 2005). Overall, the average cost to deliver potable water in 2004 was $0.83/kL (Dion Robins *pers. comm.* 2005). The average annual cost is variable and is a function of the contribution by each source and treatment process required for a given year. The current average water consumption per service is comparable with the original township.

## STORMWATER DRAINAGE

The streets in Leigh Creek are sealed between kerbs (see Figure 139) and have the potential to increase the volume of stormwater runoff; however, in the late 1970s stormwater harvesting was not planned as part of the design of the new town. Rains can come in any month but intense fails of up to 49mm an hour are likely to accompany convective thunderstorms (ETSA n.d.). In some areas, seasonal runoff from hard surfaces such as car parks is harvested and drained into planted areas to supplement drip irrigation. However, stormwater runoff from the roads is caught in kerbs and open drains and conveyed to the outskirts of town.

**Roads Sealed with Kerbs** **Combined footpath and channel**

**Figure 139 Leigh Creek – Typical Streetscapes (Rabone 1993)**

The stormwater runoff from the town streets is discharged through a large culvert shown in Figure 140 into the periodically inundated wetland. The network of ag drains installed under some of the developed area to provide soil drainage and remove saline groundwater is also discharged from this culvert. Downstream of the discharge point, some trees were planted in the (normally dry) wetland area abd have grown to around 5m tall after 5 years (Beat Odermatt *pers comm*. 1993).

**Stormwater Discharge** **Downstream of Discharge**

**Figure 140 Leigh Creek – Town Stormwater Discharge (Rabone 1993)**

Stormwater reuse was not planned in the design of the new town. It is expensive to go back and do it retrospectively.

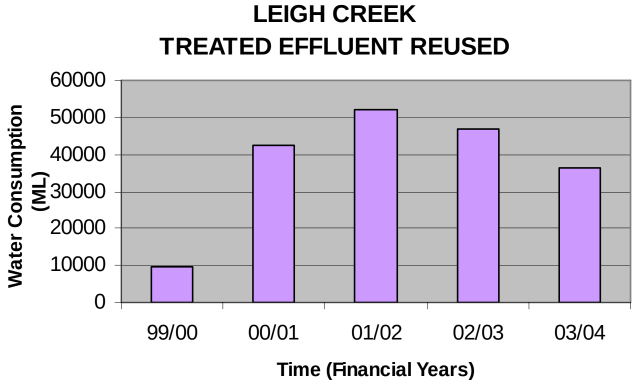
## WASTEWATER SYSTEM

The township of Leigh Creek is served by a conventional sewerage system equivalent to the standards set by SA Water. Wastewater from serviced allotments is discharged into the sewer and gravitates to three pumping stations located in the low points. Household wastewater flows through the sewer system into a pumping station No. 1 and sewage from the town services compound and the caravan park are pumped into pumping stations No. 2 & No. 3 respectively. From there, the sewage is pumped to the wastewater treatment system located around 500m to the east of the developed area. The treatment system is designed to serve a population of up to 1,500. There was a time when 2000 people were in Leigh Creek and the system was not performing properly under the strain.

## LEIGH CREEK – WASTEWATER SYSTEM STATISTICS

| | |
|---|---|
| **ADMINISTRATION** | NRG Flinders |
| **WASTEWATER SYSTEM** | Full wastewater system |
| **CONSTRUCTED** | 1981 |
| **EST. POPULATION SERVED** | 1500 EP |
| **CONNECTIONS** | 250 |
| **RATING STRUCTURE** | No rates levied |
| **ANNUAL SEWAGE INFLOW** | Not recorded |
| **LEVEL OF TREATMENT** | • Secondary Treatment<br>• Disinfection |
| **AVE. EFFLUENT AVAILABLE** | 38.5 ML/year |

*Dion Robins (2006)*



*Source: Dion Robins, NRG Flinders (2005)*

| | |
|---|---|
| **EFFLUENT DISPOSAL** | • Reuse irrigation system<br>• Mine for dust suppression |

**Treatment Plant (ETSA 1993)** **Reuse Extraction (Rabone 2005)**

**Figure 141 Leigh Creek - Wastewater Treatment Plant**

Wastewater is treated in a series of five lagoons; two aeration lagoons and three clarification ponds (see Figure 141). Two large mechanical aerators stir the incoming sewage water allowing large amounts of oxygen to be dissolved into the water. Every 24hours the direction of the aerators is reversed to remove any build up of material from the paddles. The amount sewage flowing into the wastewater treatment is not recorded. The effluent then gravitates through the three clarification ponds. From the final pond, treated effluent is chlorinated, pumped to the irrigation tank and used for watering the town and school ovals, cemetery, golf club and buffer zones trees (via drip irrigation system). If there is too much effluent a pump will cut in automatically and pump the excess as waste to the mine to be used for dust suppression on roads.

## NON-POTABLE WATER HARVESTING & REUSE

In Leigh Creek all treated effluent is used to irrigate the two sports ovals, the grassed nine-hole golf course and several thousand trees in buffer zone plantings.

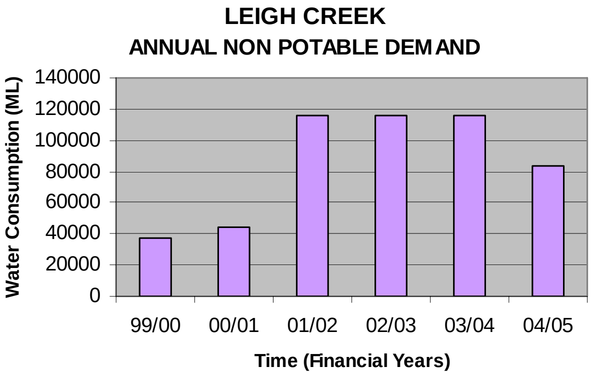
**Figure 142 Leigh Creek – Community Oval Irrigated with Treated Effluent**

A small pump for dripper lines to the buffer tree plantings and large pumps for the ovals take water from the steel irrigation tank (Beat Odermatt *pers comm*. 1993). The water is pumped through a sand filter before entering the irrigation system. Automatic sprinklers on the ovals, cemetery and town drip irrigation system are controlled by computer to operate overnight. In addition, a complex underground drainage system constructed with agricultural pipe is used to remove excess irrigation water to minimise the risk of soil salinisation. The area of the main oval is around 1.6ha and the plantings irrigated by drippers around 8.7ha (Beat Odermatt *pers comm*. 1993). Since then the golf course also irrigates an area of around 7ha with pop up sprinkler (Dion Robins *pers comm*. 2006). Originally, the demand for effluent by these areas was carefully matched with effluent production to ensure that during the summer months the resource is fully utilised but not exceeded (ETSA n.d.). The demand for non-potable water to maintain established irrigated areas has grown to nearly double the volume available.

## LEIGH CREEK – NON-POTABLE WATER SUPPLY

| | | |
|---|---|---|
| **ADMINISTRATION** | NRG Flinders | |
| **WATER SOURCE** | Treated effluent augmented with potable water | |
| **DISTRIBUTION** | Limited; dedicated pipe system to irrigated areas | |
| **COMMISSIONED** | 1982 | *Dion Robins (2006)* |
| **SERVICES** | 4 irrigation runs | *Dion Robins (2006)* |
| **QUALITY TESTING** | Physical tests daily onsite<br>Biological tests monthly off site | |
| **RATING STRUCTURE** | Not rates levied. Used by town management. | |
| **RETAIL PRICE PAID** | Not applicable | |
| **AVE. WATER USE** | 85 ML/year | *Average calculated from 99/00 – 04/05* |

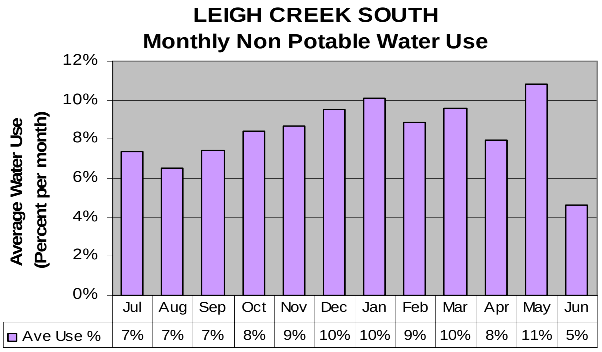
Annual demand for irrigation purposes includes potable make up water. The marked increase from 2001/02 is due to monitoring initiatives that record the potable water component (Dion Robins 2006).



*Source: Dion Robins, NRG Flinders (2005)*

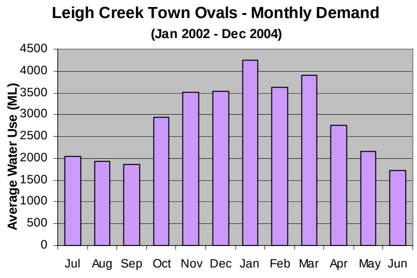
**LEVEL OF REUSE** 100% of effluent treated

**CONSUMPTION PATTERN** The monthly demand varies slightly depending on the irrigation requirements.

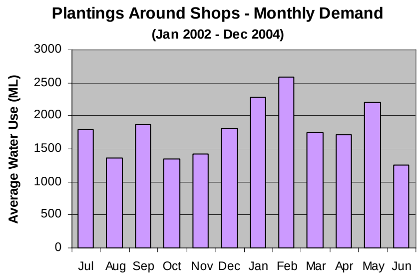


| | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ▨ Ave Use % | 7% | 7% | 7% | 8% | 9% | 10% | 10% | 9% | 10% | 8% | 11% | 5% |

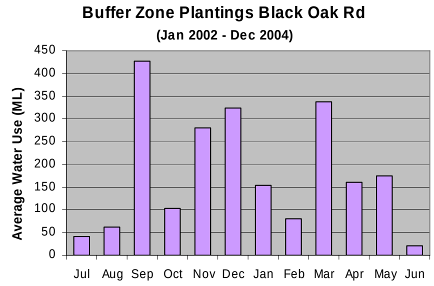
*Source: Data courtesy Dion Robins, NRG Flinders (2005)*



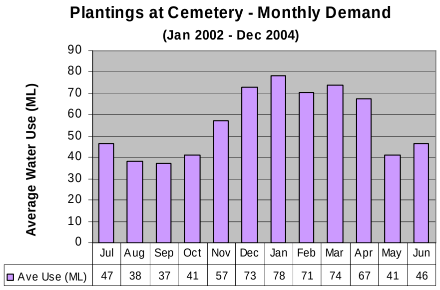
*Source: Data courtesy Dion Robins, NRG Flinders (2005)*



*Source: Data courtesy Dion Robins, NRG Flinders (2005)*



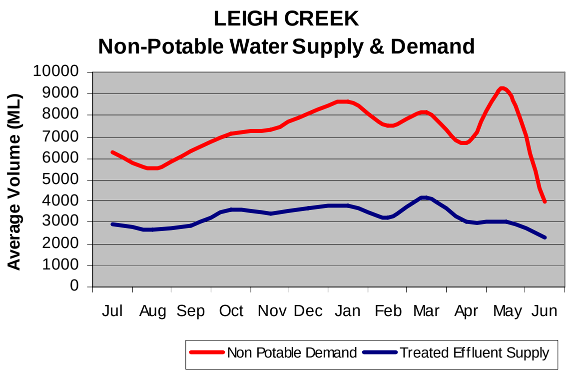
*Source: Data courtesy Dion Robins, NRG Flinders (2005)*



| | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ▨ Ave Use (ML) | 47 | 38 | 37 | 41 | 57 | 73 | 78 | 71 | 74 | 67 | 41 | 46 |

*Source: Data courtesy Dion Robins, NRG Flinders (2005)*

**SUPPLY & DEMAND MATCH** The average irrigation demand can not be met without being supplemented with potable water. Treated effluent meets between 33% and 58% of the annual demand with an average around 43%.



*Operational data courtesy of Dion Robins , NRG Flinders*

The non potable effluent supply is monitored weekly and the volume pumped into the irrigation storage is calculated on a monthly basis. Until January 2002, the volume of irrigation water applied to each different area, ie. ovals and the drippered plantings, was not known. A program to install water meters at strategic points was undertaken to provide improved operational information to the system operator (Dion Robins *pers comm*. 2005). In 2004, the cost of delivering treated effluent to Leigh Creek for irrigation purposes was $0.48/kL with the of the demand met by potable water with an average cost of $0.83/kL. (Dion Robins *pers. comm*. 2005). The overall average cost to deliver water for irrigation purposes in was $0.68kL (Dion Robins *pers. comm*. 2005). The average cost is a function of the contribution each source of water for a given year.

## WATER SENSITIVE LANDSCAPING PRACTICES

The value of water is well recognised in this town and water conservation strategies are widely promoted. Many existing trees and shrubs have been incorporated into the landscaping of both public and private areas. To conserve water public plantings use local native or Western Australian natives as much as possible, practise mulching and drip irrigation, and discourage planting of large lawns (see Figure 143). Pebbles from local creek beds are used as mulch about 100 mm thick. It is effective as weed control and allows infiltration while easing erosion (breaks the impact of the rainfall). In some areas, seasonal runoff from hard surfaces (ie. car parks) is drained into planted areas to supplement irrigation.

**Mulched Plantings (Rabone 1994)** **Native Plantings (Rabone 2005)**

**Figure 143 Leigh Creek – Low Water Use Landscaping**

Gardening in Leigh Creek, with its hot, arid climate and limited water, can be very challenging for people wanting to develop private gardens. However, a variety of techniques have been developed to help provide enjoyable gardens while using a minimum of resources. Some hardy native groundcovers make effective and attractive lawn substitutes, especially where usage and wear are minimal. They also have the advantages of needing little water, no mowing or pest control treatments. In high use areas, lawns can be replaced by paving or perhaps combined with overhead shade from pergolas or large trees. In Leigh Creek, shade in the garden is always desirable, particularly when small children will be using the garden. This can be achieved by using a shade house extension to the living room, or by planting tall spreading trees which provide shade from the summer sun (see Figure 144).

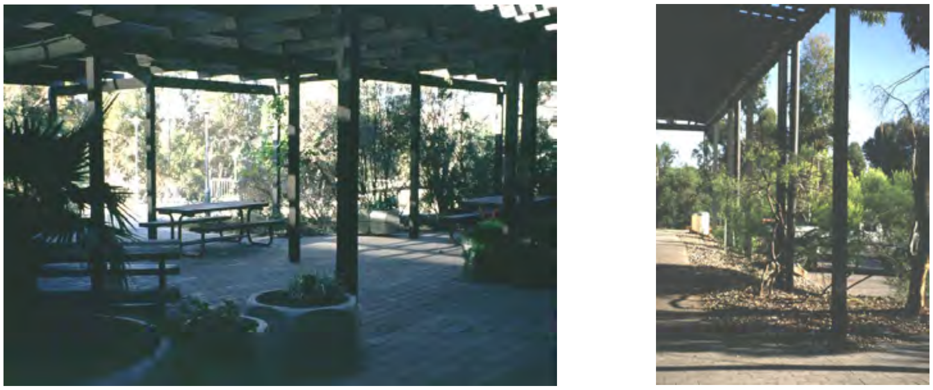


**Figure 144 Leigh Creek – Low Water Use Landscaping (Rabone 1994)**

The most effective way to reduce water consumption has been limiting the lawn size. All public grassed areas are water automatically at night. Householders are also required to water lawns at night. The maximum allowable size for lawns in home gardens is 100m$^2$. People living here have accepted constraint on lawns. As Leigh Creek is a closed town with nearly all facilities owned and managed by the mine operator it is possible to implement comprehensive water conservation techniques throughout the town (Zwar 2004).

Potable water is a limited and expensive commodity. ETSA was committed to a high level of landscape development for Leigh Creek and has created a cool, shady and relaxed environment, with some 250,000 trees, shrubs, groundcover and climbing plants established using a range of effective water conservation methods to (ETSA n.d; Beal 1991). The award winning new town of Leigh Creek South has been recognised as an excellent example of arid zone town planning (Zwar 2004). However, it is very easy for high standards to slip and the high water consumption per household indicates that it may be necessary to remind residents of their obligations towards water conserving practices. The current average water consumption per service has now approached a level comparable with the original township.

In the early 1990s, the golf club approached ETSA (former mine operator) to see about access to treated effluent but was denied full access (Beat Odermatt *pers comm*. 1993). There was not enough non-potable water available to maintain the existing grassed ovals and planted areas in summer and support additional plantings at the golf course. Water could be supplied in winter months between March and October for private storage and use in the summer months. Nevertheless, innovative and enthusiastic local members planted a number of trees without a secure irrigation supply or even an irrigation system.

The water needs of the young trees were met using a series of 20L containers with drip taps on the bottom (See Figure 145). These were filled up and brought to the golf club manually. Since then the golf course has installed a pop up sprinkler irrigation system to water plantings of around 7ha (Dion Robins *pers comm.* 2006).

**Figure 145 Leigh Creek – New Plantings on the Golf Course (Rabone 1993)**

The natural vegetation around Leigh Creek varies greatly according to soil types, aspects, prior impact and topography. The native vegetation often presents itself as being very tough and resilient. It is true that vegetation can tolerate climatic extremes of drought and frost, but if vegetation becomes damaged, it can take a long time to recover, and can lead to the destruction of wildlife habitat and to soil erosion. For example, European rabbits destroy local arid vegetation by eating young seedlings and mature plants including the roots. To combat their impact (see Figure 146) a large scale rabbit control program was implemented for Leigh Creek. Rabbits were controlled by ripping and baiting. Since its beginning, the control of rabbits has led to the natural regeneration of more than 500,000 trees and shrubs (ETSA n.d.).

**Uncontrolled Area** **Controlled Area**

**Figure 146 Leigh Creek – Effect of Rabbits on Vegetation (Rabone 1993)**

## REFERENCES AND OTHER READING

*Electricity Trust of South Australia (ETSA)*: Special thanks to Mr Beat Odermatt for showing me around Leigh Creek water, wastewater and stormwater infrastructure Creek and sharing the experiences encountered in developing and delivering the water sensitive public plantings in arid areas.

*NRG Flinders (NRG)*: special thanks also to Mr Dion Robins who provided additional information about the water, wastewater and stormwater infrastructure.

ETSA (n.d.) "*An Environmental Guide to Leigh Cree*k." Information booklet published for visitors and residents alike, about the issues pertinent to living in an arid region.

Beal,AO (1991): "*Low Water Use Horticulture – The Leigh Creek Experience*" Proceedings of the Centre for Continuing Education ANU Canberra. Arid Zone Water: A Finite Resource, Issues in water management conference, Alice Springs.

McLaren,N; Heath,D; Morias,A (1987) "*Water Conservation for Communities in Arid Areas of South Australia"* also provided useful facts on Leigh Creek.

Zwar,JR (1993): "*Water Efficient Plantings*" The Australian Garden Journal October/November 1993, 23-27

Zwar,JR (2004): "*Water sensitive Urban Design: a perspective from outback South Australia*". Paper presented at the International Conference on Water Sensitive Urban Design: Cities as Catchments, WSUD2004, Adelaide, 21-25 November 2004, 647-659.

# Lock, Eyre Peninsula (Climate Index 5)

## GENERAL STATISTICS

Lock is a small town located on Eyre Peninsula about 130km north of Port Lincoln and about 300km west of Adelaide (or 600km by road). The first settlers did not arrive until the 1860s due to the low rainfall, marginal conditions and a lack of reliable surface water resources. The land around Lock was initially held as pastoral leases. The arrival of the railway line from Port Lincoln in 1913 opened up the wheat growing potential of the region. Today, the inland areas of the Eyre Peninsula are major agricultural industries. Lock is situated almost in the geographical centre of the Peninsula with a resident population of nearly 200 people and acts as a service centre for the local thriving farming and cereal growing community of around 1000 persons. As in many South Australian towns, the recreation and social aspects of community life in Lock revolve around sport.

**Welcome Signs (Rabone 1993)**

**Grain Silos (Rabone 1993)**

## LOCK – GENERAL STATISTICS

| | | | |
|---|---|---|---|
| **CLIMATE INDEX** | 5 | | |
| **REGION** | Eyre Peninsula | | |
| **POPULATION** | 180 (Base) | 110% (Ultimate) | *District Council* |
| **URBAN FORM** | Inland rural community | | |
| **AVE. ANN. RAINFALL** | 404mm | | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 2,055mm | | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 90 (Occupied) | | *District Council of Elliston (2006)* |
| **PERSONS PER DWELLING** | 2.0 | | *Estimated* |

# WATER SUPPLY

## Early Water Supplies on the Eyre Peninsula (1860s – 1950s)

As with most of Eyre Peninsula, lack of reliable surface water resources was a problem for the first settlers of Lock due to the low rainfall and marginal conditions. Eyre Peninsula has no perennially flowing streams and little reliance can be placed on regular rains (EWS 1973). From the 1880s, the government's attention was directed to establishing water supplies on stock routes and as back-up to individual supplies of the settlers (EWS 1984). However, the extensions of the railways through Eyre Peninsula and the consequent rapid opening of the country to settlement made the problem of water supply a matter of grave concern to the Government (EWS 1973). In 1912, it was proposed that shed tanks should be built by the Government on newly surveyed land to encourage settlers to take up the land and within 4 years over 200 farm sheds and rain tanks had been erected (EWS 1984).

A Royal Commission appointed in 1916 made extensive enquiries on water supply and concluded that the lack of attention by the government to water supply was causing severe hardship to the settlers on Eyre Peninsula (EWS 1973). The government accepted responsibility for providing a regional water supply with the commencement in 1918 of the Tod Reservoir Water Scheme (EWS 1984). The Tod River, located about 30km north of Port Lincoln and 100km south of Lock, is the only stream on the Eyre Peninsula which can be relied upon in normal years to provide some flow of water (EWS 1984). The Tod Reservoir is built on a tributary of the Tod River and was completed in 1922 (EWS 1973). Since its completion the reservoir has been full on 10 occasions, ie. in 1932, 1933, 1935, 1939, 1942, 1956, 1968, 1971, 1972, and 1992.

Between 1923 and 1926, the Tod trunk main was laid to carry water from the reservoir northwards to Minnipa and then to Ceduna on the West Coast a total of 800km (EWS 1987). With the commissioning of the Tod-Ceduna pipeline, Lock enjoyed the benefit of a reliable supply of water delivered from the Tod Reservoir some 100km to the south. Ironically, two years later (ie. 1928) investigations found the Polda Basin, a groundwater resource which could provide nearly 7ML/day of freshwater, located only 40km to the west of Lock.

Underground water is available at shallow depths in various locations in the southern and western portion of Eyre Peninsula. As early as 1916, investigations had indicated the potential of using groundwater on Eyre Peninsula, but there had been much scepticism concerning the quality and long term viability of the resource (EWS 1987). In spite of this, the early years of water resources management on Eyre Peninsula focused on the development of local water resources. With a steadily increasing consumption of water on Eyre Peninsula the development of further supplies was necessary and as there are no further suitable catchments where reservoirs could be constructed, underground supplies had to be tapped (EWS 1984). In 1949, groundwater from Uley-Wanilla Basin about 20km northwest of Port Lincoln was developed to overcome shortfalls in Port Lincoln (EWS 1973). The resource proved to be plentiful and within a year the basin was linked to the entire Eyre Peninsula system.

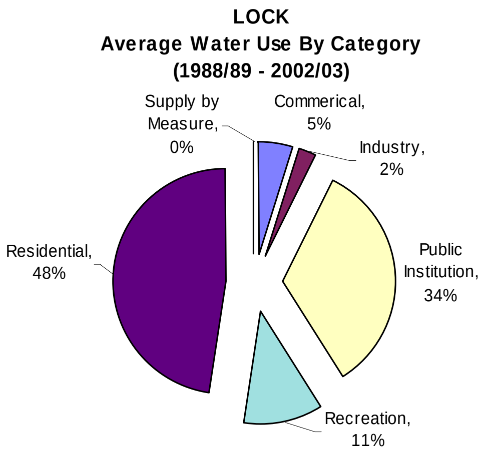
## Potable Reticulated Water Supply (1950s – 2005)

The water supply for the Eyre Peninsula is sourced from local groundwater supplies and surface water from the Tod catchment; however, since 2003 use of surface water from the Tod Reservoir ceased due to deteriorating water quality. The Southern Basin comprises the Uley-Wanilla, Lincoln, and Uley South groundwater lenses developed in 1949, 1962 and 1976 respectively. As well as these basins near Port Lincoln, good quality underground water exists in locations along the western side, about halfway up the Eyre Peninsula. The Polda Basin was developed in 1962 to augment the Tod Water Supply System. Although only 40km to the west of Lock, all water extracted from the Polda trench and bores is transferred to supply Kimba about 120km away (Francis Fung *pers. comm*. 2006).

Since 1922, the water supply to the township of Lock is provided by the Tod-Ceduna pipeline. At present, 100% of the water is sourced from the Southern Basins about 135km to the south. Through a combination of valve and pump changes there is provision to transfer water from Polda Basin to Lock township (Francis Fung *pers. comm*. 2006). Once the Iron Knob – Kimba pipeline is commissioned in 2007, the water supply for Lock township will be imported, filtered and disinfected River Murray water (Kym Bowden *pers. comm*. 2006). The new 90km Iron Knob – Kimba pipeline will interconnect the Morgan-Whyalla pipeline from the River Murray with the Eyre Peninsula water supply system and reduce the pressure on the existing groundwater basins.

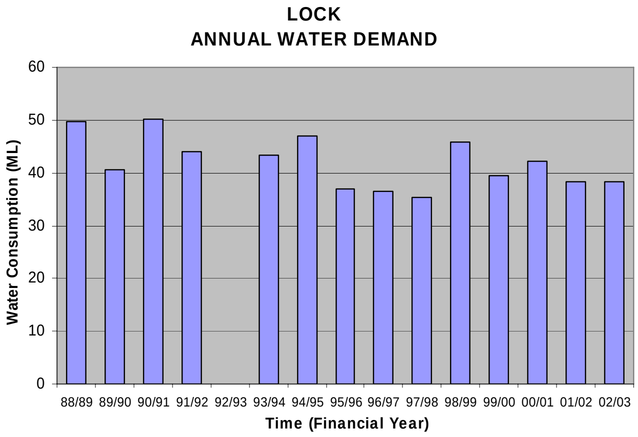
## LOCK – WATER SUPPLY STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | SA Water | | |
| **WATER SOURCE** | Groundwater from the southern bore fields of Uley South, Uley Wanilla and Lincoln lens (about 130km away) is transferred via the Tod-Ceduna pipeline. After the Iron Knob – Kimba pipeline is commissioned in 2007, water for Lock will be imported from the River Murray (ie. over 500km). | | |
| **TREATMENT** | Disinfection | | |
| **DISTRIBUTION** | Reticulated. | | |
| **RATING STRUCTURE** | Statewide pricing policy administered by the State government - pay for use with a minimum charge. . | | |
| **RETAIL PRICE PAID** | 0 – 125 kL | $0.46/kL | *Residential 2005/06* |
| | >126kL | $1.06/kL | *Residential 2005/06* |
| **AVE. WATER USE** | 317 kL/service/year<br>265 kL/house/year | | *Average 88/89 -02/03 Water Consumption Statistics* |
| | Nearly half of the water used in Lock is for non-residential purposes and just over 10% of reticulated water supply is used for community recreation facilities. | | |



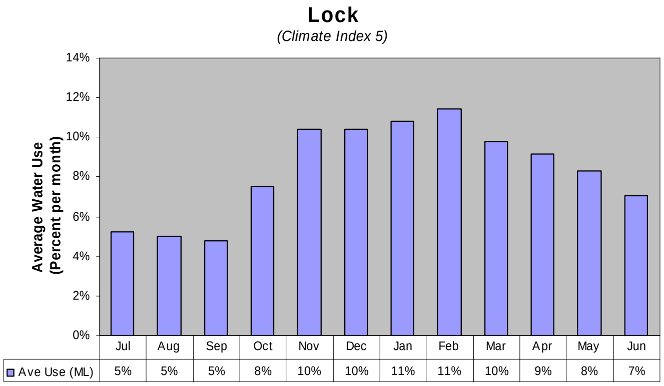
**AVE. ANN. DEMAND** 42 ML/year

*Water Consumption Statistics SA Water (1989-2003)*



*SA Water (1989 - 2003) Water Consumption Statistics*

**CONSUMPTION PATTERN** A seasonal water usage pattern is observed from looking at the water consumption information collected by SA Water.



*Source: SA Water (2001 - 2003) Water Consumption Statistics courtesy of Natasha Hall*

## STORMWATER DRAINAGE

The township of Lock has a system of surface and underground stormwater drains in place which collects rainfall from the town's impervious areas. Due to the topographical nature, the town has natural drainage towards the railway reserve on the outskirts to the east. The wide streets in Lock are sealed with bitumen which increases the volume of stormwater runoff generated (refer Figure 147).


**Wide Roads & Surface Drains** **Stormwater Discharge**

**Figure 147 Lock – Surface Stormwater Drainage System (Rabone 1993)**

The stormwater runoff collects in two separate low lying areas in railway reserve and travels in grass swales into existing low lying depressions. For years and years, the stormwater runoff was then lost to the environment, without use, by infiltration and evaporation processes. Following stormwater diversion works in 1992, runoff is harvested from two catchment areas totalling 51ha shown in Figure 148.

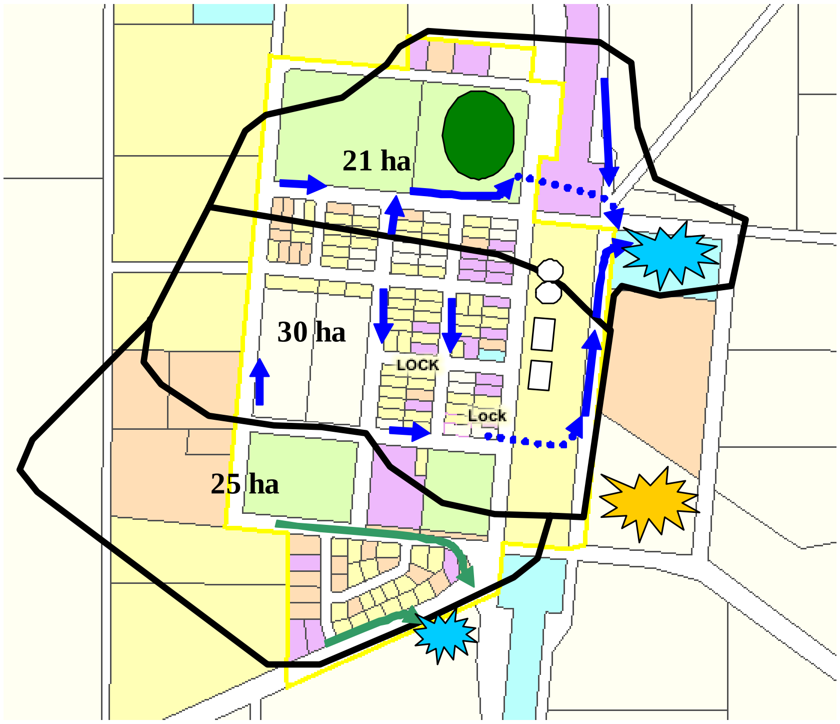


**Figure 148 Lock – Stormwater Flow Paths**

Figure 148 also shows the catchment for the Lock stormwater drainage system can be split into three zones with areas of 21ha, 30ha and 25ha from north to south (DCE 1991). All three catchments zones are a combination of developed (urban) and undeveloped (rural) land with the 30ha having the largest component of developed land (DCE 1991). Since 1993, stormwater runoff harvested from the 51ha (ie. two northern catchment zones) flows through the underground drainage and is discharged into Stormwater Dam 1 in the north eastern corner of the town. Before the dam was constructed the area was a low point where the runoff collected anyway and was lost to the environment by infiltration and evaporation.

Runoff generated from the 51ha catchment area, which includes 90% of the developed township (ie. 26ha) and all the bituminised roads in Lock, is equivalent to 75% of total stormwater runoff from the town. Until 2005, the balance of the runoff (ie. from the 25ha catchment zone) continued to be lost by evaporation and seepage in an existing low lying area to the south east of the town. Today, stormwater runoff from the southern catchment is captured in a second stormwater dam and supplements the community's non-potable irrigation supply.

## LOCK – STORMWATER DRAINAGE

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | District Council of Elliston | | |
| **CATCHMENT AREA** | Total | 76ha | *DCE (1991) study* |
| | Urban | 26ha | *Estimated from plan* |
| **ROAD DATA** | Total length | 8km | *DCE (2006).* |
| | Average width | 11m | *DCE (2006).* |
| | Kerbed | 50% | *DCE (2006).* |
| | Sealed | 70% | *DCE (2006).* |
| **RAINFALL TO PRODUCE RUNOFF** | Daily rainfall exceeds 8mm. | | *Mr Murray Wiseman (1993)* |
| **AVE. STORMWATER RUNOFF** | 55ML/year (75% is harvested) | | *Based on Fleming's Monthly Runoff Coefficients* |
| **TYPE OF DRAIN** | Underground drainage system and surface diversion culverts and open spoon drains. | | |
| **LEVEL OF TREATMENT** | Nil | | |
| **NUMBER OF DISCHARGE POINTS** | Two (after 1992 diversion works) | | |
| **DISPOSAL** | • Dam for Reuse (75%)<br>• Low lying pastoral land | | |

## WASTEWATER SYSTEM

The council provides a septic tank effluent disposal system (STEDS) to all residential and commercial properties in Lock. When it was constructed in 1970, it was common practice to provide secondary treatment of the effluent in a lagoon prior to being discharged to an adjacent low lying area. The oxidation lagoon has a total storage capacity of around 2.2ML (DCE 1991) which provides about 65 days detention (Sickerdick *pers. comm*. 2006). The volume of effluent received from the township is not recorded. On the basis of a town population of 200 people and a flow rate of 140Lpcd the total effluent discharge would be of the order of 30kL per day or 10ML per annum. The effluent lagoon is located about 250m from the south eastern corner of the town over the railway.

### LOCK – WASTEWATER SYSTEM STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | District Council of Elliston (DCE) | | |
| **WASTEWATER SYSTEM** | STEDS<br>(established with a subsidy grant) | | |
| **CONSTRUCTED** | 1970 | | |
| **EST. POPULATION SERVED** | 150 EP | (Not licensed) | *DCE (2006)* |
| **CONNECTIONS** | 100 | | *DCE (2006)* |
| **RATING STRUCTURE** | Service Charge $125pa for all properties (occupied & vacant ) | | *DCE (2006)* |
| **ANNUAL SEWAGE INFLOW** | Not recorded<br>Around 10ML/year (Estimate) | | |
| **LEVEL OF TREATMENT** | • Secondary (Lagoon) | | |
| **QUALITY TESTING** | Inflow | Intermittently | |
| | Effluent | Intermittently | |
| **AVE. EFFLUENT AVAILABLE** | Around 6ML/year (after loss due to evaporation) | | *Extracted from study for DCE (1991).* |
| **EFFLUENT DISPOSAL** | • Adjacent low lying area and evaporates | | *DCE (2006)* |

The effluent has a salinity level of 2000mg/L and is probably satisfactory for irrigation purposes but the presence of pathogenic organisms require further treatment such as chlorination to meet health standards (DCE 1991). Effluent from the town oxidation ponds could be used to supplement the non-potable irrigation supply during the summer months. Currently, treated effluent from the STEDS is not reused for irrigation purposes in Lock.

The provision of STEDS has been a partnership between the State Government and Local Government. The level of assistance (subsidy) is dependent on the estimated cost of construction and operation and rate revenue from serviced allotments. However, operation and maintenance, upgrading of the reticulation systems and treatment plants (for effluent reuse) must be financed by Councils from revenue raised by service fees (Neil Palmer *et al*. 1999; Lightbody & Endley 2002). This prerequisite may present difficulties for small towns as the components approach the end of their expected life and replacement of the existing scheme is required. In Lock, for instance the service charge for each property has traditionally been set to recover operation and maintenance costs. The District Council of Elliston reported in its annual report for 2004/05 that no reserve has been put aside for the replacement and upgrade of the Lock STEDS which is about 60% of the way through its life cycle. The challenge for the community is to undertake tariff reform which will guarantee the long term sustainability and cost effectiveness of the STEDS serving the township of Lock.

## NON-POTABLE WATER HARVESTING & REUSE

### Community Spirit & Pride

As in many South Australian townships, recreation and social aspects of community life in Lock revolve around sport. During the 1980s, the Lock Oval Watering Committee maintained the grassed oval in reasonable condition over the summer months using the reticulated town water supply on an '*as needs*' basis. However, steadily increasing price for reticulated water made it difficult for the community to meet the cost associated with continued irrigation of the town oval. Cost saving measures such as reducing the grassed area maintained and the amount of water applied were trialled. However, these resulted in a reduction in the quality of the playing surface with only marginal cost relief. The community was faced with two alternatives; (1) to cease summer irrigation of the oval or (2) develop an alternative independent water supply. A small number of motivated individuals worked to harness the community spirit and pride in safeguarding the recreation facilities.

### The 'Idea' to Meet Needs

The council and community deemed the $8,000 per year cost to irrigate the town oval with the reticulated water supply to be excessive. Financial relief was the catalyst for the small community of Lock to seek an alternative independent supply of water that would enable adequate continued irrigation of the town oval.

### Feasibility Investigations - Stage 1

Before embarking on any specific water harvesting and reuse project, the council on behalf of the community engaged an engineering consultant to assess the feasibility. The report summarised the most suitable method of harvesting stormwater and/or treated effluent to irrigate the Lock Oval. A site inspection, together with a level survey, established that runoff from the 21ha and 30ha catchments could be collected in a dam located east of the railway reserve (DCE 1991). Test pits at the selected dam site confirmed that the soils had good water holding characteristics down to a depth of at least 3m and could be used to line the floor and sides of the dam should permeable materials be encountered during the excavation (DCE 1991).

Examination of rainfall records for Lock showed that extended dry periods frequently occur between November and May. Rainfall-runoff analysis indicated the stormwater yield from the combined 51ha catchment area would be sufficient to meet the summer irrigation requirements of the oval without the need to blend with treated effluent (which is located at the opposite edge of town from the oval). The required dam storage capacity to provide 13ML of water for irrigation during drought years or years with little summer rainfall is 20ML (DCE 1991). A smaller dam of 15ML capacity would provide adequate supply for all but drought years or years with extended dry summers; that is, supply would be exhausted by March or April. The feasibility study recommended construction of the larger dam size to provide more reliable long term supply and minimise the use of mains water. On the basis of the recommendations presented in the feasibility investigation existing community support for the project was strengthened.

## Project Funding – Stage 1 & Stage 2

No outside funding was obtained for Stage 1 of the stormwater runoff harvesting project; all grant applications submitted for this stage were unsuccessful. Lock is fortunate to have an active progress association that generates a revenue stream for the community (Hitchcock *pers. comm.* 1993). The capital cost of Stage 1 stormwater harvesting was $56,000 of which the community initially contributed $40,000 (ie. just over 70%) and the council contributed $16,000 in kind (ie. nearly 30%). Over 10 years, the Council paid $30,000 back to the community (Malcolm Hancock *pers comm*. 2006). The community contribution included support from the Lock, Murdinga Tooligie Progress Association, the Lock Football Club and donations from commercial enterprises. The community also donated labour where possible to save money, for instance, the installation of the pipe to the oval (Murray Wiseman *pers. comm.* 1993).

The stormwater harvested from the streets of Lock provides an affordable source of water to maintain the oval through the summer months. In addition, the community has been able to maintain the oval over the summer period despite the introduction of permanent water use regulations for reticulated mains introduced in December 2002 for Eyre Peninsula.

**1993** **2006**

**Figure 149 Lock – Town Oval Irrigated with Stormwater (Rabone 1993)**

In 2003, the community with council support lodged a grant application for Stage 2 of the water harevestign project under the Catchment Management Subsidy Scheme. Figure 150 shows the proposed Stage 2 expansion consisting of three mini projects with an estimated value of around $265,000.

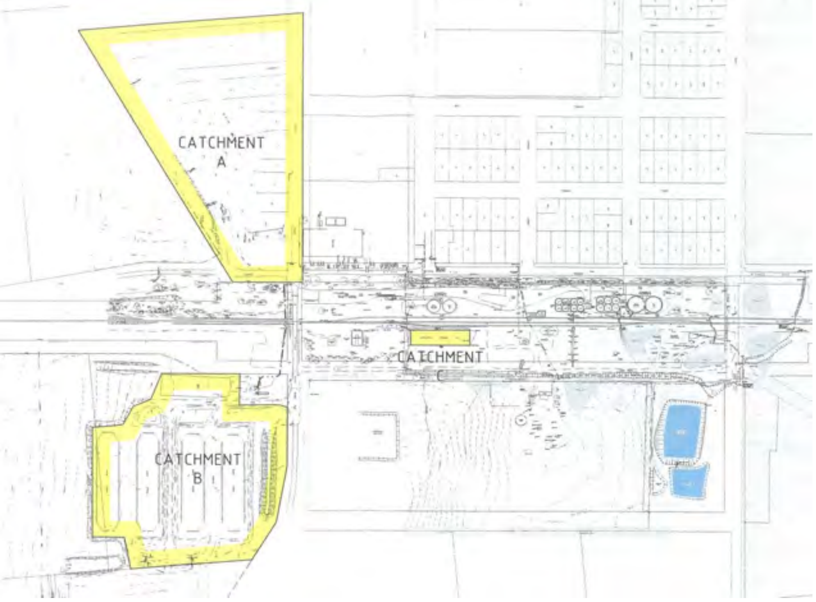


**Figure 150 Lock – Proposed Stage 2 Works (Maunsell 2004)**

The application was successful and the grant received covered 60% of the capital cost with the balance from the council and community. However, not all the moneys were expended as only two of the three mini Stage 2 projects have been constructed and commissioned. In 2005, the second stormwater dam harvesting runoff from the remaining 21ha catchment (Stage 2a) and the grain shed rainwater tank system for the bowling green (Stage 2c) and the were completed for $65,000 and $135,000 respectivley. The third dam to collect water from the Ausbulk grain storage site (Stage 2b) has been deferred pending further investigation and agreements.

## Components of the Communuity Water Harvesting System

Since 1993, a successful urban stormwater harvesting scheme has been supplying water to the Lock Oval for at least part of the summer. Stormwater harvesting was feasible because of the physical assets of the town (ie. natural slope, compact development, sealed roads with kerbs and underground drains). The existing underground stormwater system and limited number of stormwater discharge points helped to make the scheme more feasible (David Hitchcock *pers comm*. 1993). This, together with the natural drainage towards the railway track, meant most of the stormwater could be collected at one point. The 51ha catchment area comprises about 90% of the developed township. A pipeline and pumping system transfer the water to the town oval some 500m away. In 2005, the second stormwater dam was commissioned to harvest water from the remaining 25ha catchment area. Figure 151 below presents a schematic overview of the solution implemented to relieve the financial burden associated with water charges and the enable continued irrigation of the community oval.

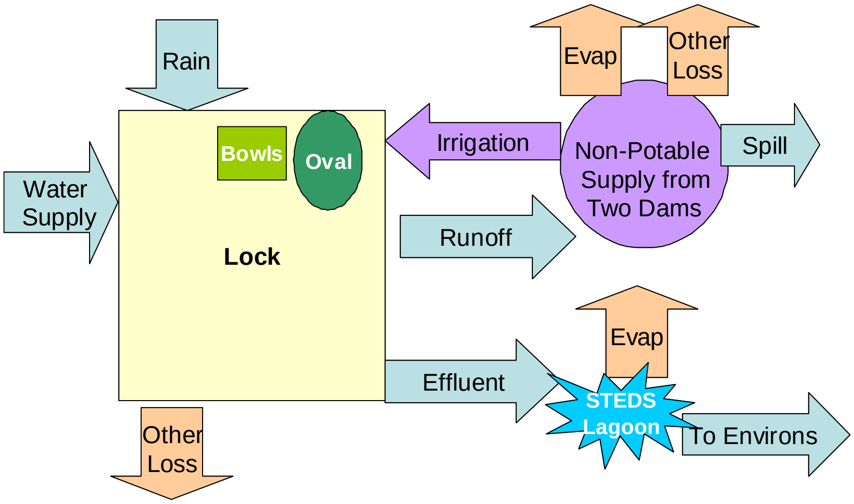


**Figure 151 Lock – Schematic of the Stormwater Harvesting System**

The solution also made the effective use and management of a valuable water resource that would otherwise not be used possible. In addition, the community expressed interest in establishing another open space recreation facility incorporating the dam as a wetland feature. Anecdotal evidence indicates that additional summer runoff is initiated when daily rainfalls exceed 8mm (Murray Wiseman *pers comm.* 1993). Gail Wiseman mentioned that when there is a good rainfall event people go down to the dam to see how much the level has risen.

Figure 152 below shows the dam excavated by private contract at the selected site on the north eastern corner of the township. Excess spoil from the excavation works was placed in an old quarry on a property in the north western corner of the town has enabled the farmer to crop this section of land (Murray Wiseman *pers. comm*. 1993). There was tremendous support from the community in time and machinery (trucks, loaders) to help with the construction and removal of overburden. The dam was ready and began to fill in June 1992 from one drain and the second drain was connected in August 1993.

**Figure 152 Lock – Stage 1 Community Stormwater Dam (Rabone 1993)**

Financial limitations meant the Stage 1 storage constructed has a capacity of 16ML rather than the 20ML storage preferred by the community. The volume of stormwater that can be stored in the dam has been estimated from measurements of the dam 90m by 67m by 3.5m deep and assuming side slopes of 1 vertical to 3 horizontal. No 'as-constructed' survey of the excavation was carried out to determine the actual capacity (David Hitchcock *pers. comm.* 2006). Pumping from the Stage 1 stormwater dam ceases when the water level in the dam drops to 0.5m (ie. nearly 3ML left in dam).

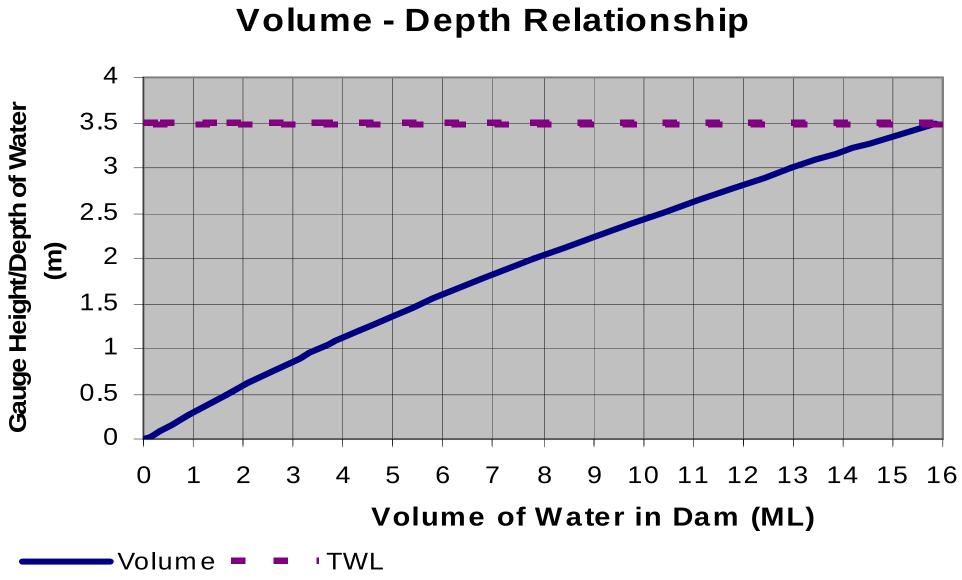


**Figure 153 Lock – Stormwater Dam 1 Volume/Depth Relationship**

The Stage 1 stormwater dam runs dry by March and is generally full again by about September. Despite concerns from the community with respect to the safety of children near open water storages, the steep sided stormwater dam was not fenced. There have been no incidents in this respect. No water quality testing is carried out. The water is not chlorinated before use on the playing surfaces. The project was not designed with research in mind so there are no records of water level in the dam and no records of extractions from Stormwater Dam 1. In retrospect it would have been valuable to install a water meter downstream of the pumps. Nevertheless, over the 10 years the Lock Community Water Harvetsing Projects has saved an estimated $120,000 in water costs. This success acted to motivate the community to explore opportunities to expand the system to other community assests such as the bowling green and the caravan park.

Following the successful application for part funding of Stage 2 in 2003, detailed engineering investigations by Maunsell in 2004, construction works commenced on Stages 2a & 2c. Figure 154 shows the second stormwater dam with capacity of 4.7ML was constructed on the southwest corner of town to collect runoff from the 21ha catchment. The Stage 2a dam was ready and began to fill with water in June 2005. Some erosion of the unprotected bank around the stormwater inlet has occurred. A solar pumping unit is used to transfer the water stored from this dam to the original dam to meet the irrigation needs of the town oval.

**Figure 154 Lock – Stage 2a Community Stormwater Dam (Rabone 2006)**

The large roof of the wheat storage complex provides a 0.19ha catchment that is ideal for rainwater collection. Rainwater from the roof is directed to balancing storage at the end of the structures and later transferred to a series of interconnected tanks with a combined capacity of nearly 0.5ML adjacent to the bowling green (see Figure 155). This water is being used to irrigate the bowling green and meets about 30% of the irrigation requirements. The balance can be supplied from new stormwater dam or reticulated mains water.

**Grain Sheds** **Balancing Storage**

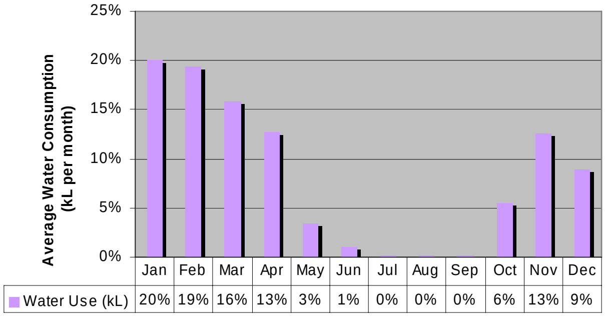
**Overseason Storage** **Bowling Green**

**Figure 155 Lock – Stage 2c Rainwater Harvesting System (Rabone 2006)**

## LOCK – NON-POTABLE WATER SUPPLY

| | | |
|---|---|---|
| **ADMINISTRATION** | Lock Muringa Tooligie Progress Association (owner & Stage 2 operator), Lock Football Club (Stage 1 operator). | |
| **WATER SOURCE** | Urban stormwater | |
| **TREATMENT** | Nil | |
| **DISTRIBUTION** | Dedicated pipe to point of use | |
| **COMMISSIONED** | 1993 (Stage 1) & 2006 (Stage 2) | *Murray Wiseman pers comm (1993)* |
| **SERVICES** | Two (Oval, Bowling Green) | |
| **QUALITY TESTING** | Nil | *Murray Wiseman pers comm (1993)* |
| **RATING STRUCTURE** | None applied | |
| **RETAIL PRICE PAID** | Not applicable | |
| **AVERAGE USE** | No records kept of water used to irrigate the oval. | |
| **LEVEL OF REUSE** | 0% (no effluent use to date) | |
| **CONSUMPTION PATTERN** | As the scheme does not include a meter, the monthly irrigation demand has been determined from 7 years of mains water consumption data recorded before the scheme was commissioned. Monthly demand is seasonal and depends on weather conditions (particularly summer rainfall). | |

**LOCK OVAL WATERING DEMAND**
**Average Monthly Use of Mains Water**
**(July 1987 to February 1993)**



| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ▨ Water Use (kL) | 20% | 19% | 16% | 13% | 3% | 1% | 0% | 0% | 0% | 6% | 13% | 9% |

*Sources: Operational data from Lock Dam Watering Committee courtesy Murray Wiseman & SA Water (1984-1993) Water Consumption Statistics*

| | |
|---|---|
| **SUPPLY & DEMAND MATCH** | The average monthly irrigation demand can generally be met until the stormwater dam runs dry (often around March). |

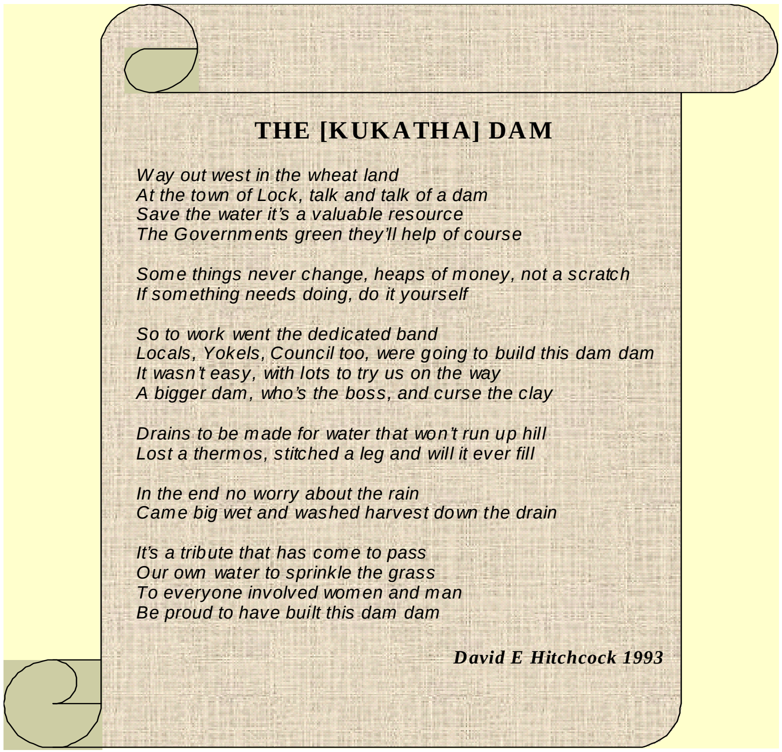
## Community Involvement & Celebrations – Stage 1

The development of the non-potable water supply for Lock was a long slow process and its success was as a result of the work by dedicated members of the community and council. The Lock experience shows that a small number of motivated individuals can be responsible for developing and using the required commitment from the local council and the community. There were a few in the community who were reluctant about the project and initially offered little support. However, the need to fund the project and undertake much of the work created a level of interest and atmosphere within the community.

**Location Recognition** **Commemorative Plaque**

**Figure 156 Lock – Stormwater Dam Community Tribute (Thyer 2000)**

The community is understandably proud of the new assets created in Lock and celebrated their achievements with a proper opening day for the dam (see Figure 156). The school children where given the task of naming the dam through a competition. The winning name, '*Kukatha*', is the name of the Aboriginal tribe that used to pass through Lock on its trade route. At the opening Mr David Hitchcock read out his poem about the construction of the dam.



**THE [KUKATHA] DAM**

*Way out west in the wheat land*
*At the town of Lock, talk and talk of a dam*
*Save the water it's a valuable resource*
*The Governments green they'll help of course*

*Some things never change, heaps of money, not a scratch*
*If something needs doing, do it yourself*

*So to work went the dedicated band*
*Locals, Yokels, Council too, were going to build this dam dam*
*It wasn't easy, with lots to try us on the way*
*A bigger dam, who's the boss, and curse the clay*

*Drains to be made for water that won't run up hill*
*Lost a thermos, stitched a leg and will it ever fill*

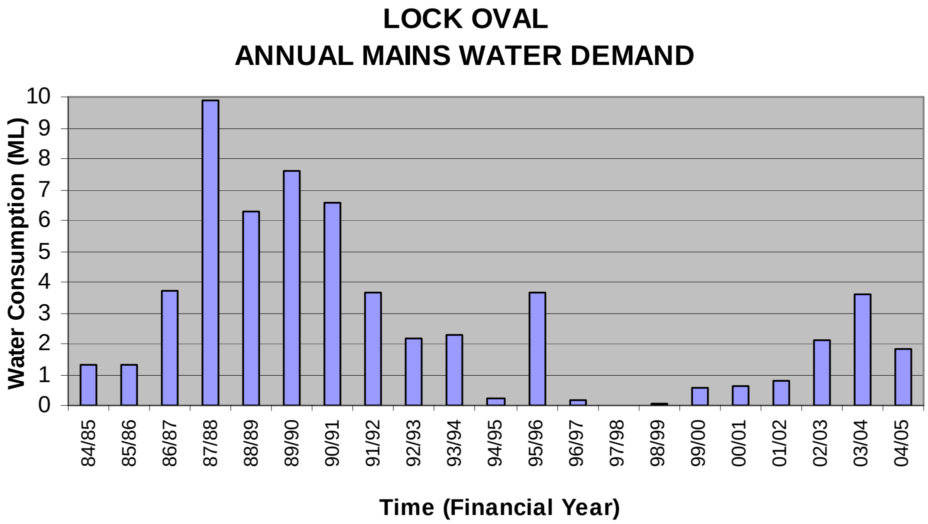
*In the end no worry about the rain*
*Came big wet and washed harvest down the drain*

*It's a tribute that has come to pass*
*Our own water to sprinkle the grass*
*To everyone involved women and man*
*Be proud to have built this dam dam*

***David E Hitchcock 1993***

## Affordability - Stage 1 Works

Since the commissioning of Stage 1 of the non-potable irrigation water supply in 1993, the community has achieved a significant reduction in the amount of potable water purchased from SA Water. Figure 157 shows the annual use of potable water for irrigation at the Lock Oval between 1984/85 and 2005/06.



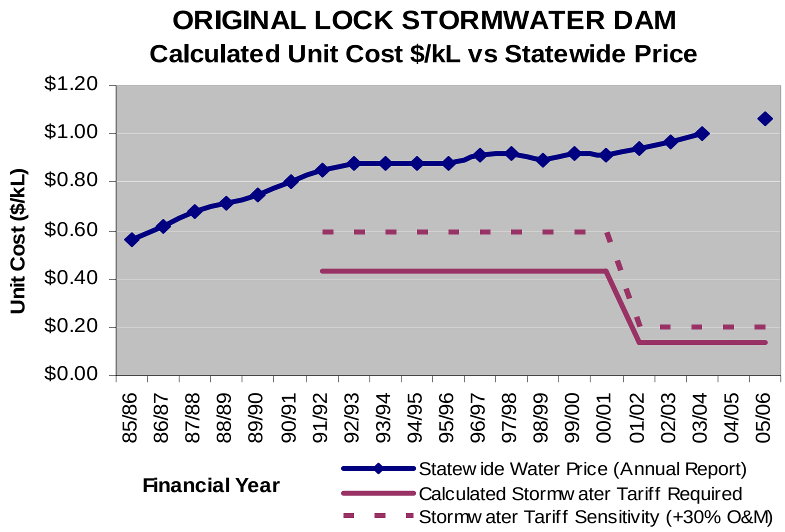
*Operational information courtesy Lock Oval Watering & Lock Dam Committees:*
*(1) Summer 1987 oval irrigation commenced*
*(2) Runoff into new stormwater dam in June 1992; dam full by October 1992.*
*(3) Irrigation with harvested stormwater commenced March 1993*
*(4) Dry summer in 1995/96 & 2003/04.*

*SA Water (1984 - 2004) Water Consumption Statistics*

**Figure 157 Lock – Historical Potable Water Use on Lock Oval**

A tariff calculation using the method recommended by the World Bank (WSP2002) has been applied to the original estimated costs for Stage 1 stormwater harvesting system. The calculation determines the required tariff to cover the cost of providing the non-potable water supply for irrigation without the application of an access charge. To test the sensitivity of the required tariff the calculation was also applied to a reduced volume of water (ie. 70% of estimated). Results of the analysis indicate that to recover original costs incurred in 1992 the estimated unit price is around half the state-wide price for mains water. Further, the state-wide price of mains water would be considerably lower than the actual unit cost incurred by SA Water to provide the service.

Figure 158 is a plot of the estimated unit price for the provision of an independent stormwater supply for irrigation against state-wide price of water for the given financial year. The plot clearly shows that as a result of the investment the community has made significant savings in watering costs compared with continued purchase of water at the state-wide price.

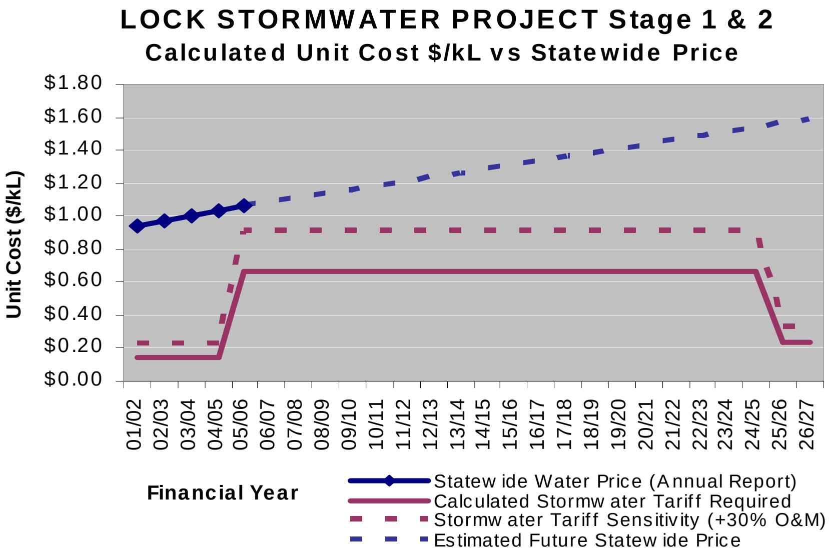


*Source: Published Statewide Water Price courtesy Trevor Govett (2004) and Project costs from Lock Oval Watering Committee courtesy of Murray Wiseman (1993)*

**Figure 158 Lock – Stormwater Unit Cost Stage 1 & Statewide Price**

## Affordability - Stage 2 Works

A similar tariff calculation analysis has been undertaken for the expanded stormwater scheme constructed during 2005. Since 18 June 2005, water has been collected in the tanks connected to the grain shed and Dam 2 (Malcolm Hancock *pers comm*. 2006). This water was first used during the 2005/06 summer on the bowling green. Figure 159 is a plot of the estimated unit price for the combined stormwater supply for irrigation of the oval and bowling greens against published and predicted future state-wide price of water. This is based on the new investment of almost $200,000 being depreciated over a 20 year period.



*Source: Published Statewide Water Price courtesy Trevor Govett (2004) and Project costs from Malcolm Hancock (2006)*

**Figure 159 Lock – Stormwater Unit Cost Stage 1&2 vs Statewide Price**

The plot shows the estimated unit price to recover costs from combined non-potable water supply system (ie. Stage 1 & 2) is around 62% of the current state-wide price. However, this increases to $2.15/kL if the $200,000 investment is recovered from just Stage 2a & 2c works which increased the volume of stormwater harvested and stored by just over 5ML per annum.

### Tariff Setting (Stage 1 & 2 Current Operations)

The cost of providing a water service depends very much on the price of the inputs, like energy cost and financing infrastructure investments. In Lock, the cost of operating the stormwater supply is met from the users, the Lock Football Club pays for power costs and repairs to Stage 1 works and the Bowling Club pays the power costs for Stage 2. No allowance is included to purchase water at the statewide price for the remainder of the irrigation season but this cost is met by users. Based on an estimated average volume of water used each year and historical cost information the unit cost of providing the stormwater supply with supplementary use of drinking water is as set out in the table below.

**LOCK – Stormwater Supply Tariff Calculation (Stage 1 & 2)**

| | **Budget (1)** | **Historical Costs (2)** | | | |
|---|---|---|---|---|---|
| | **2005/06** | **2004/05** | **2003/04** | **2002/03** | **2001/02** |
| **System Information** | | | | | |
| No. of Connections | 2 | 1 | 1 | 1 | 1 |
| Annual Water Used (3) | 21,700kL | 14,820 kL | 12,600 kL | 15,115 kL | 13,800 kL |
| **Annual Costs** | | | | | |
| • Electricity (4) | $ 500 | $ 400 | $ 400 | $ 400 | $ 400 |
| • Water source fee (5) | $ 6,910 | $ 1,875 | $ 3,598 | $ 2,050 | $ 661 |
| • Maintain – Dam | $ 850 | $ 500 | $ 2,500 | $ 500 | $ 500 |
| • Maintain - Network | $ - | $ - | $ - | $ - | $ - |
| • Depreciation (6) | $ 9,975(6) | $ - | $ - | $ - | $ - |
| • Chemicals | $ - | $ - | $ - | $ - | $ - |
| • Loan Repayment | $ - | $ - | $ - | $ - | $ - |
| • Interest | $ - | $ - | $ - | $ - | $ - |
| • Salaries | $ - | $ - | $ - | $ - | $ - |
| **Overheads** | | | | | |
| • Office, Training | $ - | $ - | $ - | $ - | $ - |
| • WQ Monitoring | $ - | $ - | $ - | $ - | $ - |
| **Total Annual Cost** | **$ 18,235** | **$ 2,775** | **$ 6,498** | **$ 2,950** | **$ 1,561** |
| **Tariff Required** | **$0.91/kL(8)** | **$0.20/kL(7)** | **$0.56/kL(7)** | **$0.21/kL(7)** | **$0.12/kL(7)** |
| **State Unit Price(9)** | $1.06/kL | $1.03/kL | $1.00/kL | $0.97/kL | $0.85/kL |

(1) *Budgeted operational costsfor Stage 1 & 2 courtesy of Mr Malcolm Hancock (2006)*
(2) *Historical operational costs for Stage 1 courtesy of Mr Malcolm Hancock (2006)*
(3) *Average annual volume usde from the stormwater dam plus potable water used to supplement the supply.*
(4) *Estimation of power costs as pumping station is not separately metered.*
(5) *The cost to purchase potable water from SA Water to maintain the non-potable water supply to oval has been calculated from the metered annual volume and the presiding unit charge for each financial year.*
(6) *New Assets depreciated over a 20 year period (even though life of major asset could be > 80years)*
(7) *Historical unit cost of Stage 1 stormwater irrigation operation assuming no access fee is applied.*
(8) *Unit cost for operation of Stage 1 & Stage 2.*
(9) *Statewide unit price that applied in the year for each stormwater unit cost calculation*

This analysis shows the impact of the inputs such as potable water costs due to low annual rainfall with dry summer and large maintenance expenditure for the major pump overhaul in 2003/04. Nevertheless, assuming the original investment had been depreciated over the first 10 years of operation, the actual cost of providing the non potable water supply (Stage 1) varied between 18% and 50% in comparison to the current $1.06/kL unit cost of reticulated water. The Lock stormwater harvesting scheme demonstrates the potential for such schemes in making irrigation of recreational areas affordable.

### Further Potential

There is further potential to increase the capacity of this secondary water supply by further expanding to include an estimated 10ML from STEDS effluent and/or 4ML runoff from the 6.6ha ABB catchment (DCE 2004). These were not investigated extensively in 1991 study commissioned by the District Council of Elliston as water adequate to meet demand is available from the proposed sources.

## WATER SENSITIVE LANDSCAPING PRACTICES

No specific water sensitive landscaping practices were observed.

## REFERENCES AND OTHER READING

Special thanks to Mr Murray & Gail Wiseman for showing me around the water, wastewater and stormwater infrastructure in Lock and sharing the experiences encountered in developing and delivering Stage 1 of the stormwater harvesting scheme. Thanks also to Mr Malcolm & Joy Hancock for providing additional information and sharing the experiences in developing Stage 2 of the scheme.

*District Council of Elliston (DCE)*: thanks Mr Rob McGregor and Mr Wayne Schultz who provided additional information about the wastewater and stormwater infrastructure.

DCE (1991) "*Irrigation Feasibility Study at Lock Oval*". This report prepared by Dare Sutton Clarke Pty Ltd for the local council provided useful facts on Stage 1 of the water harvesting scheme.

DCE (2003): "*Lock Community Water Harvesting Project.*" Application for funding submitted to Catchment Management Subsidy Scheme, January 2003.

DCE (2004): "*Lock Stormwater Reuse Project.*" Report prepared by Maunsell Pty Ltd for the local council provided useful facts on Stage 2 of the harvesting project.

EWS (1973): "*Water Supplies on the Eyre Peninsula*". Information Bulletin issued by the Engineering & Water Supply Department, October 1969. Revised April 1973

EWS (1984): "*Eyre Peninsula Water Resources Management Review*". Report by the Engineering & Water Supply Department. Library Reference 83/45, June 1984

EWS (1987): "*Water Resources Development 1836-1986*". The historical background to the water resources management strategy for South Australia

Eyre Peninsula Times (2005): "*Lock dam ready to go.*" Article by Jodie Brown appeared 02/06/05 in General News, 3.

SA Water (2003); "*Eyre Peninsula Water Supply Master Plan*". Report prepared by Parsons Brinckerhoff, May 2003.

# New Haven Village, Adelaide & Mt Lofty Ranges (Climate Index 4)

## GENERAL STATISTICS

New Haven Village is a 65 home housing development on a 2 hectare site approximately 20 kilometres from the Adelaide central business district. New Haven Village was opened in May 1995 and the first display home was opened by mid 1996. The housing estate features engineering innovations which radically change the way water and waste water is managed within a development. It demonstrates an advanced water management system, with mains water pipes entering the site but no pipes leaving it. Key water management initiatives include the on-site treatment and reuse of household effluent, an innovative stormwater drainage system, and use sub surface irrigation. The on-site treatment and reuse of household sewage (black water and grey water) and first-flush stormwater runoff, means that virtually no waste water leaves the housing development.

### GENERAL STATISTICS

| | | |
|---|---|---|
| CLIMATE INDEX | 4 | |
| REGION | Adelaide | |
| POPULATION | 150 | *Estimated* |
| URBAN FORM | Urban, medium density (33 houses per ha) | |
| AVE. ANN. RAINFALL | 530 mm | *Burrows (1987)* |
| AVE. ANN. EVAP. | 1935 mm | *Burrows (1987)* |
| NUMBER OF DWELLINGS | 64 | |
| PERSONS PER DWELLING | 2.4 (average) | *ABS (2001) CENSUS* |

The main purpose of the development was to demonstrate and evaluate ideas for urban water harvesting and reuse which might be applied in larger scale developments.

**Table 54 New Haven Village – Scorecard of Goals & Achievements**

| **2004 REPORT CARD – WATER SERVICES AT NEW HAVEN VILLAGE** | | | | |
|---|---|---|---|---|
| **GOALS** | > | = | < | **COMMENTS** |
| 1. REDUCE DEMAND ON EXTERNAL (POTABLE /FILTERED) WATER SUPPLY BY 60% | | | ✓ | • Water use data indicate that demand on external (potable/filtered) water supply into households is around 40% of total water requirements with toilet flushing and garden watering excluded. However, since late 2000, external (potable/filtered) water has also supported toilet flushing and garden watering requirements due to problems with disinfection of the treated effluent. |
| 2. MINIMISE FLOOD AND WASTEWATER DISCHARGES FROM SITE | | ✓ | | • Stormwater is retained on site via an underground soakage trench and the adjacent sports field that acts as a retention basin in case of heavy rainfall.<br>• All wastewater is collected and treated on site for reuse. However since late 2000, all of it has been directed to the playing field until adequate disinfection levels can be established. |
| 3. ESTABLISH A VIABLE LOCALLY MANAGED SERVICE TO RESIDENTS BELOW THOSE OF CENTRAL SYSTEMS | | | ✓ | • The viability of the integrated water supply would be measured by the commercial viability and simplicity of operation by the local council (ie. post 3-year support from partners).<br>• The cost effectiveness of the ongoing management and maintenance of a local integrated water management system has not been demonstrated. Analysis of financial information indicates that the cost to supply recycled water '*non-potable*' use is about 2 times the cost of mains water. |

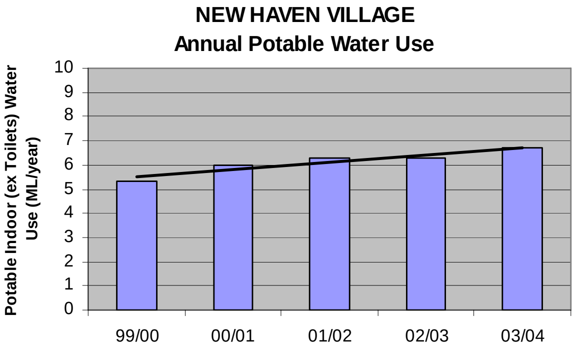
| | |
|---|---|
| > | *Better than planned* |
| = | *As planned* |
| < | *Less than planned* |

## WATER SUPPLY (POTABLE)

At New Haven Village the domestic water needs are met by provision of dual water supply to each allotment, that is, the first service dedicated for potable purposes (in house use excluding toilet flushing) and a second for non potable uses (toilet flushing and garden watering). Each household receives a metered potable water supply from SA Water in the same manner as neighbouring suburbs and traditional developments. However, the internal plumbing of houses in the estate means that potable mains water is not used for toilet flushing or garden watering. The average household potable use (excluding toilet flushing and garden watering) in New Haven Village is 110kL based on water consumption data for the 5 year period from 1999/2000 to 2003/04.

## NEW HAVEN VILLAGE – POTABLE WATER SUPPLY

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | SA Water | | |
| **WATER SOURCE** | River Murray & Adelaide Hills runoff water treated at Hope Valley. | | |
| **TREATMENT** | Filtered and disinfected | | |
| **QUALITY TESTING** | Source | As per ADWG | |
| | Product | As per ADWG | |
| **DISTRIBUTION** | Reticulated | | |
| **SERVICES** | 64 | | |
| **RATING STRUCTURE** | Two part tariff, state-wide unit rates | | |
| **RETAIL PRICE PAID** | Access Charge | $135/year | *Residential 2003/04* |
| Use | 0 – 125 kL | $0.42/kL | *Residential 2003/04* |
| | > 125kL | $1.00/kL | *Residential 2003/04* |
| **AVE. WATER USE** | 110 kL/service/year | | *5 year average for 99/00 – 03/04* |
| **AVE. ANN. DEMAND** | 6425 ML/year | | *3 year average for 01/02 – 03/04* |



| | |
|---|---|
| **CONSUMPTION PATTERN** | Consumption is expected to be relatively constant from month to month (ie. no seasonal irrigation) |

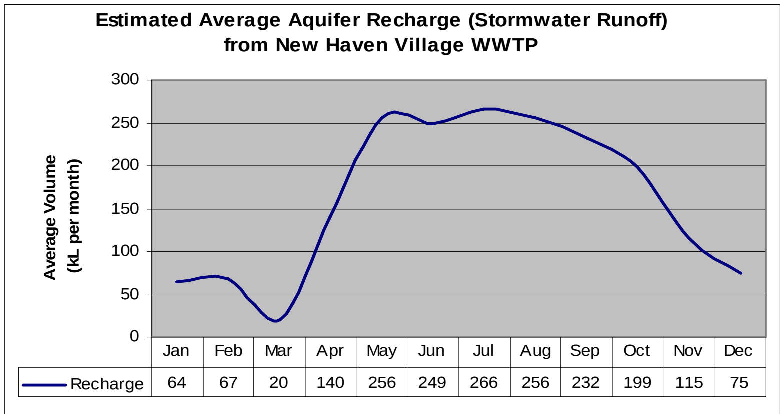
## STORMWATER DRAINAGE

The underground stormwater pipes are located centrally in the service corridor, directly under a central spoon drain as seen in Figure 160. Stormwater runoff enters the system through the grated sump inlets (rather than the traditional side entry pits) which, act as a gross pollutant trap preventing cans, milk cartons and other litter from entering the system.

**Figure 160 New Haven Village – Streetscape & Drains (Rabone 2000)**

The system has been designed to collect the first 25kL of a rainfall event (ie. equivalent to first 3mm) in an underground concrete tank. From this tank, the first flush stormwater is delivered 10kL at a time (to prevent dilution of sewage in the primary tank) to the WWTP. Once the stormwater storage tank is full, stormwater is bypassed to a soakage trench (1.2m$^2$ and 18m long). The overflow infiltrates into underlying aquifers and the trench is empty after a dry period of five days (Thomas 1999). During extremely heavy rainfall events, the soakage trench can overflow to the sports field (1.6ha) which has been lowered (about 500mm) to act as a stormwater retention basin.

This arrangement ensures that the no runoff from housing estate is discharged from the site. However, with the exception of the small first flush that is treated onsite, none of stormwater runoff harvested from the urban area is used in the recycled water supply. Figure 161 shows that in an average year around 1.9ML of stormwater can be harvested and stored in the aquifer below the playing fields in winter to meet part of the summer demand.



*Potential Recharge by stormwater being the difference between estimated stormwater runoff derived using monthly volumetric runoff coefficients for urban areas by (Fleming 1994) and measured first flush stormwater transfers to WWTP.*

**Figure 161 New Haven Village – Estimate of Stormwater Runoff Harvested**

## WASTEWATER SYSTEM

All household sewage is piped to a pumping station underneath the adjacent reserve and from there to the on-site wastewater treatment plant. The wastewater treatment plant is located under the main oval and the treated water is used for flushing toilets and for irrigation of gardens, road verges and reserves. The package treatment plant provides tertiary treatment. The plant is designed for 150 equivalent persons, an average dry weather flow of 36 kilolitres per day and to treat an influent BOD5 of 290mg/L (Thomas 1999). A private contractor is contracted to the council for the operation and maintenance of the sewage pumping station and wastewater treatment plant.

Following treatment, the effluent is sand filtered and pumped through ultraviolet disinfection unit. After disinfection the water is stored in two 22.5 kL underground concrete storage tanks for recycling to the oval, village gardens and toilets. Prior to reuse (before the effluent is pumped to the village and the oval) it is further filtered as a final safeguard to ensure no blockages occur in the subsurface irrigation systems at the reserves or at residences. Potable mains water supply backup is automatically available to '*top up*' the recycled water supply system when it is necessary to take the wastewater treatment plant off line (Thomas 1999). The quality of treated effluent has not reliably met specified requirements and for this reason since 2000 potable water has been supplied to the village in the non-potable water supply system.

Figure 162 shows that the cost to treat wastewater on site at New Haven Village ranged between $3.60 and $4.70 per kL with an average of $4.40 per kL over the 5 year period from 1999/2000 to 2003/04. This cost does not include an annualised amount for capital cost of the infrastructure which was provided as a free asset as part of the development.

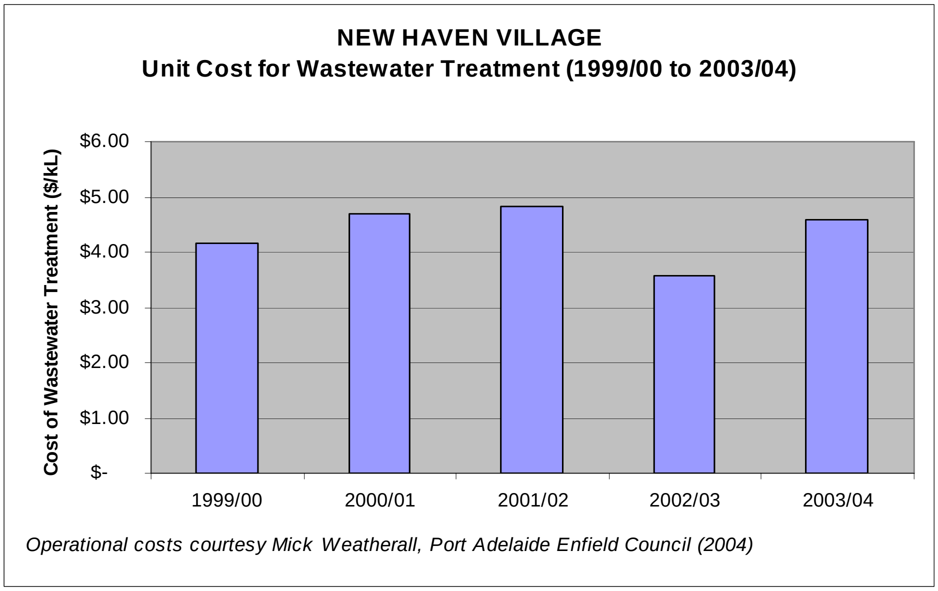
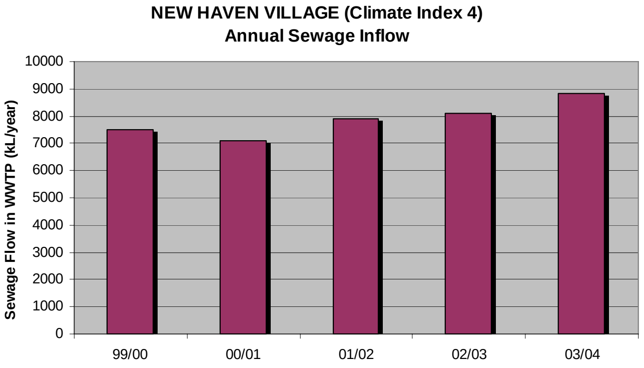


**Figure 162 New Haven Village - Unit Cost of On-site Wastewater Treatment**

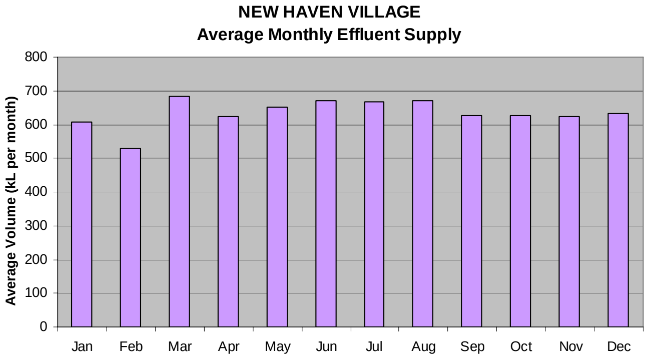
## NEW HAVEN VILLAGE – WASTEWATER SYSTEM

| | | |
|---|---|---|
| **ADMINISTRATION** | Port Adelaide Enfield Council | |
| **WASTEWATER SYSTEM** | Full wastewater system | |
| **CONSTRUCTED** | 1999 | |
| **EST. POPULATION SERVED** | 150 EP | |
| **CONNECTIONS** | 64 | |
| **RATING STRUCTURE** | Council rating policy set equivalent to sewerage rates for SA Water systems. | |
| **ANNUAL SEWAGE INFLOW** | 7ML/year (sewage inflow only) | *Average calculated from 99/00-03/04* |



*Note: Development reached 100% in 2001/02*
*Data courtesy David Potter (Aeroflow) & George Levay (Port Adelaide Enfield Council)*

| | | |
|---|---|---|
| **LEVEL OF TREATMENT** | • Secondary Treatment<br>• Disinfection | |
| **AVE. EFFLUENT AVAILABLE** | 7.5ML/year (inc. first flush runoff) | *Average calculated from 99/00-03/04* |



*Operational data courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*

| | |
|---|---|
| **EFFLUENT DISPOSAL** | • Non-potable water supply<br>• Oval irrigation system |

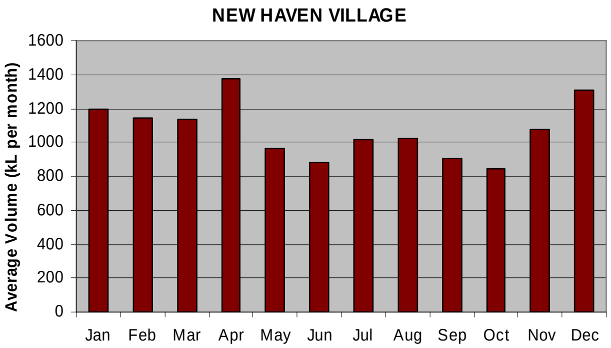
## NON-POTABLE WATER HARVESTING & REUSE

Residential properties in New Haven Village have been provided a non potable water supply for toilet flushing (constant demand) and garden watering (seasonal demand). This non-potable supply is also used to maintain the adjacent 1.6ha playing field which has a seasonal irrigation requirement.

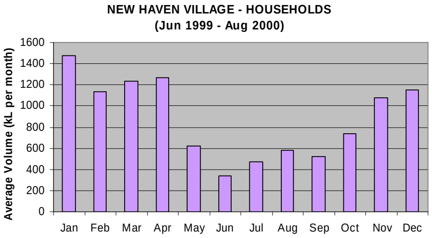
**Figure 163 New Haven Village - Oval Irrigated with Effluent (Rabone 2000)**

## NEW HAVEN VILLAGE – NON-POTABLE SUPPLY

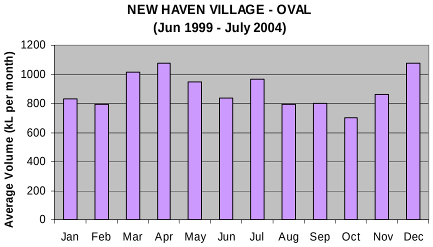
| | | |
|---|---|---|
| **ADMINISTRATION** | Port Adelaide Enfield Council | |
| **WATER SOURCE** | Treated effluent/Potable water | |
| **DISTRIBUTION** | Reticulated to households | |
| **COMMISSIONED** | 1999 | |
| **SERVICES** | 65 | |
| **QUALITY TESTING** | Monthly | |
| **RATING STRUCTURE** | Additional rate based on the property value | |
| **RETAIL PRICE PAID** | NA | |
| **AVE. EFFLUENT USE** | 22 ML/year (inc. potable top up) | *Average calculated from 99/00-03/04* |
| **LEVEL OF REUSE** | 100% of effluent treated | |
| **CONSUMPTION PATTERN** | The monthly demand for non-potable water is actually seasonal depending on the irrigation requirements. However, the average consumption pattern appears relatively constant. This is because since 2000 all effluent treated is disposed directly by irrigation to the playing field (ie. no storage). | |



*Operational data courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*



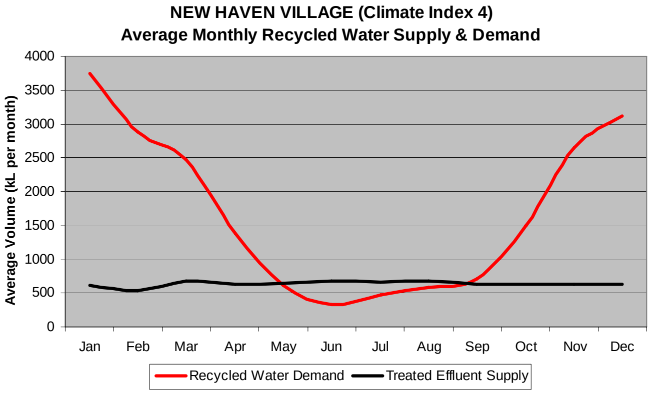
*Operational data courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*



*Operational data courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*

## SUPPLY & DEMAND MATCH

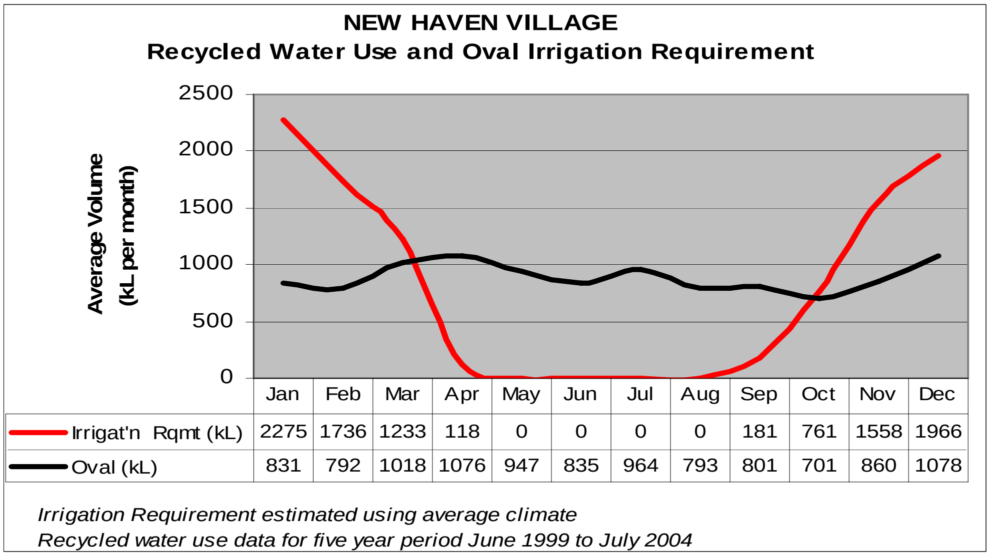
The demand for non-potable water is seasonal as it is made up of the seasonal irrigation requirements of the oval and the garden watering as well as the constant demand for toilet flushing. The average monthly supply and demand for non-potable supply is based on operational data for a period of 59 months from September 1999 to July 2004. Being derived from in house water use, the supply of treated effluent is relatively constant. However, between October and April, the supply can not meet the demand. Mains water is used to '*top-up*' the recycled water supply to meet the seasonal demand.



*Operational data courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*

## Operational Matters

Since September 2000, the reticulated non-potable water supply has not been operating as designed. Research by Thomas (1999) indicated that New Haven Village WWTP has failed to reliably meet the reclaimed water guidelines set for reuse. Originally, all irrigation systems on the estate were subsurface, however, after only 3 years approximately 50% of the houses had installed above ground irrigation (Thomas 1999). This increases the possible exposure risks associated with wastewater reuse through inhalation of aerosols, contact with spray residues or surface runoff and ingestion of pathogens. In response to the potential health risks all the treated effluent has been delivered to the oval via the subsurface irrigation system while the toilet flushing and garden watering requirements in New Haven Village have been met from potable mains water. The average monthly recycled supply and demand from the oval for this mode of operation is shown in Figure 164.



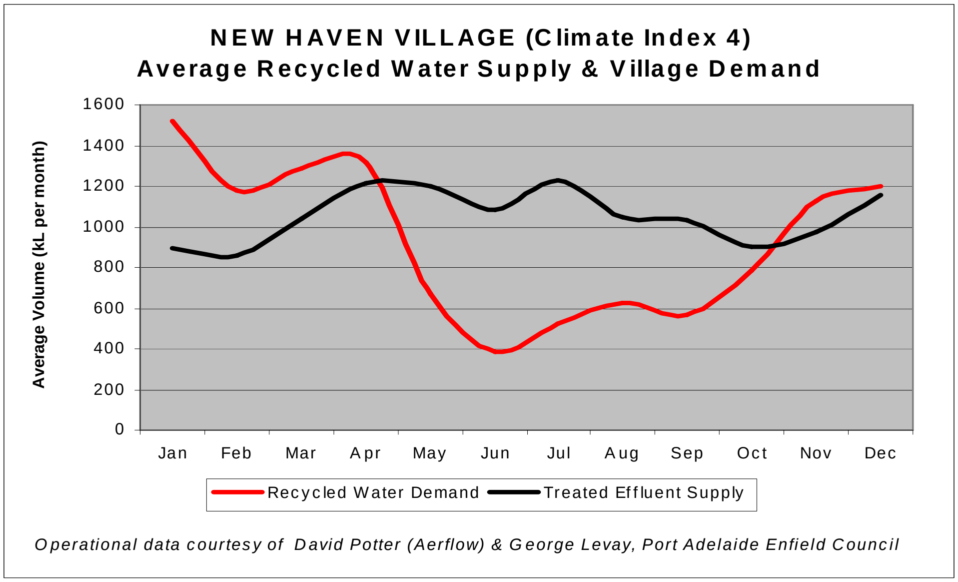
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 🟥 Irrigat'n Rqmt (kL) | 2275 | 1736 | 1233 | 118 | 0 | 0 | 0 | 0 | 181 | 761 | 1558 | 1966 |
| ■ Oval (kL) | 831 | 792 | 1018 | 1076 | 947 | 835 | 964 | 793 | 801 | 701 | 860 | 1078 |

*Irrigation Requirement estimated using average climate*
*Recycled water use data for five year period June 1999 to July 2004*

**Figure 164 New Haven Village - Effluent Supply & Irrigation Requirement**

Clearly, the constant supply of treated effluent and the seasonal demand for oval irrigation water, mean the oval is over irrigated between April and October. The treated effluent delivered to the oval subsurface irrigation system in excess of the irrigation requirement will infiltrate and recharge the aquifer in the same manner as the stormwater does via the stormwater soakage trench. The volume of treated effluent that is recharging the aquifer is around 5,100kL per annum. In addition, this mode of operation requires around 4,250kL per annum of potable mains water to top-up the recycled water supply to meet the oval irrigation needs in summer.

Figure 165 shows that if the oval adjacent to New Haven Village was not irrigated from the wastewater the 'village' residential demand could be met with little need for mains supplement water particularly if the treated effluent and stormwater can be stored in the aquifer in winter and extracted to meet the summer demand. The average demand for recycled water by the village is around 11,200 kL per year and the average supply of treated effluent is around 10,700 kL per annum. This demand can change seasonally depending on rainfall.

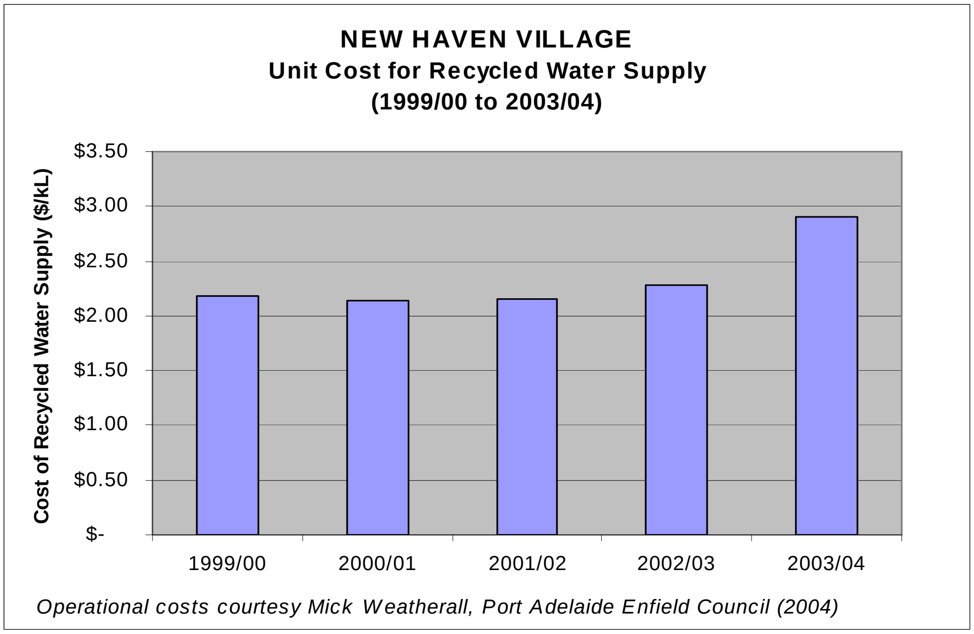


*Operational data courtesy of David Potter (Aerflow) & George Levay, Port Adelaide Enfield Council*

**Figure 165 New Haven Village - Treated Effluent Supply & Village Demand**

## Affordability

Unlike the potable water supply, the non potable water supplied to individual households is not metered. Residents are levied an additional rate based on the property value for the wastewater treatment and recycled water supply as part of the annual council rates. The rating policy adopted by the Port Adelaide Enfield Council limits the revenue received for the wastewater treatment and recycled water supply to an amount equivalent to SA Water sewerage rates incurred by people living neighbouring suburbs. Figure 166 presents the unit cost to the council for provision of onsite wastewater treatment and recycled non-potable water supply.



*Operational costs courtesy Mick Weatherall, Port Adelaide Enfield Council (2004)*

**Figure 166 New Haven Village - Unit Cost of Recycled Water Supply**

The unit cost shown includes the cost of purchasing potable mains water from SA Water to 'top-up' the recycled water supply system. The unit cost does not include an annualised amount for the dual reticulation infrastructure as the capital cost is not known and was provided as a free asset as part of the development. Even so, the unit cost is considerably higher than the current price of $1.06 c/kL to use potable mains water to irrigate reserves, toilet flushing and garden watering.

The charges to recover the full cost of the scheme are too high when price for potable mains water. The current irrigation regime applies more water than is necessary to maintain healthy turf. A significant amount of water is being recharged to the aquifer which is not being recovered for use to meet summer demands. The future implementation of these systems is strongly dependent of the ability to consistently provide quality treated effluent at minimal risk to the health of the consumer.

## WATER SENSITIVE LANDSCAPING PRACTICES

No specific water sensitive landscaping practices were observed.

## REFERENCES AND OTHER READING

Special thanks to Mr David Potter for arranging to show me around New Haven Village and its water, wastewater and stormwater infrastructure.

*Port Adelaide-Enfield Council*: thanks Mr George Levay and Mr Mick Wetherall who provided additional information about the wastewater and stormwater infrastructure.

Thomas,KD (1999) *"Critical Analysis of the Factors Affecting the Success of Programs for the Sustainable Recycling and Reuse of Water"*. This thesis submitted in partical fulfillment of the award of Honors Degree of Bachelor of Science at Flinders University of South Australia provided useful facts on the water harvesting and reuse scheme.

# Oodnadatta, Far North (Climate Index 21)

## GENERAL STATISTICS

Oodnadatta, on the Neales River, is a small isolated town in the far north of South Australia with a mixed Aboriginal and European population located about 100km north of Adelaide. It was surveyed in 1890 and proclaimed in 1897. The name is derived from '*utnadata*' meaning '*mulga blossom*'. It became the end of the railway line from the south, between 1891 and 1929, when the rail link to Alice Springs was completed. In 1981 the railway was replaced by a new line 100km further to the west.

**Aerial View of Town (Peter Martin 2002)**

**Location of Hawker**
*(http://en.wikipedia.org/wiki/Hawker)*

The South Australian Outback is promoted as a tourist destination, and many communities provide services for visitors, government and industry (SA Water 2005). There is no all weather road access and the town is sometimes isolated after heavy episodic storm rains.

## OODANADATTA – GENERAL STATISTICS

| | | |
|---|---|---|
| **CLIMATE INDEX** | 21 | |
| **REGION** | Far North | |
| **POPULATION** | 185 (Base) | *ABS (1991) CENSUS* |
| **URBAN FORM** | Inland rural community | |
| **AVE. ANN. RAINFALL** | 176mm | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 3,714mm | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 65 (Occupied) | *Estimate based on water service numbers* |
| **PERSONS PER DWELLING** | 2.8 | |

## WATER SUPPLY

In the far north of the South Australia, surface water resources are almost non existent and so northern inland areas rely primarily on bores, springs or small dams. However, many Outback water supplies do not meet health and water industry standards (SA Water 2005). Water supply drawn from the Great Artesian Basin groundwater resources in the area contain naturally elevated levels of sulphate, iron and salinity. Many townships do not conform to health and aesthetic drinking water standards and their water supplies are declared by the State government as '*non-potable*'. Oodnadatta is one of these remote towns with a non-potable and residents at the towns have been advised that it is not suitable for drinking (SA Water 1998). Water can be supplied to the township through two artesian bores drilled to 475m and 440m in 1894 and 1974 respectively. Water drawn from the bores is pumped direct to the distribution system and into an elevated tank. The water are known to be corrosive to concrete.

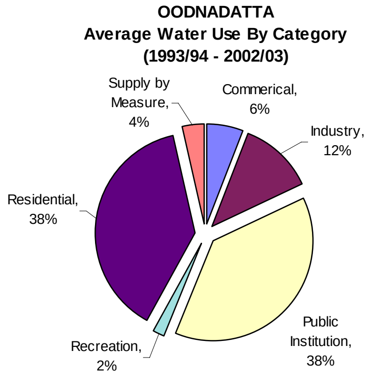
**Bore No 1** **Elevated Tank**

**Figure 167 Oodnadatta – Water Supply Infrastructure (Rabone 2003)**

## ODDNADATTA – WATER SUPPLY STATISTICS

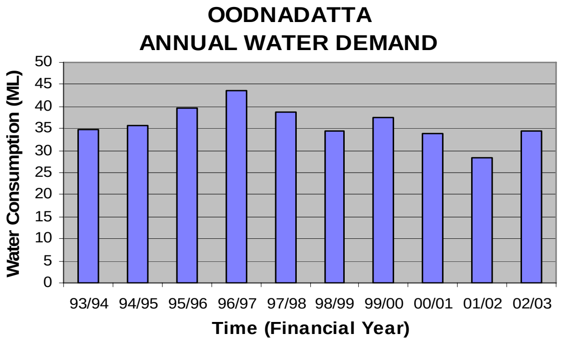
| | | | |
|---|---|---|---|
| **ADMINISTRATION** | SA Water | | |
| **WATER SOURCE** | Local groundwater. This has elevated levels of sulphate, iron and salinity making it unsuitable for drinking purposes. | | |
| **TREATMENT** | Nil (limited cooling in tanks) | | |
| **DISTRIBUTION** | Reticulated 'non-potable' supply. | | |
| **RATING STRUCTURE** | Statewide pricing policy administered by the State government - pay for use with a minimum charge. . | | |
| **RETAIL PRICE PAID** | 0 – 125 kL | $0.46/kL | *Residential 2005/06* |
| | >126kL | $1.06/kL | *Residential 2005/06* |
| **AVE. WATER USE** | 545 kL/service/year | | *Average 93/94 -02/03 Water Consumption Statistics* |
| | 346 kL/house/year | | |

Around 60% of the water used in Oodnadatta is for non-residential purposes. Only a small amount is used for community recreation facilities.



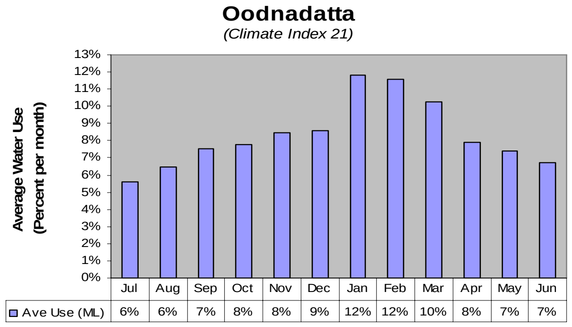
**AVE. ANN. DEMAND** 34 ML/year

*SA Water (1998-2003)*



*SA Water (1992-2003) Water Consumption Statisitics*

**CONSUMPTION PATTERN** A moderate seasonal water usage pattern is observed from the water consumption information collected by SA Water. A 3% increase in monthly use is observed between January and March.



*Source: SA Water (1993-2003) Water Consumption Statistics*

Desalination was investigated as a potential solution for treating and improving the quality of the town water supply (SA Water 1998). However, the Oodnadatta water supply is operated and managed from the Port Augusta depot some 800km away and this was considered too expensive and impractical. Further investigations into water quality improvements continue.

## STORMWATER DRAINAGE

No underground stormwater infrastructure is required to serve the township. Streets in Oodnadatta are relatively wide. Some of the streets are paved but there is no kerbing in place. Oodnadatta is relatively flat and infrequent stormwater runoff eventually drains into an ill defined creek flows through the town. Often after such events access to and from the township by road is closed for several days to a couple of weeks. Figure 168 shows the main street near the Pink Roadhouse Hotel and stormwater runoff after intense storms in September 2005.

**Sealed Main Street (Rabone 2003)** **Flooding (Lehmann 2005)**

**Figure 168 Oodnadatta – Typical Streetscapes & Drainage Issues**

## WASTEWATER SYSTEM

In 1990, a limited septic tank effluent disposal system (STEDS) was constructed to serve the Dunjiba dwellings, with financial assistance from the State and Federal Governments (DACC 1998). New 300 litre septic tanks and connecting pipework was installed to all premises owned by the Dunjiba Council (Harvey 1992). In addition, some privately owned septic tanks were connected to the STEDS ie. public toilets, progress association premises, teacher and police housing etc. The STEDS comprises a network of gravitational drains linking each property which discharge into a pumping station. From the pumping station the effluent is discharged to an evapotranspiration bed where the effluent is disposed of by the combined effect of soil infiltration, evaporation and transpiration via specifically planted vegetation (Harvey 1992). Treated effluent is not used for irrigation purposes.

**Figure 169 Oodnadatta – STEDS Evapotranspiration Beds (Rabone 2003)**

## OODNADATTA – WASTEWATER SYSTEM STATISTICS

| | | |
|---|---|---|
| **ADMINISTRATION** | Outback Areas Community Development Trust | |
| **WASTEWATER SYSTEM** | STEDS<br>(established with a subsidy grant) | *Local Government Association completed STEDS list (2000)* |
| **CONSTRUCTED** | 1990 | *LGA (2000)* |
| **EST. POPULATION SERVED** | 110 EP | *Local Government Association completed STEDS list (2000)* |
| **CONNECTIONS** | 40 (about out of total 65 houses) | |
| **RATING STRUCTURE** | No service charge levied; operation costs funded by State and Federal government. | *OACDT (2006)* |
| **ANNUAL SEWAGE INFLOW** | Not recorded<br><6 ML per year (Estimate) | *Estimate based on 150Lcpd* |
| **LEVEL OF TREATMENT** | • Secondary | |
| **QUALITY TESTING** | Inflow Not required<br>Effluent Not required | |
| **AVE. EFFLUENT AVAILABLE** | <6 ML per year (Estimate) | |
| **EFFLUENT DISPOSAL** | • Evapotranspiration bed | |

### Operation & Maintenance Matters

Naturally occurring minerals present in Oodnadatta's reticulated water supply has a detrimental effect on the structural integrity of concrete components in the septic tank effluent drainage system (STEDS). Concrete corrosion has led to spalling of concrete manholes and failure of septic tanks in the collection system, increased maintenance costs and reduced useful operating life of these components. In a short space of time, the septic tank dividers have virtually corroded away (Bob Williams *pers. comm*. 2003). This means that the sewage is not actually being treated on-site before entering the STEDS. The failure of septic tanks could result in potential environmental and health problems in the community. Concrete access points have been treated with a two part epoxy coating to protect them from water and sulphide gas attack. Bob (*pers. comm*. 2003) confirmed that this has not been very successful; the coating has been applied twice in the last 8 years and in bad state of repair again.

In 1992, an inspection of the recently constructed STEDS revealed a number of matters requiring attention which impact on the operation (Harvey 1992). The standard for concrete structures in STEDS incorporates the use of sulphide resistant cement and calcareous aggregate; however, information is not available that confirms that this standard was installed. There has been little or no maintenance carried out on the system. Local reports of sludge accumulation within the pump station and the evapotranspiration bed suggest that the septic tanks are not operating effectively as primary treatment (Harvey 1992). The evapotranspiration bed is largely ineffective is largely ineffective as a means of disposing of the effluent because it has been constructed using inappropriate material.

## NON-POTABLE WATER HARVESTING & REUSE

No specific non-potable water harvesting or reuse practices were observed.

## WATER SENSITIVE LANDSCAPING PRACTICES

No specific water sensitive landscaping practices were observed.

## REFERENCES AND OTHER READING

*SA Water*: thanks Mr Ray Reid (retired) and Mr Kym Hoffrichter who provided information about the water supply. Also to, Bob Williams who showed me around the township during a flying visit and to Derek Lehmann for photos teken of flooding while in the town working on recommissioning Bore No 2.

Harvey, B (1992): "*Oodnadatta Septic Tank Effluent Disposal Schemes*." Report by the Executive Officer STEDS Advisory Committee based on investigation, October 1992.

Dunjiba Aboriginal Community Council (1998): "*Concept Design Report for Oodnadatta Effluent Disposal Schemes Stage 1*". Report prepared by consulting engineers Roger Stokes & Associates, January 1998.

SA Water (1998) "*Hawker, Blinman, Marree and Oodnadatta Water Supplies: Report on Adequacy and Options for Desalination.*" Consultants Roger Stokes & Associates in association with Gutterridge Haskins & Davey were engaged to carry out this investigation.

SA Water (2005): "*Outback Water Supplies Discussion Paper*." Draft report by the Working Group for Outback Water Supplies, August 2005.

# Roxby Downs, Far North (Climate Index 17)

## GENERAL STATISTICS

Roxby Downs is a relatively young mining town located in outback South Australia about 560km north of Adelaide (see location marked in red below). In 1986, the township of Roxby Downs was purpose built to service the Olympic Dam mine and processing plant located 16km to the north. Olympic Dam is now one of the biggest mining operations in Australia producing high quality copper, uranium oxide, gold and silver. Plant workforce, government and service industry employees accommodated in Roxby Downs enjoy a high level of community amenities (WMC 2000).

**Richardson Place looking East (c. 1999)**
***(http://www.roxby.net.au)***

**Location of Roxby Downs**
*(http://en.wikipedia.org/wiki/Roxby_Downs)*

The Roxby Downs Council was proclaimed in May 1986 covers an area of 110 square kilometres and does not include the Olympic Dam area. In addition to normal services provided such as stormwater, wastewater and recreational facilities, the council also manages the water supply for the community.

### ROXBY DOWNS – GENERAL STATISTICS

| | | |
|---|---|---|
| **CLIMATE INDEX** | 17 | |
| **REGION** | Far North | |
| **POPULATION** | 4,406 (Base) | *Roxby Council 2006* |
| **URBAN FORM** | Inland Community – mining | |
| **AVE. ANN. RAINFALL** | 162mm | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 2 703mm | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 1 309 (Occupied) | *Roxby Council 2006* |
| **PERSONS PER DWELLING** | 3.3 | |

Theoretical studies of the formation of copper deposits and subsequent exploration in 1975 led to the discovery of copper near the waterhole 'Olympic Dam' on the Roxby Downs station (WMC 1992). The only established towns in the region are Andamooka 32km to the east and Woomera 80km to the south. In 1982, an indenture agreement between the Joint Venturers (Western Mining Corporation and BP Australia) and the South Australian government was ratified (Zwar 1988). The broad development and design philosophies adopted in the conceptual planning of the new town to serve the mining venture are described in the *Olympic Dam Project Draft Environmental Impact Statement* (RMS 1982). This was approved in 1983, the feasibility study was completed in 1985 and construction of the new town of Roxby Downs commenced in 1986 (Zwar 1988).

The natural environment is a harsh one, with high summer temperatures, low rainfall and poor quality soils (see Figure 170). The land surface consists mainly of linear sand dunes separated by swales containing frequent claypans which form the natural drainage points for rainfall. There are no natural water courses in the area. Dunes are from 5m to 10m high and are generally well vegetated. The general pattern of vegetation is trees and grasses on the sand dunes and small shrubs in swales (or corridors). The selected Roxby Downs town site, one of six which were investigated, is in dune fields varying from moderately spaced to closely spaced dunes which generally run east-west (Zwar 1988).

**Figure 170 Roxby Downs – Typical Natural Environment (Rabone 1993)**

Climatic extremes and the relative isolation required sensitive town planning and house design, and had a major influence on subdivision layouts, design and orientation of housing, and policies for maintenance of existing vegetation. The form and structure of the town site with its pronounced patterns of sand dunes and swales was considered an important environmental feature. Dune ridges and areas of significant vegetation have been incorporated where practical into parklands and recreational areas; approximately 20% of the town development area of the town has been reserved as open space (RMS 1982).

Water is of critical importance and the town of Roxby Downs was designed to maximise its supply of available water. In accordance with normal practice in Australia, independent systems for the collection and disposal of stormwater and wastewater were planned for Roxby Downs. The design of the wastewater system included storage and reuse of treated effluent for use in the irrigation of recreation facilities and parklands (RMS 1982). Town planners also realised that urban development would lead to greater and more frequent stormwater runoff and planned to capture and utilise this resource (McKay 1987). Wherever practicable surface water runoff would be opportunistically harvested and used for supplementary watering (RMS 1982). Accordingly, Roxby Downs is a unique example of water cycle management.

The township and infrastructure for Roxby Downs was designed and planned to grow with the expanding mining operations (see Figure 171). It was intended that the town centre would provide the principal focus of the new town and that at the planned ultimate development size of 9,000 people most will live within 2km of this centre (RMS 1982). The Olympic Dam mining operation currently provides employment for approximately 1,130 staff and 550 contractors on site and around 4,000 people are housed in Roxby Downs (Planning SA 2005).

**Figure 171 Roxby Downs – Aerial Photo of Town (www.roxby.net.au 2000)**

Following a successful takeover in June 2005 of Olympic Dam, BHP Billiton proposes to expand the mining operation (Sunday Mail 2005). During the construction and operation of the proposed expansion, the workforce will increase significantly and it is estimated that in the order of 10,000 people would be housed at Roxby Downs and in the order of 3,000 people at a construction camp (Planning SA 2005). Projected increased accommodation needs will require additional infrastructure and services at the Olympic Dam Village (i.e. the construction camp), Roxby Downs and potentially other local townships. The expansion project is in the planning phase with several options for major infrastructure being investigated.

## WATER SUPPLY

BHP Billiton draws water by under licence from two bore fields in the Great Artesian Basin (GAB) about 200km north of Roxby Downs. The current water licence provides for 42ML/d from the GAB, of which approximately 32 Ml/d is currently used (Planning SA 2005). BHP Billiton operates a reserve osmosis (RO) desalination plant at Olympic Dam (see Figure 172) to treat groundwater to drinking water standards. The RO facility has a capacity of 14.7ML/d and consists of three main sections; (1) chemical pre-treatment (ie. chlorination, sand filtration, and scale inhibitor), (2) the reverse osmosis plant (dechlorination, RO modules) and (3) post treatment section (pH adjustment). The extensive infrastructure required makes the production cost of potable water some 1.8 and 2.7 times greater than the price of potable water in Adelaide (WMC 2000).

**RO Plant Facility** **Pre-treatment Sand Filters**

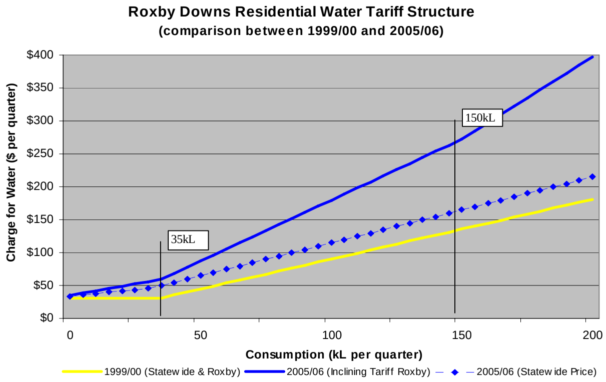
**Figure 172 Roxby Downs - Olympic Dam RO Plant (Rabone 2000)**

The council purchases potable water produced in the RO plant from BHP Billiton for reticulation in Roxby Downs. Under the *Roxby Downs (Indenture Ratification) Act* the price council pays for water is capped at approximately half this cost (RDC 2002). Depending on weather conditions, the council purchases between 500ML and 750ML of potable water in any given year (RDC 2002). Water from the desalination plant is pumped from the 10ML lined and covered dam on the north western side of town. Water is chlorinated and distributed to approximately 1,300 water services within the township. As far as practicable, council follows standards of operation equivalent to the standards set by SA Water. Potable water is used for irrigating home gardens and all public landscaped areas except the recreation reserve (which uses the non-potable supply). In June 2000, the Council introduced a water pricing system designed to provide financial incentives to consumers to reduce water consumption. While the price paid for water is significantly higher than Adelaide prices it is still subsidised by approximately 50% (RDC 2002).

For the proposed expanded mine operation, it is estimated that up to 120ML/d of additional water would be required (Planning SA 2005). A number of options are being considered to source and supply this water, including additional GAB bore fields, a local or regional saline aquifer bore fields, seawater desalination in the Upper Spencer Gulf and further on-site recycling of water. If the additional water is sourced from anywhere other than a coastal seawater desalination plant, an expansion to the existing Olympic Dam desalination plant would be required. It is also likely that the existing desalination plant would need to be relocated to accommodate the proposed open pit (Planning SA 2005).

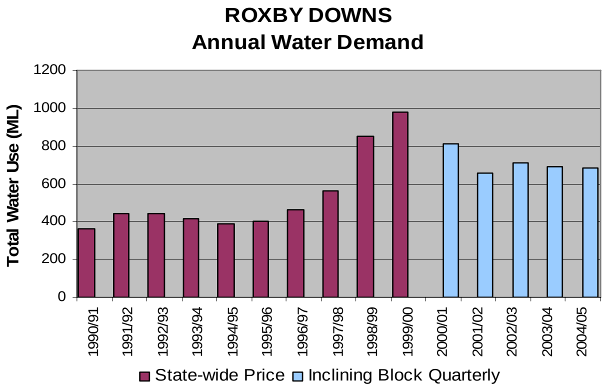
## ROXBY DOWNS – WATER SUPPLY STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Roxby Water (Council business) | | |
| **WATER SOURCE** | Desalinated potable water purchased from BHP Billiton. | | *Roxby Downs Council (2004)* |
| **TREATMENT** | Disinfection | | |
| **DISTRIBUTION** | Reticulated in township | | |
| **SERVICES** | 1485 (inc. community houses) | | *Trevor Kroemer 2005* |
| **RATING STRUCTURE** | Pay for use with a minimum charge. The water bill includes a two step consumption, three tier pricing system (applied on a quarterly basis) for residential and business customers. A lower rate is applied to businesses for consumption above second step. | | |
| **RETAIL PRICE PAID** | 0 – 34 kL | $0.70/kL | *Residential 2005/06* |
| | 35-150kL | $1.85/kL | *Residential 2005/06* |
| | > 150kL | $2.50/kL | *Residential 2005/06* |



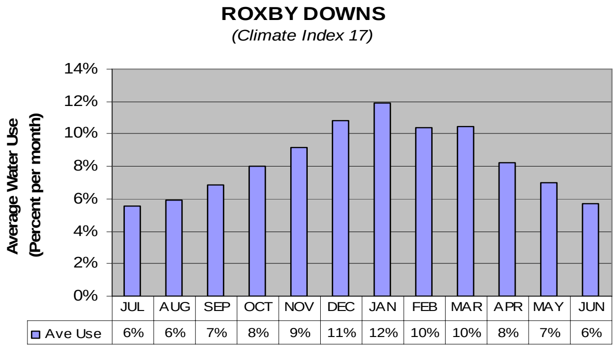
*Water tariff information courtesy of Trevor Kroemer of Roxby Water (2005)*

| | | |
|---|---|---|
| **AVE. WATER USE** | 540 kL/service/year | *Average 00/01 -03/04* |
| | 356 kL/house/year | *Trevor Kroemer(2004)* |
| **AVE. ANN. DEMAND** | 726 ML/year | *1997/98-2004/05 data*<br>*Trevor Kroemer 2005* |



*Note: In 1998/99 & 1999/00 a leak in the 10ML storage dam was discovered and the population also increased (temporarily) from around 4,000 to 7,000*
*Source: Water Use Data from Trevor Kroemer, Roxby Downs (August 2005)*

**CONSUMPTION PATTERN** A seasonal water usage pattern is observed; a result of outdoor household water use on gardens.



*Source: Trevor Kroemer Roxby Downs (2005)*

Water conservation is promoted by means of a garden guide booklet produced by the mining company and issued free to residents, by articles in the local newspaper and an advisory service provided by the council. New residents are provided with free native plants and subsidised drip irrigation.

## STORMWATER DRAINAGE

The stormwater drainage system was designed to provide hydrologic characteristics similar to those existing in the natural catchments; where feasible existing drainage paths, catchments and pondage areas were maintained. Stormwater flow is principally by street channels with limited underground drainage system towards the low points of catchments. Town planners realised that urban development would lead to greater and more frequent stormwater runoff and deliberately designed to capture and utilise this resource. The township has a catchment of about 5 $km^2$ (Radcliffe 2004). Stormwater discharges from the developed areas (ie. sealed streets) of the town, usually in summer, are collected in three ponds constructed along the western edge of the town (see Figure 173 below).

Each stormwater pond is designed to hold the runoff from an estimated 1yr ARI storm. McKay (1987) noted that stormwater runoff in occurs for rainfall events in excess of 5mm and depending on rainfall the ponds can fill several times a year. Rainfall events of 25mm in December 1987 and 23mm March 1988 yielded catches of 7ML and 4ML respectively (McKay 1987). Recently had a 44mm rain event and the 10ML dam filled with a catchment area of 300ha (Trevor Kroemer *pers comm.* 2004). Based on a catchment area of 300ha the average runoff coefficient from these observed events is 0.08. This increases to 0.42 if it is assumed that the runoof was generated by the area of sealed roads. The temporary stormwater ponds also reduce the impact of discharging excess runoff from the developed area on adjacent natural catchment. Rain is primarily from tropical cyclones that venture south, usually between January and April. These can bring torrential rainfall, but the water soaks into the desert sand and that is that.

**Sealed Roads (Rabone 2000)** **A Temporary Pond (Rabone 1993)**

**Figure 173 Roxby Downs – Stormwater Drainage System**

To avoid losses and to provide collection of subsequent stormwater flows it is essential that these stormwater ponds be emptied as quickly as possible after filling. The temporary stormwater ponds are located next to the town sewage pump stations which allow inexpensive transfer of stormwater catches into the sewage system. The stormwater is added to the holdings in the sewage treatment lagoons where it undergoes treatment through a facultative process over about 42 day period to bring it to standards suitable for reuse (Radcliffe 2004).

## ROXBY DOWNS – STORMWATER DRAINAGE

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Roxby Downs Council | | |
| **CATCHMENT AREA** | Total | 500 ha | *Radcliffe (2004)* |
| | Urban | 300 ha | |
| **ROAD DATA** | Total length | 45 km | *Trevor Kroemer 2006* |
| | Average width | 10 - 13 m | *Trevor Kroemer 2006* |
| | Kerbed | 95% | *Trevor Kroemer 2006* |
| | Sealed | 100% | |
| **RAINFALL TO PRODUCE RUNOFF** | Rainfall events in excess of 5mm | | *McKay (1987)* |
| **AVERAGE RUNOFF** | 15 to 75 ML/year | | *Radcliffe (2004)* |
| **TYPE OF DRAIN** | Surface diversion with some underground network | | |
| **LEVEL OF TREATMENT** | Secondary (in the lagoons at the wastewater treatment plant) | | *Radcliffe (2004)* |
| **NUMBER OF DISCHARGE POINTS** | Six stormwater dams (water from four of these transferred for use). | | *Trevor Kroemer 2006* |
| **DISPOSAL** | • Reuse System<br>• Water course (Overflow) | | |

## WASTEWATER SYSTEM

The township of Roxby Downs is served by a conventional sewerage system. Wastewater from allotments is discharged into the sewer and gravitates to pumping stations located in the low points. From there, the sewage is pumped to the wastewater treatment system located approximately 1.5km to the west of the developed areas (McKay 1987). The treatment system is designed to serve a population of up to 4,000 and is extendable as required (RMS 1989). Wastewater is treated in a series of four lagoons; two primary lagoons for settling which may be operated alternately or in parallel and two facultative ponds (ie. a secondary lagoon and a final storage pond which follow in series). Treated effluent can be pumped for irrigation of grassed areas from either the final storage pond or the secondary lagoon. When the lagoons are full the effluent overflows and is lost (see Figure 174).

**Treatment Lagoons** **Treated Effluent Overflow**

**Figure 174 Roxby Downs – Wastewater Treatment Lagoons (Rabone 1993)**

The wastewater lagoon system can hold a maximum of 100ML, but require a minimum holding of 33ML in the primary lagoons and secondary dams for effective treatment of effluent through the system (Radcliffe 2004). The amount of water pumped to the wastewater treatment lagoons (effluent plus stormwater) can vary from 150ML to 400ML per year (Radcliffe 2004). Management issues can arise when a large influx of stormwater enters the primary sewer lagoons disrupting the normal facultative breakdown process (Radcliffe 2004). In addition, up to 150ML can be lost by evaporation (Kroemer *pers comm.* 2004).

Evaporation losses need to be minimised to maintain effluent quality particularly with respect to salinity levels (McKay 1987). All lagoons are capable of operation of varying depths to permit temporary storage of water by increasing the depth during the winter months when evaporation losses and effluent demands are low. To cater for seasonal variations in demand for irrigation all ponds are surcharged by an additional 0.5m depth providing an additional 11ML storage (McKay 1987). It is essential that advantage be taken of this storage capacity if effluent availability if to be maximised. Treated water (effluent and stormwater blend) from the third and forth lagoons is pumped to two concrete storage tanks (combined capacity 200kL) for watering grassed areas in the township. The effluent/stormwater blend is chlorinated before use.

## ROXBY DOWNS – WASTEWATER SYSTEM STATISTICS

| | | |
|---|---|---|
| **ADMINISTRATION** | Roxby Water (Council business) | |
| **WASTEWATER SYSTEM** | Full wastewater system | |
| **CONSTRUCTED** | 1986 | |
| **EST. POPULATION SERVED** | 4000 EP | |
| **CONNECTIONS** | 1,300 | |
| **RATING STRUCTURE** | Annual Fee<br>$340/year for residential premises | *Roxby Water (2004)* |
| **ANNUAL SEWAGE INFLOW** | Estimated 305ML/year sewage plus 12-14ML/year of stormwater | *Trevor Kroemer pers. comm. 2005* |
| **LEVEL OF TREATMENT** | • Secondary Treatment<br>• Disinfection | |
| **AVE. EFFLUENT AVAILABLE** | 150 ML/year (based on actual volume of irrigation water use) | *Trevor Kroemer pers. comm. 2005* |
| **EFFLUENT DISPOSAL** | • Reuse System<br>• Overflow to low lying area | |

### NON-POTABLE WATER HARVESTING & REUSE

The township of Roxby Downs presents a unique operational example of water sensitive urban development with integrated water management infrastructure to accommodate stormwater harvesting and treated effluent reuse. These '*urban wastewaters*' have allowed the development of recreation facilities which may not have been available to the community if expensive potable water was used. In Roxby Downs, sewage effluent and harvested stormwater is used after treatment to irrigate the entire central parklands, consisting of the main oval (see Figure 175), an adjoining playing field near the school, and part of the golf course (see Figure 176 further below).

**Figure 175 Roxby Downs – Irrigated Town Oval (Rabone 2000)**

Water (effluent and stormwater) from the final wastewater treatment lagoons is pumped to two concrete storage tanks (combined capacity 200kL) for watering grassed areas. The effluent/stormwater blend is chlorinated before use. The recreation reserve is irrigated at night using an automatically controllers sprinkler irrigation system. Night irrigation conserves water and maximises daytime use of the playing fields (Zwar 1988).

## ROXBY DOWNS – NON-POTABLE WATER SUPPLY

| | | |
|---|---|---|
| **ADMINISTRATION** | Roxby Water (Council business) | |
| **WATER SOURCE** | Blend of treated sewage effluent and stormwater. | |
| **TREATMENT** | • Class A | *Trevor Kroemer pers. comm. 2005* |
| **DISTRIBUTION** | Dedicated pipe to point of use. | |
| **COMMISSIONED** | 1987 | |
| **SERVICES** | Parklands, ovals, golf club | |
| **RATING STRUCTURE** | No rates (community service). | |
| **RETAIL PRICE PAID** | Not Applicable | |
| **AVERAGE USE** | 150 ML/year | *Trevor Kroemer pers. comm. 2005* |
| **LEVEL OF REUSE** | 95% effluent/stormwater available (ie. around 50% sewage recovery) | *Trevor Kroemer pers. comm. 2005* |
| **CONSUMPTION PATTERN** | The monthly demand is seasonal with an average of 1ML in winter and 6-9ML in summer. | |
| **SUPPLY & DEMAND MATCH** | Monthly demand can be met between April and January. Restrictions are sometimes necessary in late summer (Trevor Kroemer *pers comm*. 2004) | |

In many rural areas of South Australia, golf courses are generally dry. Roxby Downs has an 18-hole golf course with five fairways irrigated with the non-potable stormwater and effluent blend (Zwar *pers. comm.* 1993). It is a luxury to have a golf course facility like this in a region with such a harsh environment.

**Golf Course Aerial View (c 1999)** **An Irrigated Green (Rabone 1993)**

**Figure 176 Roxby Downs – Golf Course with Some Irrigated Greens**

The water harvesting and reuse system in Roxby Downs designed for watering grassed areas in the township is well planned and set up. There has been the odd problem or two with the sand filters that can be corrected with regular maintenance. From time to time, large brown patches can develop on the oval area due to uneven watering and lack of sprinkler maintenance. In hindsight, to prevent the sprinklers from blocking up there is a filter (and a spare to replace it) at the concrete storage tanks as a final filter before going into the irrigation system (Zwar *pers comm*. 1993). The community recreation facilities and water infrastructure in the care and control of the council represent a significant investment and should not be let to fall into semi-neglect through haphazard on maintenance.

The stormwater/effluent recycling program saves the community $200,000 annually over the purchase of potable water if the effluent were sent to an evaporation basin (Kroemer 2003 in Radcliffe 2004).

## WATER SENSITIVE LANDSCAPING PRACTICES

The value of water is well recognised in this town and water conservation strategies are widely promoted. Many existing trees and shrubs have been incorporated into the landscaping of both public and private areas. Most houses and building in town have no gutters and rooftop runoff from rain infiltrates on allotments benefiting the surrounding gardens. Wherever practicable surface water runoff is harvested and used for supplementary watering of playing fields and parks. To conserve water public plantings use as much native flora as possible, practise mulching and drip irrigation, and discourage planting of large lawns.

Lawns are one of the most expensive elements in public landscaping and by reducing the area of grass considerable savings have been made in water use and in maintenance costs (Zwar 1993). Some hardy native groundcovers make effective and attractive lawn substitutes, especially where usage and wear are minimal. They also have the advantages of needing little water, no mowing or pest control treatments. In high use areas lawns can be replaced by paving or perhaps combined with overhead shade from pergolas or large trees. Figure 177 shows the extensive use of brick paving and small areas of lawns with seating in the town centre.

**Civic Centre (Rabone 1993)** **Main Street (Rabone 2000)**

**Figure 177 Roxby Downs – Low Water Use Landscaping**

The grassed playing fields in Roxby Downs are supplemented by other sporting and recreational facilities including tennis courts, an indoor sports stadium, and an outdoor swimming centre. Figure 178 shows sports facilities where artificial turf provides an excellent surface for bowling greens, tennis and netball court.

**Bowling Green** **Tennis Courts**

**Figure 178 Roxby Downs – Use of Synthetic Turf Surfaces (Rabone 1993)**

In Roxby Downs most plantings in public areas are of native arid zone species including some local endemic species. Figure 179 shows the water conserving style of landscaping adopted around the golf clubroom where potable water used. Street verges have been landscaped and the trees, shrubs and ground covers are irrigated by drip irrigation systems. It is estimated that over 140,000 trees have been planted in the Roxby Downs (including Olympic Dam) area sine 1980 (WMC 1992). A 16km long rabbit proof fence enclosing approximately 1400ha surrounds the town to protect vegetation (Zwar 1993; Zwar 2004).

**Golf Club** **Landscaped Street Verge**

**Figure 179 Roxby Downs – Use of Natives in Public Plantings (Rabone 1993)**

## REFERENCES AND OTHER READING

Special thanks to Mr John Zwar for showing me around Roxby Downs and sharing the experiences encountered in developing and delivering the water sensitive public plantings in arid areas. Personal notes made in 1987 by Brian McKay, engineer, on the operational experiences of stormwater harvesting and effluent reuse systems.

*Roxby Downs Council*: information published on the website and special thanks also to Mr Trevor Kroemer who provided additional information.

Planning SA (2005): "*Draft Guidelines/Issues Paper For An Environmental Impact Statement On The Proposed Expansion Of The Olympic Dam Operations At Roxby Downs*", November 2005.

Radcliffe,J (2004); '*Water Recycling in Australia*.' The review undertaken by the Australian Academy of Technological Sciences and Engineering includes a section of Roxby Downs, 107-108

Roxby Management Services (1982): '*Olympic Dam Project - Draft Environmental Impact Statement*.' Report prepared by Kinhill-Stearns Roger describes the broad design philosophies adopted in the conceptual planning of the town. October 1982

Roxby Management Services (1989): '*Township Sewerage Treatment and Effluent Reuse*.' Paper prepared describes lagoon management to maximise use. May 1989

Sunday Mail (2005) '*Roxby is SA's next boomtown*.' Article by Brad Couch appeared 05/06/2005, 21.

Western Mining Corporation and Roxby Downs Council (1992) "*Olympic Dam Operations & Roxby Downs Township*". Information booklet.

Western Mining Corporation (1997) "*Olympic Dam Expansion Environmental Impact Statement*". URL: www.wmc.com.sustain/olympic. Accessed June 2000.

Western Mining Corporation (n.d.) "*Olympic Dam Operations Environmental Handbook*". The booklet describes the environment of the area and sets down the responsibilities of individuals.

Zwar,JR (1988): "*Roxby Downs – A Water Conscious Community in Australia*". Article appeared in the ARID LANDS Newsletter, Volume 26, Spring/Summer 1988, 10.

Zwar,JR (1993): "*Water Efficient Plantings*" The Australian Garden Journal October/November 1993, 23-27

Zwar,JR (2004): "*Water sensitive Urban Design: a perspective from outback South Australia*". Paper presented at the International Conference on Water Sensitive Urban Design: Cities as Catchments, WSUD2004, Adelaide, 21-25 November 2004, 647-659.

# Snowtown, Mid North (Climate Index 5)

## GENERAL STATISTICS

Snowtown is a small town located in the mid-north about 145km north of Adelaide in an area known for its ideal conditions for sheep grazing and wheat crops. Early settlement centred around a railway station on the Brinkworth-Wallaroo line. The first settlers arrived sometime between 1867 and 1869 when farming was rapidly expanding in the north; in fact, the old Snowtown Pub was built in 1868 to service these settlers (www.en.wikipedia.org). In 1878 the small township of Snowtown was proclaimed and remains an active service centre for other smaller townships on the local area. Like many other wheat belt townships it is characterised by iron roofed houses; a mixture of sealed bitumen and unsealed roads, wheat silos, a football/cricket oval, a bowling club and a considerable amount of community spirit (Moore 1990).

**Railway Terrace East** **Bowling Green**

**Figure 180 Snowtown – Typical Features of the Town (Growden 2006)**

Snowtown is located on the plain between the Mt Lofty Ranges and the Barunga Range. Rainfall from the Barunga Range collects in Lake Bumbunga directly south of the township (www.en.wikipedia.org) where salt is mined commercially.

## SNOWTOWN – GENERAL STATISTICS

| | | | |
|---|---|---|---|
| **CLIMATE INDEX** | 5 | | |
| **REGION** | Mid North | | |
| **POPULATION** | 358 (Base) | 118% (Ultimate) | *ABS (2001) CENSUS* |
| **URBAN FORM** | Inland rural community | | |
| **AVE. ANN. RAINFALL** | 405mm | | *Burrows (1987)* |
| **AVE. ANN. EVAP.** | 2,190mm | | *Burrows (1987)* |
| **NUMBER OF DWELLINGS** | 167 (Occupied) | | *ABS (2001) CENSUS* |
| **PERSONS PER DWELLING** | 2.1 | | |

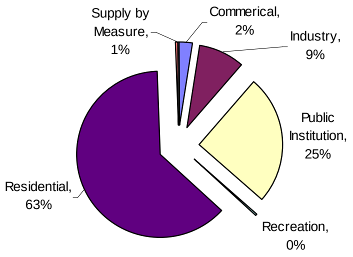
## WATER SUPPLY

## SNOWTOWN – WATER SUPPLY STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | SA Water | | |
| **WATER SOURCE** | River Murray via the Morgan-Whyalla pipeline<br>Bundaleer Reservoir (ceased 1998) | | |
| **TREATMENT** | Filtered at Morgan | | |
| **DISTRIBUTION** | Reticulated. | | |
| **RATING STRUCTURE** | Statewide pricing policy administered by the State government - pay for use with a minimum charge. . | | |
| **RETAIL PRICE PAID** | 0 – 125 kL | $0.46/kL | *Residential 2005/06* |
| | >126kL | $1.06/kL | *Residential 2005/06* |
| **AVE. WATER USE** | 283 kL/service/year<br>235 kL/house/year | | *Average 88/89 -02/03 Water Consumption Statistics* |

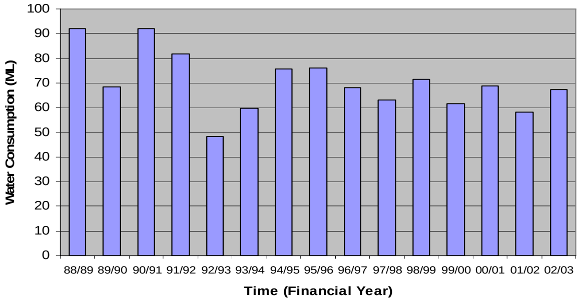
Nearly two thirds of the reticulated water used in Snowtown is for residential purposes.

SNOWTOWN
Average Water Use By Category
(1988/89 - 2002/03)



| | | |
|---|---|---|
| **AVE. ANN. DEMAND** | 65 ML/year | *Water Consumption Statistics SA Water (1989-2003)* |

SNOWTOWN
ANNUAL WATER DEMAND



SA Water (1989 - 2003) Water Consumption Statistics - Total based on individual water meters

| | |
|---|---|
| **CONSUMPTION PATTERN** | Monthly consumption information for Snowtown is not available; however, a seasonal water usage pattern is expected. |

## STORMWATER DRAINAGE

The streets in Snowtown are relatively wide and the Council has progressively sealed town roads which has the potential to increase the volume of stormwater runoff and some roads have kerbs (refer Figure 181). With the exception of some culvert crossings, no underground stormwater drainage has been constructed to serve the township. Snowtown has topography with a natural drainage to the east.

**Progressively Sealed between Kerbs** **Wide Roads & Surface Drains**

**Figure 181 Snowtown – Typical Streetscapes (Rabone 2003)**

## SNOWTOWN – STORMWATER DRAINAGE

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Wakefield Regional Council | | |
| **CATCHMENT AREA** | Total | 62.3 ha | *Mr Ed Spencer (1993)* |
| | Urban | 62 ha | *Moore (1990)* |
| **ROAD DATA** | Total length | 8.5km | *Mr Ed Spencer (1993)* |
| | Average width | 20m | *Glen Growden (2006)* |
| | Kerbed | 95% | *Glen Growden (2006)* |
| | Sealed | 100% (ie.19ha) | *Glen Growden (2006)* |
| **RAINFALL TO PRODUCE RUNOFF** | Summer runoff initiated from sealed roads when daily rainfall exceeds 10mm. | | *Moore (1990)* |
| **AVE. STORMWATER RUNOFF** | 54 ML/year (estimated) | | *Based on Fleming's Monthly Runoff Coefficients* |
| **TYPE OF DRAIN** | Surface diversion by kerbing, culverts and open spoon drains | | |
| **LEVEL OF TREATMENT** | Primary (Sedimentation) | | |
| **NUMBER OF DISCHARGE POINTS** | One (after diversion works 1982) | | |
| **DISPOSAL** | • Dam for Reuse<br>• Overflow to land (past school) | | |

In the past, stormwater runoff caused the main street to flood forcing businesses to close and damaging footpaths and guttering (Farming Ahead 1996?). A plan was devised to control and harvest the stormwater to prevent future flooding and secure sufficient water for summer irrigation of local recreational ovals. Following stormwater diversion works in early the 1980s, runoff is harvested from the two catchment areas shown in Figure 182.

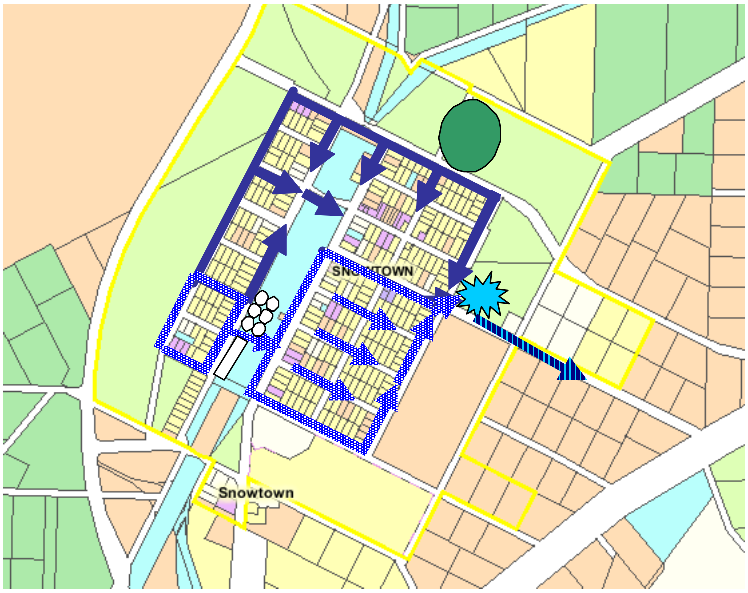


**Figure 182 Snowtown – Stormwater Flows (Ed Spencer *pers comm*. 1993)**

Most of the stormwater runoff from the 62.3ha town area is diverted in surface drains and collects in the small excavated dam within the parklands to the east of the town. To maximise area from which water can be harvested the natural direction of flow down some streets was altered. The area of the town drained into the stormwater dam by the northern and southern catchment is 37.8ha and 24.5ha respectively. The southern catchment area is lower so when the water level in the dam is high it no longer contributes but continues past the school (overflow). The catchment area comprises about 90% of the developed township including runoff from the wheat storage silos 3.4 ha catchment (Moore 1990). The large roofs of the wheat storage complex (see Figure 183) are ideal for rainwater collection and the runoff from these is directed to the southern culvert under the railway and along the street to the stormwater dam.

**Grain Store** **Wheat Silos**

**Figure 183 Snowtown – Wheat Grain Store and Silos (Rabone 2003)**

However, some of the stormwater diversion works resulted in localised flooding over part of the roads during intense rainfall events, ie. along the Railway Terrace and the eastern end of Fouth Street which is relatively flat. In 1995, a retention basin (see Figure 184) was constructed to hold stormwater collected an area north-west of the town and prevent it from rushing along the Fourth Street (Glen Growden *pers. comm*. 2006).

**Retention Basin (Upstream)** **Restricted Outlet Pipe**

**Figure 184 Snowtown – Retention Basin (Glen Growden 2006)**

Water is released from the retention basin through a restricted outflow pipe into the main street. Kerbing along the main street has been made higher than usual to cope with the flow of water from the retention basin (Farming Ahead 1996?). When the stormwater dam is full, water is released into an overflow channel which feeds into the large natural salt lakes to the south of town. An overflow system to use this water more efficiently will be developed in the future.

The earth drain along East Terrace has been functional but the flat terrain results in ponding of stormwater along its length which is subsequently lost to the environment and not harvested for later use. Over the past 23 years, the efficiency of the drain has decreased further due to the formation of crab holes which allows up to 30% of the flow to be lost by infiltration (WRC 2006). The council propose to construct an impervious drain along East Terrace to ensure that all stormwater harvested drains into the stormwater dam. The work will involve grading and sealing 650m of open drain and improve the effectiveness of the existing Snowtown Stormwater Harvesting Scheme (WRC 2006).

## WASTEWATER SYSTEM

The council operates and maintains the septic tank effluent disposal system (STEDS) to all properties in Snowtown. It was constructed in 1986, with financial assistance from the State Government STED subsidy scheme, when it was common practice to provide secondary treatment of the effluent in a lagoon and disposal by evaporation. All septic tank effluent collects (gravity) at a single submersible pumping station about 800m to the east of the township. Automatic pumping units transfer the effluent to the two lagoon system about 2.3km to the north east of the town. There are no flow meters on the pumps; however, they are periodically inspected to check the pumping hours for both units is about the same. The effluent is discharged into the oxidation (first) lagoon which is divided into a number of areas by fences to make a long flow path before the effluent reaches the evaporation (second) lagoon which is usually empty except in winter.

## SNOWTOWN – WASTEWATER SYSTEM STATISTICS

| | | | |
|---|---|---|---|
| **ADMINISTRATION** | Wakefield Regional Council | | |
| **WASTEWATER SYSTEM** | STEDS<br>(established with a subsidy grant) | | |
| **CONSTRUCTED** | 1986 | | |
| **EST. POPULATION SERVED** | 1000 EP | | *Glen Growden (2006)* |
| **CONNECTIONS** | 265 | | *Glen Growden (2006)* |
| **RATING STRUCTURE** | Service Charge<br>$150pa for occupied properties<br>$130pa for vacant land | | *Wakefield Regional Council Rating Policy (2006)* |
| **ANNUAL SEWAGE INFLOW** | Not recorded<br>19 ML per year (Estimate) | | *Based on 150Lcpd* |
| **LEVEL OF TREATMENT** | • Secondary (Lagoon) | | |
| **QUALITY TESTING** | Inflow | Not required | *Glen Growden (2006)* |
| | Effluent | Not required | |
| **AVE. EFFLUENT AVAILABLE** | 15 ML per year (Estimate) | | *Depends on storage size and evaporation* |
| **EFFLUENT DISPOSAL** | • Evaporation | | |

In Snowtown, treated effluent from the STEDS is not used for irrigation purposes because the effluent lagoons are located some distance from the town making it expensive to access (ie. additional pipe and pumping costs).

## NON-POTABLE WATER HARVESTING & REUSE

### The 'Idea' to Meet Needs

The catalyst for the stormwater harvesting scheme by this small community was the increasing cost of maintaining community recreation areas, particularly the town oval and the bowling greens.

### Feasibility Investigations

In 1980, investigations were carried out into the feasibility of harvesting stormwater runoff for the irrigation of the town recreational areas. The area of impermeable surfaces was estimated and possible storage sites were inspected and potential for diverting waters around the streets were field tested (Moore 1990). Methods for funding the water harvesting project were also investigated (Moore 1990). On the basis of the recommendations from the feasibility investigation existing community support for the project was strengthened.

## Details of the Harvesting System

Since 1982, a successful urban stormwater harvesting scheme has been supplying water to the recreational areas of Snowtown. A small area of undeveloped parkland on the downstream edge of the township was chosen as the location for the stormwater dam (Moore 1990). The catchment area comprises about 90% of the developed township; a pipeline and pumping system take the water to the recreation areas some 500m away. There are some swales and banks to divert excess stormwater runoff onto paddocks (spill) outside the township. Treated effluent from the STEDS is not reused for irrigation purposes in Snowtown.

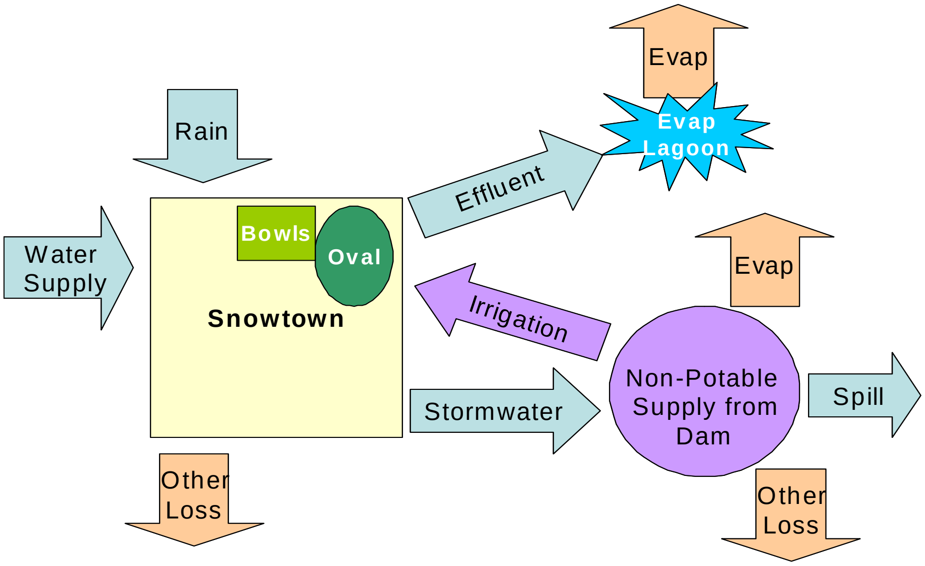


**Figure 185 Snowtown – Schematic of the Stormwater Harvesting System**

Figure 186 shows the dam with storage capacity of 15ML that was excavated by private contract at the selected site and the area was developed as a fauna park and water reserve. Excess spoil from the excavation works was placed around the oval perimeter to improve spectator viewing (Moore 1990).

**Figure 186 Snowtown - Community Stormwater Dam (Rabone 2003)**

The volume of stormwater that can be harvested, ie when the water level in the dam is 4.5m deep, has been estimated from the initial design drawings and a survey of the nearly constructed pond. The survey found the dam was 2ML short of the required 15ML and consequently the contractor was required to return to complete excavation works (Steve Moore *pers comm*. 1993). Regrettably, no 'as-constructed' survey was completed. Figure 187 shows that that the volume of water stored will decrease more quickly (ie. steeper slope) as the depth of water in the dam decreases.

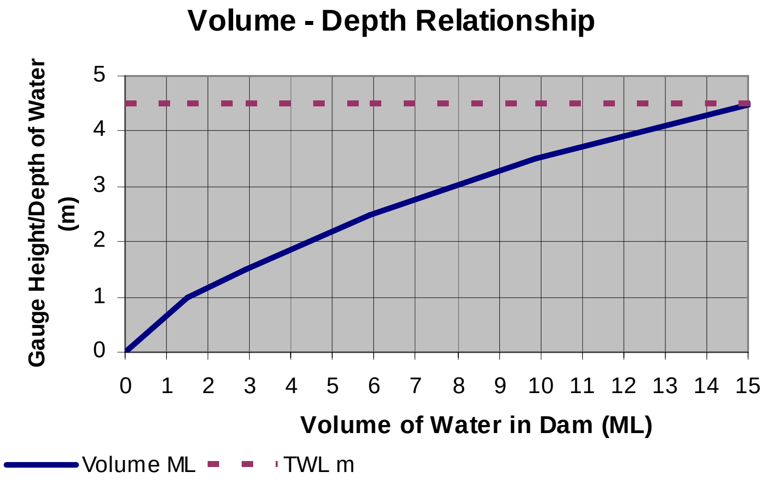


**Figure 187 Snowtown - Stormwater Dam Depth/Volume Relationship**

Works included earthen levees and road culverts designed to direct runoff to the stormwater dam. Figure 188 shows the swale channel where stormwater runoff from the northern catchment areas leaves the township and the small settling basin (ie. gross pollutant trap) that receives water from both catchment areas. Water flows from the settling basin into the stormwater dam for storage. The quality of the runoff is improved (ie. sediment removal) during its passage through the settling basin and during storage in the dam.

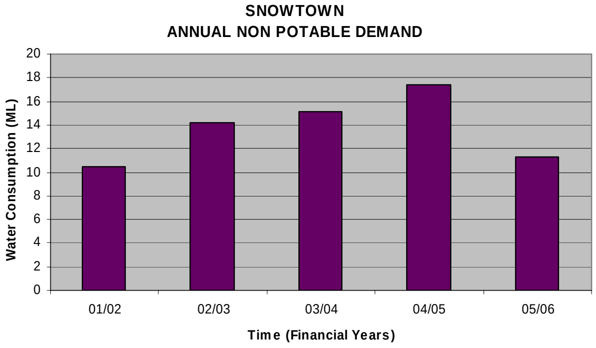
**Northern Catchment Area Swale** **Stormwater Settling Basin**

**Figure 188 Snowtown – Stormwater inlet works (Rabone 1993)**

The southern part of the town catchment is lower than the full water level and is isolated when the dam is nearly full to divert excess stormwater along Glen Davidson Drive past the school and into a lake in the middle of the golf course.

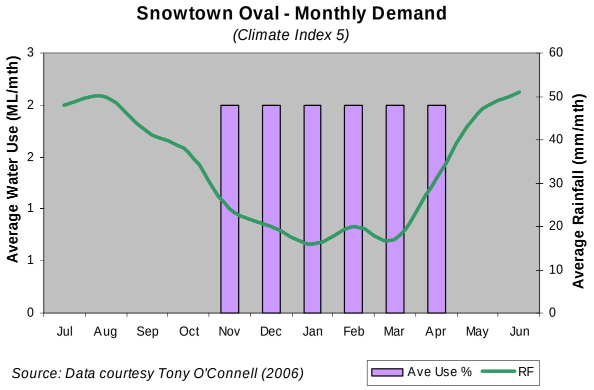
## SNOWTOWN – NON-POTABLE WATER SUPPLY

| | | |
|---|---|---|
| **ADMINISTRATION** | Snowtown Centenary Park Inc | |
| **WATER SOURCE** | Urban stormwater | |
| **DISTRIBUTION** | Dedicated pipe to point of use | |
| **COMMISSIONED** | 1982 | *Moore (1990)* |
| **SERVICES** | Two (Town Oval, Bowling Green) | |
| **QUALITY TESTING** | Nil | |
| **RATING STRUCTURE** | None applied | |
| **RETAIL PRICE PAID** | Not applicable | |
| **AVERAGE USE** | 12 ML per year | *O'Connell (2006)* |
| | The annual irrigation requirement can vary between 8ML and 17ML depending on weather conditions. | |



*Operational data courtesy of Tony O'Connell (2006)*

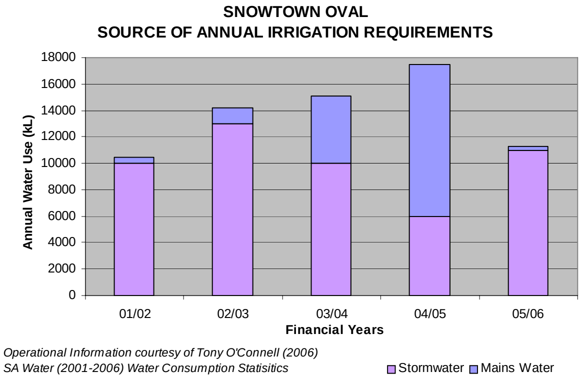
| | |
|---|---|
| **LEVEL OF REUSE** | 0% (effluent disposed by evaporation) |
| **CONSUMPTION PATTERN** | The monthly demand varies between 8ML and depending on weather conditions. |



*Source: Data courtesy Tony O'Connell (2006)*

### SUPPLY & DEMAND MATCH

In good rainfall years of 330mm or more and when summer rains occur the average monthly irrigation demand can generally be met until the stormwater dam runs dry (often around March/April). In low rainfall years, the dam may only hold 8ML at the beginning of the irrigation season and reticulated mains water is used to meet the shortfall (Tony O'Connell *pers comm*. 2006).



*Operational Information courtesy of Tony O'Connell (2006)*
*SA Water (2001-2006) Water Consumption Statisitics*

Since 2000, on average harvested stormwater meets 80% of the annual demand; however, the contribution dropped to 35% during dry conditions in 2004 and 2005.

## Project Funding

The initial capital cost of all works for the stormwater harvesting scheme was $34,000. Moore (1990) reported the pay back period for the capital cost of this project was only 5 years in terms of equivalent expenditure to purchase water at the statewide price. Part of the funding (around 40% of the capital cost) for the project was sourced from a local government grant with the balance (around 60%) from the community (Moore 1990). The community contribution included support from the district council in the form of earth and concrete structural works and a donation from the Centenary Park Committee (ie. sporting complex management). This case study demonstrates the importance of powerful commitment from members of the local community to develop a small-scale stormwater harvesting scheme.

## Operational Matters

The original stormwater harvesting scheme was designed by Steve Moore in 1981 and commissioned in 1982 and has been operating successfully ever since, apart from some seepage losses along East Terrace. These will be addressed following the successful application *Community Water Grant* which will fund around 40% of the capital cost to upgrade 650m long by 4m wide drain. The works planned for 2006 will improve the effectiveness of the existing drain and increase the yield of stormwater that is available for irrigation.

Anecdotal evidence has it that additional summer runoff is initiated when daily rainfalls exceed 10mm (Moore 1990). Summer runoff is an advantage that urban catchments have over rural catchments from which water is harvested (ie. increase yield). In good rainfall years (ie >300mm) by September around 12ML of stormwater is stored in the dam and usually lasts until March or April (Tony O'Connell *pers comm*. 2006). In years of low rainfall only 8ML is harvested and the remaining irrigation requirement is supplemented with reticulated drinking water (Tony O'Connell *pers comm*. 2006). When the water level in the dam drops to 0.5m, pumping from the stormwater dam ceases.

No water quality testing is carried out. The water is not chlorinated before use on the playing surfaces. The oval curator reports a significant response by irrigated turf to the low salinity water from the stormwater dam (Moore 1990). The project was not designed with research in mind so there are no records of water level in the dam and no records of extractions from the dam. Nevertheless, based on 10 years of operations and anecdotal evidence Moore (1990) derived an annual VRC of 0.28 for the Snowtown catchment. In retrospect it would have been valuable to install a water meter downstream of the pumps.

**Figure 189 Snowtown – Irrigated Town Oval Irrigated (Rabone 2003)**

The stormwater harvested from the streets of Snowtown provides an affordable source of water to maintain the oval and bowling greens through the summer months. The Education Department has shown an interest in purchasing water from the scheme to water the school oval if sufficient quantities are available. The school currently uses reticulated drinking water for all purposes.

### Affordability (Feasibility)

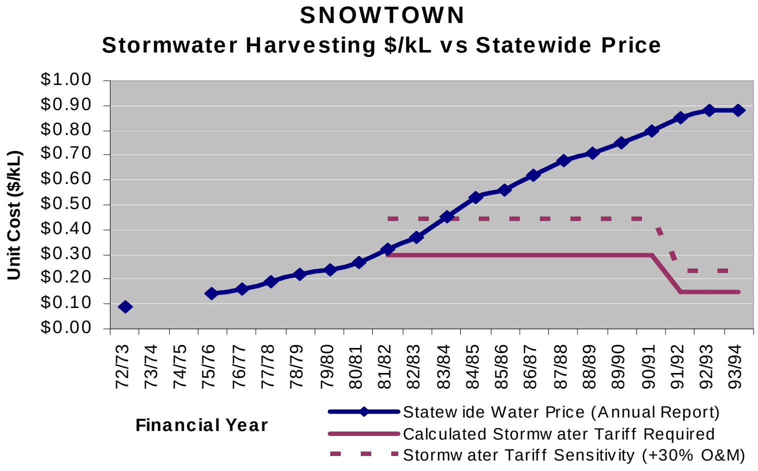
Moore (1990) determined the unit cost of the harvested water to be about half the State-wide price of the potable water and speculated that this would be considerably lower than the actual unit cost incurred by SA Water to import water to Snowtown from the River Murray. Using the same cost information data as Moore, the World Bank (WSP2002) tariff calculation method was applied to the Snowtown stormwater harvesting system. The calculation determines the required tariff to cover the cost of providing the non-potable water supply for irrigation without the application of an access charge. For the Snowtown stormwater scheme, the calculation was based on an estimated average volume of 15ML of water available. To test the sensitivity of the required tariff the calculation was also applied to a reduced volume of water (ie. 70% of estimated). The results of the analysis to recover costs associated to meet original costs in 1982 are set out in the table below.

## SNOWTOWN – Original Stormwater Tariff Calculation (Feasibility)

| | **Required Tariff Based on Original 1981/82 Costs** | | | |
|---|---|---|---|---|
| | **Year 0**<br>Estimate | **Year 0**<br>-25% Water | **Year 11**<br>Estimate | **Year 11**<br>-25% Water |
| **System Information** | | | | |
| Annual Water Sales (1) | 15,000 kL | 10,000 kL | 15,000 kL | 11,000 kL |
| **Annual Costs** | | | | |
| • Electricity (2) | $ 500 | $ 500 | $ 750 | $ 750 |
| • Water source fee | $ - | $ - | $ - | $ - |
| • Maintain – Dam | $ 200 | $ 200 | $ 650 | $ 650 |
| • Maintain - Network | $ - | $ - | $ 750 | $ 750 |
| • Depreciation (3) | $ 3,400 | $ 3,400 | $ - | $ - |
| • Chemicals | $ - | $ - | $ - | $ - |
| • Loan Repayment | $ - | $ - | $ - | $ - |
| • Interest | $ - | $ - | $ - | $ - |
| • Salaries | $ - | $ - | $ - | $ - |
| **Overheads** | | | | |
| • Office, Training | $ - | $ - | $ - | $ - |
| • WQ Monitoring | $ - | $ - | $ - | $ - |
| **Total Annual Cost** | **$ 4,100** | **$ 4,100** | **$ 2,150** | **$ 2,150** |
| **Tariff Required** | **$0.30/kL(4)** | **$0.44/kL(5)** | **$0.15/kL(4)** | **$0.23/kL(5)** |
| **State Unit Price(8)** | $0.32/kL | $0.32/kL | $0.32/kL | $0.32/kL |

*(13) Average annual volume of water for sale, ie. above the 0.5m water level and after evaporation losses.*
*(14) Estimated power costs*
*(15) Asset depreciated over a 10 year period (even though life of major asset could be > 80years)*
*(16) Tariff required to recover original investment of $34,000 in 1982. No access fee applied. Based on cost information contained in Moore (1990)*
*(17) Tariff required once the asset has been depreciated. Assumes no access fee is applied*
*(18) Statewide unit price in the year the tariff calculation would have been made, ie. 1981/82*

Figure 190 is a plot of the estimated unit cost of providing stormwater against the published state-wide price of water for the given financial year.



*Source: Published Statewide Water Price courtesy Trevor Govett (2004) and Snowtown project costs from Moore (1990).*

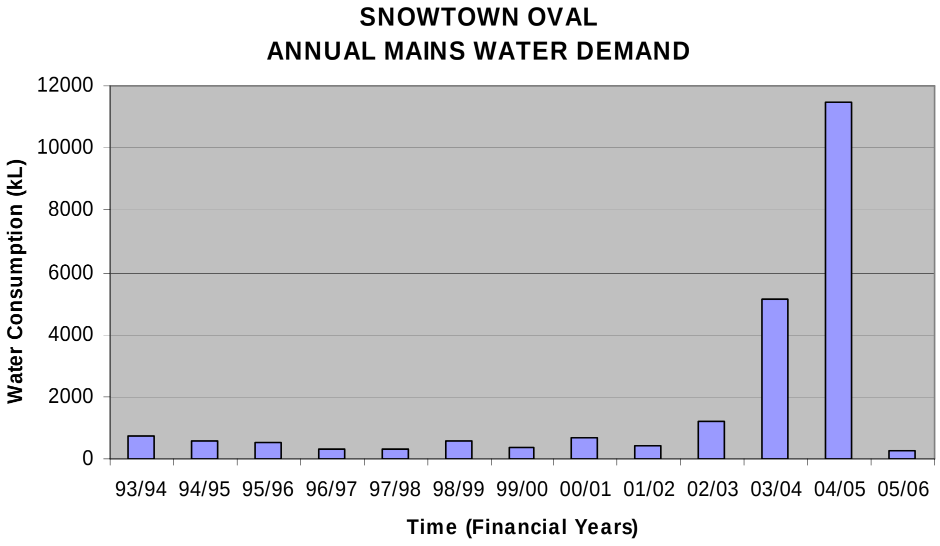
**Figure 190 Snowtown – Unit Cost Harvested Stormwater & Statewide Price**

The plot clearly shows that as a result of the investment the community has made savings in watering costs as the state-wide price for water has increased. At the time the project was initiated the estimated unit price to recover costs for the provision of stormwater for irrigation was comparable to the state-wide price. However, the state-wide price of reticulated drinking water may be considerably lower than the actual unit cost incurred by SA Water to provide the service.

### Tariff Setting (Current Operation)

Water undertakings are usually required to raise all of their operating costs and to service all or some of the debt associated with their capital expenditure through revenue received. The revenue requirement can be met from a number of sources including expected sales, subsidies and other forms of government support. Annual costs include the overhead depreciation and interest costs, maintenance and repair allowance and the annual power costs. In Snowtown, the cost of operating the stormwater supply is met by groups using the recreation facilities and the Snowtown Progress Association. The stormwater harvesting system is managed on behalf of the community by Snowtown Centenary Park Incorporated (SCPI).

The SCPI includes an allowance of $3,100 per annum in the budget for operation and maintenance of the dam; this includes power costs associated with the pumping. It does not include an allowance to purchase water at the statewide price for the remainder of the irrigation season if the storage runs dry (see Figure 191). However, Snowtown is fortunate to have an active progress association that generates a revenue stream for the community. The cost of reticulated mains water used for summer irrigation of the town oval is shared between the Snowtown Progress Association and the Snowtown Football Club.



*SA Water (1993-2006) Water Consumption Statistics*

**Figure 191 Snowtown – Historical Potable Water Use on Town Oval**

Based on estimated and historical cost information the unit cost of providing the non-potable stormwater supply with supplementary use of reticulated drinking water for summer irrigation of the oval is set out in the following table.

## SNOWTOWN – Irrigation Supply Tariff Calculation

| | **Budget (1)** | | **Historical Costs (1)** | |
|---|---|---|---|---|
| | **2005/06** | **2004/05** | **2003/04** | **2002/03** |
| **System Information** | | | | |
| Annual Water Used (2) | 12,000kL | 17,450 kL | 15,120 kL | 14,200 kL |
| **Annual Costs** | | | | |
| • Electricity (3) | $ 1,600 | $ 1,600 | $ 1,600 | $ 1,600 |
| • Water source fee (4) | $ - | $ 11,661 | $ 4,940 | $ 805 |
| • Maintain – Dam/Pump | $ 1,500 | $ 1,500 | $ 7,000 (5) | $ 1,500 |
| • Maintain - Network | $ - | $ - | $ - | $ - |
| • Depreciation (6) | $ - | $ - | $ - | $ - |
| • Chemicals | $ - | $ - | $ - | $ - |
| • Loan Repayment | $ - | $ - | $ - | $ - |
| • Interest | $ - | $ - | $ - | $ - |
| • Salaries | $ - | $ - | $ - | $ - |
| **Overheads** | | | | |
| • Office, Training | $ - | $ - | $ - | $ - |
| • WQ Monitoring | $ - | $ - | $ - | $ - |
| **Total Annual Cost** | **$ 3,100** | **$ 14,761** | **$ 13,540** | **$ 3,905** |
| **Tariff Required (7)** | **$0.28/kL** | **$0.91/kL** | **$0.97/kL** | **$0.30/kL** |
| **State Unit Price(8)** | $1.06/kL | $1.03/kL | $1.00/kL | $0.97/kL |

*(10) Budgeted and historical operational costs courtesy of Mr Tony O'Connell (2006)*
*(11) Annual volume of water used for irrigation from the stormwater dam plus potable water used to supplement the stormwater supply estimated by Mr Tony O'Connell (2006).*
*(12) Estimation of power costs as pumping station is not separately metered.*
*(13) The cost to purchase potable water from SA Water has been calculated from the metered annual volume and the published unit charge for each financial year. Due to the timing of the reading the actual payment is made in the next financial year however it the costs are shown in the year the water was used.*
*(14) Major overhaul of the irrigation (first one since 1982).*
*(15) Assets were depreciated was over a 10 year period (ie completed by 1991/92)*
*(16) Unit cost of providing irrigation water assuming no access fee is applied.*
*(17) Statewide unit price that applied in the year for each stormwater unit cost calculation*

For years when nearly all of the irrigation water is met from harvested stormwater the unit cost to the community for maintaining green recreation facilities is about $0.30/kL. In comparison to the current $1.06/kL unit cost of reticulated water supply above 125kL the cost of providing this non-potable water supply varies from around 25% to 91%. This analysis shows the cost of a water service depends very much on the price of the inputs, like electricity costs, maintenance costs, and purchase of supplementary water to meet irrigation requirements in low rainfall years when stormwater supply is not adequate. Nevertheless, the Snowtown stormwater harvesting scheme demonstrates the potential for such schemes in making irrigation of recreational areas affordable.

## Further Potential

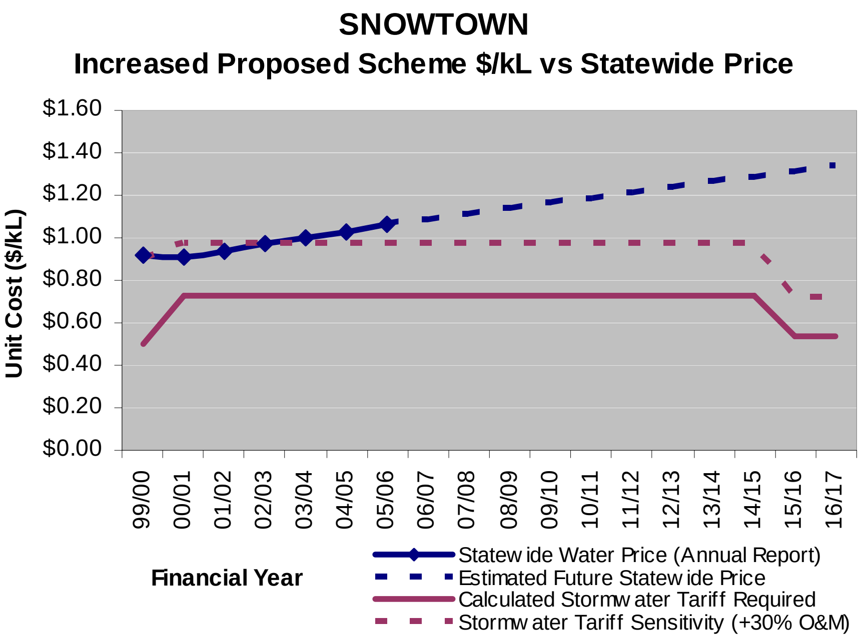
The development of the new grain bulk management facility on the south western perimeter of the township represents a significant opportunity to increase the capacity of the stormwater harvesting system. The preliminary estimate using limited information indicates that in the short term (upon completion of the main shed and two bunkers) the average annual water could be 13ML however, this may increase to 30ML with the construction of additional bunkers (Moore 2000). The main system components required to utilise this water include additional storage (around 20ML in the first instance) and around 2km of pipeline to transfer the collected water under gravity to the storage (Moore 2000). The budget estimated capital cost for the short term works is of the $100,000 (in 2000 dollars). Based on the estimated average water available (ie. existing scheme plus additional water from silo site), estimated capital costs and allowing for depreciation of new infrastructure over a 15 year period, the unit cost of extending the stormwater supply to include harvesting water from the ABB grain silo facility is set out in the table below.

**SNOWTOWN – Non Potable Stormwater Tariff Calculation (Feasibility)**

| | **Required Tariff Based on Estimate Future Costs** | | | |
|---|---|---|---|---|
| | **Year 0** | **Year 0** | **Year 16** | **Year 16** |
| | Estimate | -25% Water | Estimate | -25% Water |
| **System Information** | | | | |
| Annual Water Available (1) | 20,000 kL | 15,000 kL | 20,000 kL | 15,000 kL |
| **Annual Costs (2)** | | | | |
| • Electricity | $ 2,500 | $ 2,500 | $ 4,000 | $ 4,000 |
| • Water source fee | $ - | $ - | $ - | $ - |
| • Maintain – Dam | $ 2,500 | $ 2,500 | $ 4,000 | $ 4,000 |
| • Maintain - Network | $ 1,000 | $ 1,000 | $ 2,000 | $ 2,000 |
| • Depreciation (3) | $ 7,500 | $ 7,500 | $ - | $ - |
| • Chemicals | $ - | $ - | $ - | $ - |
| • Loan Repayment | $ - | $ - | $ - | $ - |
| • Interest | $ - | $ - | $ - | $ - |
| • Salaries | $ - | $ - | $ - | $ - |
| **Overheads** | | | | |
| • Office, Training | $ - | $ - | $ - | $ - |
| • WQ Monitoring | $ - | $ - | $ - | $ - |
| **Total Annual Cost** | **$ 13,500** | **$ 13,500** | **$ 10,000** | **$ 10,000** |
| **Tariff Required** | **$0.73/kL(4)** | **$0.97/kL(5)** | **$0.54/kL(4)** | **$0.72/kL(5)** |
| **State Unit Price(6)** | $0.94/kL | $0.94/kL | $0.94/kL | $0.94/kL |

*(1) Average annual volume of water harvested from town (existing) plus strategic silo site .*
*(2) Estimated annual costs*
*(3) New assets to be depreciated over a 15 year period*
*(4) Tariff required to recover additional $100,000 investment if made in 2000. No access fee applied. Based on cost information contained in Moore (2000)*
*(5) Tariff required once the asset has been depreciated. Assumes no access fee is applied*
*(6) Statewide unit price in the year the tariff calculation would have been made, ie. 2000/01*

The results of the analysis to recover costs associated to meet additional investment are plotted in Figure 192 against published and predicted future state-wide price.



*Source: Published Statewide Water Price and estimated project costs for harvesting stormwater from strategic silo site Moore (2000).*

**Figure 192 Snowtown – Estimated Unit Cost of Stormwater - Future Works**

In addition, the integration of treated effluent from the STEDS lagoon could further increase the volume of non-potable water available for irrigation purposes should this be needed. The unit cost would need to be adjusted to allow for depreciation of investment made to achieve this.

## WATER SENSITIVE LANDSCAPING PRACTICES

No specific water sensitive landscaping practices were observed.

## REFERENCES AND OTHER READING

This project only exists because of the resolution and dedication to community affairs of three men, Mr Ray Atkinson, Mr Mick McCormack and Mr Glen Davidson (Moore 1990).

Special thanks to Mr Steve Moore for arranging with Ray Atkinson, Lloyd Carter and Keith Krieg to show me around Snowtown. Thanks also to Mr Tony O'Connell who provided historical operational information.

*Wakefield Regional Council (WRC)*: thanks Mr Ed Spencer and Mr Glen Growden who provided additional information about the wastewater and stormwater infrastructure.

Moore,SD (1990): *"The Exploitation of Stormwater Runoff in Rural Townships"* provided useful facts on the water harvesting and reuse scheme. Paper presented at the Asia Pacific Conference of the International Federation of Parks and Recreation.

Moore,SD (2000): *"The Potential for Further Development of the Snowtown Stormwater Harvesting System."* This paper looks at the runoff yields from the new ABB Strategic Silo Site.

Farming Ahead (1996?): "*Stormwater provides a valuable source.*" Article published between 1995 and 1997, 42-43

WRC (2005): Round 1 Community Water Grants Application under the National Water Initiative for "*East Terrace drain upgrade*". The submission was successful.

# PART III APPENDICES & SUPPORTING INFORMATION

# Appendix 1
# Sustainability Literature Review

An understanding of the concept of '*sustainability*' is a precondition to assessing the sustainability of management, allocation and use of the South Australia's water resources. This appendix contains a complete copy of my assignment *Measuring Urban Water Sustainability – A Literature Review* submitted in June 2005 for Subject EMDV8041 Sustainability as part of a Master of Infrastructure Management from the Australian National University. The views expressed in this paper are those of the author and do not necessarily reflect those of SA Water.

## A1.1 INTRODUCTION

Humans have always consumed freshwater and for many millennia man's impact on water resources was both insignificant and local in character. However, in many parts of the world, growing demands for water use are beginning to outstrip available supplies, and there is competition between users for the available water (Anderson 2005). Current trends indicate that water scarcity is likely to threaten up to 50% of the world population in the next generation (Figueres *et al*. 2003). To avoid depletion of the world's resources, development practices need to be made more sustainable (Daniell *et al.* 2004). As Bossel (1999 in Bell & Morse 2003) and Harding (2005) point out there is only one alternative to sustainability: unsustainability. This paper seeks to outline underlying conceptual issues and relevant aspects of sustainability that may be applied to water and wastewater services to urban centres. A literature review was conducted to identify issues associated with the provision of sustainable water services to urban communities; however, as is often the case, this research raised more questions than answers. Finally, the paper presents a synopsis of matters that SA Water, and its engineers, will be required to balance in planning future water services for urban centres in South Australia. It concludes that moving towards more sustainable water services in South Australia will depend on rethinking water management (ie policies and practices), technological change, , as well as social change into the future.

## A1.2 EVOLUTION OF THE 'SUSTAINABILITY' CONCEPT

'*Sustainability*' is a dominant global view because of the finite nature of readily accessible materials. The term *'sustainable development'* has been employed to denote alternatives to traditional patterns of physical, social and economic development in both developed and developing countries (Hamnett 2003). That is, implementation of alternative development patterns that can act to mitigate environmental problems such as pollution, exhaustion of natural resources, overpopulation, loss of biodiversity, destruction of ecosystems and the deterioration of human living conditions (Hamnett 2003).

### A1.2.1 *Definition of 'Sustainability'*

Perhaps the most commonly quoted definition of '*sustainable development*' originates from the report *Our Common Future* published by the World Commission on Environment and Development in 1987 (Cocks 1992; Fleming 1999; Hamnett 2003; Foley *et al.* 2003), also referred to as the Brundtland definition, is:

> *…development which meets the needs of the present without compromising the ability of future generations to meet their needs and aspirations.*

The Brundtland definition identified the importance of considering the '*needs*' of both present and future generations (ie time is an underlying factor). However, as Hamnett (2003) observes that some of the things which are seen as '*needs*' in an Australian city, like Adelaide, might be regarded as extravagant luxuries in Jakarta or Manila. However, the '*generic*' nature of this definition of '*sustainable development*' has made interpretation of what is required to achieve '*sustainability*' controversial.

For these reasons, the Brundtland definition has been expanded and developed by many different groups and individuals to define sustainability in their own terms. For example, the definition proposed by Gilman (1992 in Foley *et al*. 2003) describes sustainability as a characteristic (ie. process or capacity) of a system;

> *…the ability of a society, ecosystem, or any such ongoing system to continue functioning into the indefinite future without being forced into decline through exhaustion or overloading of key resources on which that system depends.*

The concept of change, as well as the need to determine if the change or shift observed is beneficial or not, is a fundamental underlying factor of sustainability. Papers by Foley *et al.* (2003) and Daniell *et al.* (2004) both considered Gilman's definition the most appropriate platform to describe the concept of sustainability and enable discussion relating to its measurement as far as it can be applied to the main components (ie. key resources) of any system over time. That is, sustainability is a description of the pattern (or dynamic) of change in that system over indefinite time periods. A review of international experience by Ashley *et al.* (2004) concluded that there is no means of avoiding the need to make value judgements in the definition of sustainability; therefore, any assessment process used must make the judgements involved explicit. This is important as the demographics and attitudes (and values) of a given systems may all be subject to change over time, as people move into an area or leave it.

Regardless of the range of definitions of sustainability, there seems to be general agreement that is involves simultaneous satisfaction of economic, environmental and social factors (Fleming 1999; Bell & Morse 2003; Harding 2005). Figure 193 below shows the three factors as separate parts, each of which is considered a separate discipline with its own specialised body of knowledge.

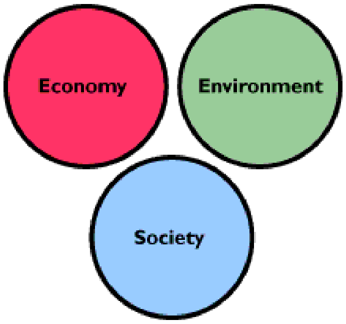


**Figure 193 Classic Components of Sustainability**

Progress towards sustainable water services requires the integration of these three components into the decision-making process because the concept of sustainability spans across the discipline boundaries. Understanding the three parts and their links is key to understanding sustainability.

### A1.2.2 *Conceptual Models of Sustainability*

Classic conceptual models of sustainability portray the interconnection between environmental, economic and social components (see Figure 194 below). Linked part models are useful in visualising the interactions between the main traditional components of sustainability and their corresponding importance (Daniell *et al.* 2004).

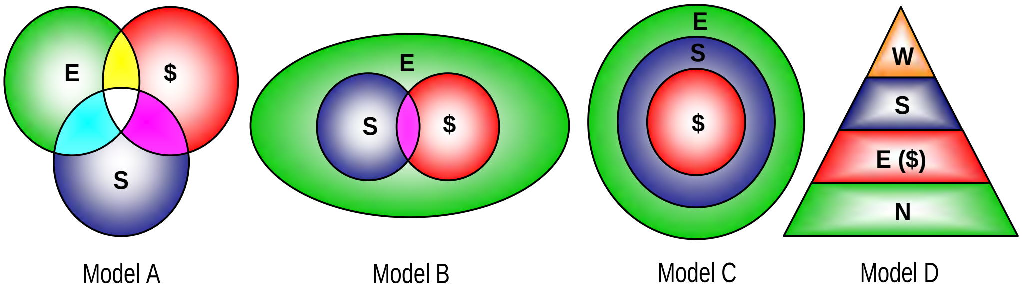
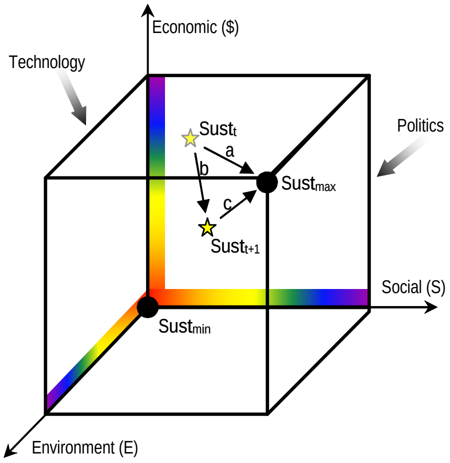


**Figure 194 Simple Sustainability Conceptual Models (Daniell *et al.* 2004)**

The simple conceptual models shown above (see Figure 2 above) are too general for assessment of complex systems and fail to incorporate the time factor (Daniell *et al.* 2004); a key component of sustainability highlighted earlier. Regardless of people's understanding of sustainability outcomes, the institutional frameworks of society need to facilitate actions in keeping with sustainability (Harding 2005). For example, desalination has emerged as the keystone of water resource planning across the world in arid coastal areas. However, as Harding (2005) points out there is little sense in turning a 'water problem' in an urban area into an 'energy-greenhouse-climate change problem' by simply adopting desalination which is fuelled by high fossil fuel energy use and carbon dioxide release.

The Sustainability Space model (in Figure 195) developed by Foley and Daniell (2002 in Daniell *et al.* 2004) is a more advance conceptual model which also take accounts of time, political and technological advances.



Sustainability Space (Foley and Daniell, 2002)

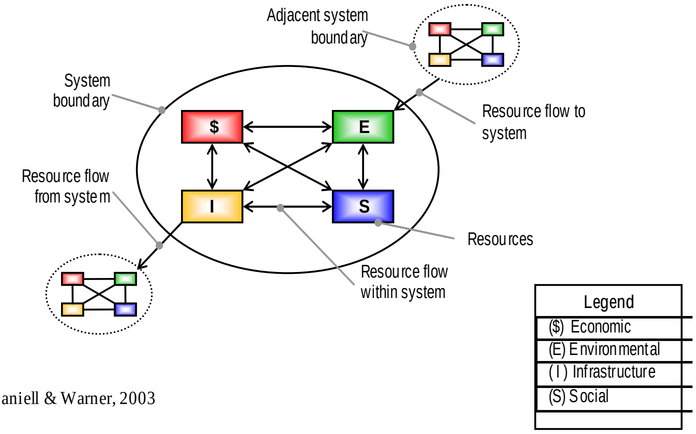
**Figure 195 Advanced Sustainability Space Model (Daniell *et al* 2004)**

Sustainability is measured as satisfying sustainable goals on each of three axes whereby sustainability is maximized by achieving predetermined goals for economic, social and environmental factors in the system under consideration. The point of maximum satisfaction (Sust$_{max}$) can move to represent changes in sustainability goals to reflect changing social values, technological improvements or political decisions.

Despite broad agreement on the tripartite nature, the concepts remain confusing to people and this has hampered progress in implementing sustainable practices (Harding 2005). Social, economic and technical developments exert pressures on the environment, changing its state, such that this ultimately elicits a response that feeds back to all stages in the system (Ashley *et al.* 2004). Systems theory can also demonstrate the importance of location to the overall assessment of sustainability (Foley *et al* 2003; Daniell *et al.* 2004).

### A1.2.3 *Systems Theory*

Accepting that sustainability is a characteristic of a system, an understanding of the system being considered is required, prior to discussions relating to whether or not a system is sustainable. Boundaries of any systems, being the distinction between those parts and interactions that are '*inside'* as against '*outside*', are always subjectively determined by the human observer (see Figure 196 below). Groups or individuals identifying ostensibly the same system will typically set differing boundaries and so perceive a slightly different system (Keen *et al.* 2005). Systems do not exist as ‘things in the world’, but as ‘systems of interest’ to a person or group (Dyball *pers comm*. 2005). In other words, they are relationships between variables selected by an observer, at least in part as a result of the tradition of understanding that the observer carries with them (Dyball *pers comm*. 2005). In all cases, it is important to identify the boundaries of the relevant systems, as well as adjacent systems which interact with the system being studied (Foley *et al.* 2003).



Foley, Daniell & Warner, 2003

**Figure 196 Representation of a System (Foley *et al.* 2003 in Daniell *et al.* 2004)**

The sustainability of any system depends on the level and quality of the key resources, and on the ability of the system to function effectively over time, without exhausting those resources. However, sustainability does not depend solely on the maintenance and management of natural resources alone. As pointed out by Foley *et al.* (2003) it also relies on the maintenance and management of human resources such as semi-permanent infrastructure of society, and a vast range of consumable products.

Systems theory provides a means to reflect on the links between humans and their ecosystems within an integrated framework, and gives an understanding of the change processes arising from their interactions (Costanza *et al.* 1993 in Keen *et al.* 2005). Change then is caused by the way that the parts (or variables) selected by the observer constrain each other – it is a description applied to the generic behaviour of the system as a whole (Dyball *pers comm*. 2005). Causing new behaviour requires either introducing new variables (or removing existing ones) or changing the way that the variables constrain each other or a combination of both (Dyball *pers comm*. 2005). Development of sustainable water services should be a conscious and continuous reflection, that is, sustainability does not represent the end point of a process; rather, it represents the process itself' (COA 2002; Bell & Morse 2003).

## A1.3 APPLICATION TO URBAN WATER SERVICES

Water managers in Australia need to question conventional and historic operation of water systems to identify opportunities for efficiencies (Figueres *et al.* 2003; Quinn 2004). Past development and use of water resources by humanity has made serious - and unsustainable - impacts on the environment. This is driving the need to embed sustainability principles more formally in development decision-making processes. However, research indicates that explicit inclusion of sustainability in the decision support process as been difficult to date (Ashley *et al.* 2004).

### A1.3.1 *Rethinking Water Management (Institutional)*

An engineer planning water services for urban centres today is required to do this '*sustainably*' which can seem to be a complex and overwhelming requirement. Then again, some aspects of sustainability have long been central to the development of resources and social infrastructure, particularly provision of safe water and sanitation services. For example, traditional water service objectives related to the social and economic well-being of the community being served. On the other side, water is embedded in the environment and interconnected in space through the natural water cycle allowing actions by one individual or group may generate effects far off-site. Also, water is unequally distributed and available resources are subject to increasing scarcity due to increasing demand. A particular challenge for the engineer planning water services is to educate and re-orient their institutions to more conscious and sustainable practices. It will require bridging the artificial compartments of water supply and wastewater services (Bell & Morse 2003; Quinn 2004).

The international *Water & Sanitation Program* (2003) conclude the provision of sustainable water services to a community has the following five interrelated, dimensions, all with specific equity perspectives:

- *Technical:* Reliable and correct functioning of the technology, ie. delivery of enough water of an acceptable quality for a water supply.
- *Financial*: Systems can only function if financial resources meet at least the costs of operation and maintenance.
- *Institutional:* Communities need institutions to keep systems operational, accessible and widely used. Institutions have cultural characteristics, agreed and valued procedures and rules for operation, and varying capacities for management and accountability
- *Social:* Services will only be sustained by users if they satisfy expectations, ie. services match socio-cultural preferences and practices that users consider worth the cost they incur to obtain them.
- *Environmental:* Water resources face multiple threats; for example over extraction and contamination of water sources from irrigation, industry and wastewater disposal threaten reliable and safe drinking water supplies.

For any intervention (ie to improve sustainability) to be effective it must have a plan for sustainability and equity built into the design, and some means of verifying the progress being achieved once implementation gets under way (WSP 2003). Tools are available for analysis of environmental impact and resource utilisation, risk assessment and economic evaluation; however, methods for evaluating socio-cultural and functional criteria must be further developed (Ashley *et al.* 2004). There is not much point finding out at the end whether or not it achieved sustainable and equitable outcomes; however, gauging the sustainability before it has actually resulted can only be hypothetical.

### A1.3.2 *Recycling Water (Technological Change)*

Water reuse and recycling has been the subject of intense scrutiny in Australia as demand for the resource approaches supply limits (COA 2002; Radcliffe 2004). Infact Australia has experienced a fourfold increase in the demand for recycled water between 1996/97 to 2000/01 (Dolnicar & Saunders 2005). South Australia has achieved the highest per capita level of water recycling in Australia for non-drinking purposes (Hamnett 2003). This has been accomplished by research and development into the technical feasibility of developing alternative water sources and services, while relatively little is understood about the social dimensions of the alternative pattern of development (Cooper *et al*. 2005; Hurlimann & McKay 2005). Other issues requiring more definition include governance, management, regulation, ownership, and public acceptance of the different attributes of recycled water (Hamnett 2003; Hurlimann & McKay 2005). Introducing reclaimed water as an alternative to traditional water supply involves changing practices as well as technology (Hamnett 2003; Marks 2005).

### A1.3.3 *Awakening a Philosophy of 'Water Wisdom' (Social change)*

During periods of drought, communities can become acutely '*water aware*' and inclined to support innovative, non-conventional water management strategies (Khan & Gerrard 2005). Further complicating our understanding is the behaviour of humans themselves. Humans do not necessarily respond the same way when subject to the same influences. The reactions can vary greatly across space and time in response to changing values, contexts, incentives or understandings (Keen *et al.* 2005). Broad and impartial water education is a key to successful community engagement, and should be strongly supported by governments and the community (Quinn 2004).

## A1.4 CONCLUSIONS

Water management in the 21st century must change: '*business as usual*' is no longer a viable option (Figures *et al.* 2003). However, while the principle of sustainability has gained widespread agreement, Ashley *et al.* (2004) argued that not many water management and water service organisations have translated sustainability into action. Major impediments to rapidly increasing the sustainability of water services are; the long life of the public infrastructure (including financing), resistance to change (from. institutions), time to effect social change with regard to water use practices and behaviours (ie. businesses and individuals) and the difficulty in predicting the future (ie. impact of climate change etc). This is made more difficult as water management is also a part of political game with constantly changing goalposts at the international and national level (Quinn 2004).

Provision of effective and efficient water services that can be sustained over time is central to economic development activity and '*quality of life*' in South Australian communities. South Australia must remain innovative and flexible, and be prepared to meet challenges with a technically strong water industry supported by a well educated and engaged community.

# Appendix 2

# Water Industry Reform in Australia

The Australian water industry is vulnerable to political moves at state or federal level (Gale 2000). The water industry is one of Australia's largest, with assets valued at over $90 billion in replacement cost terms with some $40 billion of these assets in country areas. Around 90% of water supplied to non-metropolitan areas is used to irrigate crops and pastures (Productivity Commission 1999). Under Australia's Constitution, water quality and management of water resources is a State and Territory responsibility. However, all governments, including the Federal Government, recognise the need for coordinated action to stop the widespread degradation of Australia’s natural resources (COA 2004). This has led to considerable differences in regulation and water quality across Australia (Water 2000).

During the 1980s, Australia’s leaders were of the opinion that to prosper as a nation, maintain and improve living standards and opportunities for Australian people, they had no choice but to improve productivity and international competitiveness of its firms and institutions. This meant that Australian organisations, irrespective of their size, location or ownership, needed to become more efficient, more innovative and more flexible (Hilmer *et al*. 1993). The outcome has been an increase in competitive pressures and the Australian water industry has become part of the international market for water services (Carpenter 1998). This Appendix contains an overview of the major directions, policies and guidelines that have impacted directly on the water industry.

## A2.1 NATIONAL POLICY DIRECTIONS

### A2.1.1 *Review of Trade Practices Act (Commonwealth) (1992)*

In 1992, a Committee of Inquiry, chaired by Professor Fred Hilmer, was established to investigate a national competition policy. The Committee recommended implementation of a national competition policy for Australia that would promote and maintain competitive forces to increase efficiency and community welfare. Most areas of the economy would be affected, with the greatest impact on sectors previously sheltered from competition such as major infrastructure industries and some areas of agricultural marketing and the professions.

Table 55 shows the six main elements recommended on the deficiencies found in a review of the *Trade Practices Act 1974*. Items two to six of the recommended national competition policy had a significant impact on the changes in the Australian water industry.

**Table 55 Elements of the National Competition Policy**

| Elements of the National Competition Policy | |
|---|---|
| **Policy Element** | **Area of Concern** |
| 1. Limiting anti-competitive conduct of firms | Competitive conduct rules of Part IV of the Trade Practices Act (Cth), but without the numerous exemptions. |
| 2. Reforming regulation which unjustifiably restricts competition | Reviews by individual governments without a systematic national focus. |
| 3. Reforming the structure of public monopolies to facilitate competition | Mostly examined on a case by case basis by individual governments. |
| 4. Providing third-party access to certain facilities that are essential for competition | Some arrangement in place or being developed on an industry specific basis (eg telecommunications); no general mechanism capable of effectively dealing with these issues across the economy. |
| 5. Restraining monopoly pricing behaviour | Surveillance of declared firms' prices under Commonwealth Prices Surveillance Act with important exemptions; various mechanisms in the States and Territories. |
| 6. Fostering "competitive neutrality" between government & private businesses when they compete | Largely addressed on an ad hoc basis by individual governments; increasing moves towards corporatisation but disparate models.<br>Requirement for government businesses to make tax-equivalent payments. |

*Source: Hilmer et al. (1993), Box 1, p xvii and Box 1.1, p 7.*

A report for the Economic Planning Advisory Council in 1992 reached the following conclusions (WSAA 1998):

> *Major capital city and rural water supply authorities servicing residential and other users typically achieve very low rates of return on the substantial capital involved. Greater efficiency in water use, greater conservation of water supplies, and postponement of the building of further dams would result from higher and more economically rational systems of charging for reticulated water supplies*

### A2.1.2 *COAG Water Reform Framework (1994)*

The reform of Australia's water management regulation began in 1994 with a strategic framework encompassing economic, environmental and social objectives being developed and agreed by the Council of Australian Governments (COAG). The role of COAG is to initiate, develop and monitor the implementation of policy reforms that are of national significance and which require cooperative action by Australian governments. The COAG participants agreed to the following in relation to water resource issues (WSAA 1998):

> *The Council endorsed the strategic framework (which) embraces pricing reform based on the principles of consumption-based pricing and full-*

> *cost recovery, the reduction or elimination of cross-subsidies and making subsidies transparent.*

Through COAG, a national policy for the efficient and sustainable reform of Australia's rural and urban water industries was developed. Eleven elements formed the basis of water reform designed to achieve an efficient and sustainable national water industry. The framework recognised the importance of a consistent approach to water reform throughout Australia. At the same time it allowed each State and Territory the flexibility to adopt its own approach to implementation depending on its own unique institutional and natural characteristics, but agreed the full framework would be implemented by the year 2001 (COA 2004).

Interim deadlines for major components of the reform package were also set. As the reforms progressed, timeframes for implementation were subsequently extended for certain aspects including allocations and trading, which were extended to 2005 (COA 2004). The interim deadlines included (AAR 2004):

- 1998 – urban water pricing; institutional reform
- 2001 – rural water pricing; environmental water allocations to stressed rivers
- 2005 – environmental water allocations to all river systems and groundwater.

Much of the benefit from water reform will come from the more sustainable exploitation and efficient allocation of a scarce resource which is subject to increasing demands, and more efficient investment in infrastructure (Productivity Commission 1999). To achieve these outcomes, water prices for many users will have to increase to reflect more closely the costs of its provision. That said, the extent to which water prices actually rise will depend largely on the ability of service deliverers (and regulators) to increase efficiency and contain costs.

Of the eleven original commitments, the reforms of particular importance, in terms of their overall impact on rural and regional South Australia and support the development of water harvesting and reuse projects in towns are presented in Table 56 below.

**Table 56 Elements of the Water Reform affecting Reuse Projects in Towns**

| | |
|---|---|
| **Cost Recovery & Pricing** | **Bulk Water Supply**<br>• charging on a volumetric basis to recover all costs<br>**Rural Water Supply**<br>• where charges do not currently fully cover the costs of supplying water to users, agree that charges and costs be progressively reviewed so that no later than 2001 they comply with the principle of full cost recovery with any subsidies made transparent<br>• that future investment in new schemes or extensions to existing schemes be undertaken only after appraisal indicates it is economically viable and ecologically sustainable |
| **Allocation and Trading in Water Entitlements** | • that water be used to maximise its contribution to national income and welfare, within social, physical and ecological constraints of catchments |

| | |
|---|---|
| | • determine allocations or entitlements to water, including allocations for the environment as a legitimate user of water; having regard to the water needs to maintain the health and viability of river systems and groundwater basin<br>• where future irrigation activity or dam construction is contemplated, undertake appropriate assessments to allow natural resource managers to satisfy themselves that the environmental requirements of river systems will be met before any harvesting of the water resource occurs |
| **Institutional reform**: | • adoption of an integrated catchment management approach to water resource management<br>• to the principle that, as far as possible, the roles of water resource management, standard setting and regulatory enforcement and service provision be separated institutionally<br>• that constituents be given a greater degree of responsibility in the management of irrigation areas, for example, through operational responsibility being devolved to local bodies |
| **Community Consultation and Education**; | • to the principle of public consultation by government agencies and service deliverers where change and/or new initiative are contemplated involving water resources |
| **Environment & Water Quality**; | • support ARMANZ and ANZECC in the development of National Water Quality Management Strategy<br>• to support the establishment of landcare practices that protect areas of river which have high environmental value or are sensitive for other reasons |

### A2.1.3 *National Competition Policy Reform (1995)*

Under this policy, payments are made available for States and Territories that successfully implement a range of important reforms — including the COAG water reform framework. A separate body, the National Competition Council, is responsible for assessing the progress of jurisdictions in implementing reforms annually. As a result of this process, implementation and continued observance of the COAG water reforms is now a requirement for States and Territories to receive their full share of the payments under the National Competition Policy.

In the water sector, the thrust of the reforms has been on establishing a market environment which will discourage overexploitation and the misuse of scarce water resources, and lead to more efficient investment in water infrastructure. The water industry is one of Australia's largest, with assets valued at over $90 billion in replacement cost terms. Some $40 billion of these assets are in country areas. Around 90% of water supplied to non-metropolitan areas is used to irrigate crops and pastures (Productivity Commission 1999). This has sometimes required significant increases in prices for some water users, in contrast to the price reductions which the NCP reforms have delivered to many energy users (Productivity Commission 1999). Primarily because of past practice, government provision of water infrastructure was often used to support regional development in rural and remote Australia.

A key triumph of the water reform framework to date has been the fact that through it, the needs of the environment are genuinely becoming recognised in water use decisions. While progress in implementing the reforms at the institutional level has varied amongst the jurisdictions, the achievements so far should not be underestimated. Policy and institutional settings are now significantly different from those in 1994 when COAG agreed to the reform framework. A major step towards implementation has been the introduction of institutional and legislative changes to lay the groundwork for the reforms. The time and complexity involved in such legislative change has in some instances been greater than expected, but the implementation of appropriate legislation provides an important pathway for maintaining the momentum of reform.

In December 2001, COAG officials agreed to prioritise national water reform commitments across the 2002 to 2005 assessments as follows:

- The 2003 assessment (completed in June 2003) was on urban water pricing and cost recovery, institutional reform, intrastate trading arrangements, integrated catchment management and water quality reforms.
- The 2004 assessment will focus on rural water pricing and cost recovery, interstate trading arrangements and progress with implementing environmental allocations.

A full assessment across all aspects of reform will be carried out in 2005. There remain some significant challenges if the framework's goals of environmentally sustainable resource management are to be met. First and foremost more progress is needed in determining environmental flow requirements and allocations. This requires a good information base and effective processes for community involvement. Reforms to improve pricing structures and the efficiency of service provision commenced in urban areas in the early 1990s. In country areas, however, the likely adverse social and economic impacts of such reforms on some sectors of the community posed a major stumbling block to change (Productivity Commission 1999). The Council of Australian Governments (COAG) agreed that there is a need to refresh the 1994 water reform to increase the productivity and efficiency of water use, sustain rural and urban communities, and to ensure the health of river and groundwater systems.

### A2.1.4 *The National Water Initiative (2004)*

In August 2003, COAG announced the 'National Water Initiative' (NWI) – a $500 million package aimed at restoring environmentally sustainable flows to the Murray-Darling Basin (AAR 2004). The NWI will build on the achievements of the 1994 COAG strategic framework for the reform of the Australian water industry, the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality.

Under this NWI, the Commonwealth will contribute $200 million, NSW and Victoria will each contribute $115 million, South Australia will contribute $65 million, and the Australian Capital Territory will contribute $5 million to a series of measures intended to:

- improve the security of water rights by equating them to property rights;
- create a nationally compatible system of water entitlements;
- ensure water is put to best use by creating and encouraging trading in a water market encompassing the entire Murray-Darling Basin;

- restore over-allocated river systems to environmentally sustainable levels; and
- encourage water conservation in cities.

COAG also agreed to establish a National Water Commission (NWC). The NWC will assess progress in implementing the NWI and advise on actions required to better realise the objectives of the Agreement. The urban component of the NWI will reinforce the need for urban users to use water efficiently for example by promoting water reuse and recycling, the adoption of more efficient technologies and by reviewing the effectiveness of pricing policies.

## A2.2 NATIONAL WATER QUALITY MANAGEMENT STRATEGY (NWQMS)

Water quality is being addressed through the development of a National Water Quality Management Strategy which encourages all responsible parties, including government and the community, to contribute to better water quality management. The strategy is based on policies and principles that apply nationwide and will include guidelines and other documents which focus on a part of the water cycle or a particular activity within the cycle (eg rural land uses and water quality).

In 1992, the National Water Quality Management Strategy (NWQMS) was introduced by the Commonwealth, State and Territory Governments as a response to community concern about the condition of the nation's water bodies and the need for them to be managed in an environmentally sustainable way. The main policy objective of the NWQMS is to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development. The process for water quality management involves the community working with government to set and achieve local environmental values and water quality objectives for water bodies and to develop management plans for catchments, aquifers, estuarine areas, coastal waters or other water bodies.

Under Australia's Constitution, water quality and management of water resources is a State and Territory responsibility. Consequently, those jurisdictions determine whether and how the NWQMS and its guidelines are to be implemented and will necessarily involve State and Territory water policies and community preferences. The commitment was strengthened in 1994 when the NWQMS was included in the Council of Australian Governments (COAG) Water Reform Framework (discussed separately in section A2.1.3).

The national guidelines developed under the NWQMS cover issues across the whole of the water cycle. They provide information and tools to help communities manage their water resources and protect water quality including developing local action plans for water quality management. A total of 19 guideline documents have been released and two more are being prepared. The following sections include a brief precis of five national guidelines which are part of the suite of 21 documents forming the NWQMS that can be used a refernce as a sound basic reference for communtiies investigating the feasibility of implementing small local water reuse projects.

### A2.2.1 *Australian Drinking Water Guidelines (ADWG)*

The current *Australian Drinking Water Guidelines* were released in 1996 to replace the 1987 version and are based on the *World Health Organisation Drinking Water Guidelines 1993*. The new guidelines include chapters on system management, system performance and small water supplies (those serving fewer than about 1000 people) and a suggested approach to community consultation to ensure adequate public participation in the water industry's decision making process (ADWG 1996). Likewise, these principles can be used to negotiate different standards for small water reuse projects.

### A2.2.2 *Australian and New Zealand Guidelines for Fresh and Marine Waters*

The *Australian and New Zealand Guidelines for Fresh and Marine Water* released in 2000 replaces the 1992 version (ANZECC 1992). It collates scientific information and management experience on the water quality required to sustain the range of community values that Australian waters may support (eg. agricultural water, swimming, commercial or recreational fishing, and protection of ecosystems). The guidelines are an important reference tool for the development of catchment management plans and policies, allowing governments and the community to make informed decisions about water quality requirements and the consequences of management decisions.

### A2.2.3 *Guideline for Sewerage Systems: Use of Reclaimed Water*

This document has been developed as a basis for a common and national approach throughout Australia for the use of treated effluent (reclaimed) water. The guideline deals with effluent from municipal (ie. community) wastewater plants treating mainly domestic and some industrial wastes. The prime focus is to facilitate treatment of wastewater to a level acceptable for beneficial use after allowing for local conditions. The document can be used as a reference by water resource managers, communities, and industries to develop reclaimed water schemes.

### A2.2.4 *Guidelines for Urban Stormwater Management*

The management of stormwater is an integral part of environmental management. Growing community concern about the condition of water bodies and increasing understanding that sustainable management of stormwater resources requires recognition of environmental needs, has led to demands for changes in the management of stormwater.

### A2.2.5 *Guidelines for Groundwater Protection in Australia*

One million people in 600 communities around Australia enjoy great benefits from their groundwater resources. It is also an important source of water for major cities, industries and rural towns. For many isolated communities and rural properties, their very existence relies on the availability of good quality groundwater.

# Appendix 3

# Regulating Effect of Water Pricing

This appendix contains a complete copy of my assignment Review of the *Impact of Water Pricing Reform on Residential Water Use in South Australia* submitted in October 2004 for Subject INFR8082 Managing Utilities 2 as part of a Master of Infrastructure Management from the Australian National University. The views expressed in this paper are those of the author and do not necessarily reflect those of SA Water.

## A3.1 INTRODUCTION

Water is one of the Australia's largest industries so the potential for economic gains from improved performance is considerable. Demands for water from urban centres often compete with those of other major water users including natural ecosystems and irrigated agriculture. Population growth, sustainable yields, and provision for environmental flows are likely to increase the supply and demand imbalance. Water pricing reform is one measure, among various measures, designed to encourage efficient use of water resources. For more than a decade now, as part of the Council of Australian Governments (COAG) water reform, Australian communities have been reviewing and changing approach to the way water services are paid for. Today, most Australian's living in urban centres face water prices that reflect the amount of water they use. South Australia has been a part of this process of change.

Changing the pricing structure for water and making the price of water more cost reflective may have significant and very different effects on different groups of customers and within those groups, on individual customers (WSAA 1998). This paper outlines water pricing reforms in South Australia since the early 1990s and explores how these changes have impacted residential customers. The review begins with a background discussion of the urban water supply in South Australia. Next the paper looks at the major structural changes in the residential water tariff before examining the financial impact on residential customers and associated adjustment in residential water use based on historical water consumption data over the same period.

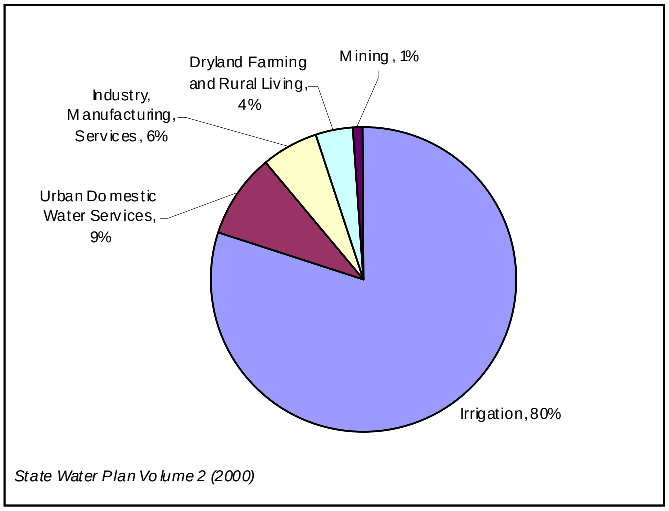
## A3.2 BACKGROUND

### A3.2.1 *Australian Water Industry Reform*

Water is one of the Australia's largest industries so the potential for economic gains from improved performance is considerable. Unlike most businesses, which operate in competitive marketplaces, government departments operate in monopolistic markets and lack direct competition (Eggleton 1994). As a consequence, normal market indicators of performance are not available. Between 1994 and 2004, the national COAG water reform has contributed to significant structural changes in the way government business enterprises operate around Australia. The recent National Water Initiative (NWI) 2004 is expected to build on the achievements of the 1994 COAG water reform of the Australian water industry and provide consistency across sectors and jurisdictions.

### A3.2.2 *Water Use in South Australia*

Demands for water from urban centres compete with those of other major water users such as natural ecosystems (ie. environmental flows) and irrigators. This competition is likely to become more intense as the forecast reductions in rainfall associated with climate change take effect (COA 2002). Figure 197 shows the estimated breakdown of water use for South Australia to be 80% for irrigation, 15% urban and industrial, and 5% rural towns and mining (GSA 2000). Urban water authorities provide water for domestic (residential), industrial, commercial and institutional uses. Residential water use embraces domestic household uses, including washing, cooking, sewage and waste disposal and outdoor uses (garden and yard). At 9% of total water use in South Australia, urban domestic (residential) water use is a significant component of total urban water consumption.



*State Water Plan Volume 2 (2000)*

**Figure 197 Water use by Sector in South Australia**

### A3.2.3 *Urban Water Infrastructure Development*

Concern over monopoly often leads the government to either provide infrastructure services itself or regulate the prices and quality of service of private infrastructure (Gomez-Ibanez 2003). The characteristics that have encouraged government involvement in water supply include; the need for capital intensive network that distribute products or services over geographical space, investments that are durable and immobile, and economies of scale mean that the cheapest way to serve a community is with a single company (Gomez-Ibanez 2003). Development of water supply has been interwoven in the political and social history of South Australia from early days (Hammerton 1986).

The traditional response to meet demand has been to build pipelines to transfer water to areas where local supply is unreliable or constrained. This approach has resulted in the development of extensive regional water supply infrastructure; where the cost of constructing and operating in many country areas is not covered by the income from water charges. It is reported in ESCOSA (2004) that SA Water assets are valued at $6.6 billion, and the water supply assets at $4.1 billion; with around 50% in regional areas.

All but 2% of the State's population have access to reticulated water supplies that can be used for all purposes provided (on behalf of the State Government) by either SA Water or United Water (under contract to SA Water). This past development practice has also given communities a perception that there is an abundance of water available from year to year and season to season (COA 2002). Combined with low charges for water, these perceptions led to a steep incline in water consumption. Changes in water infrastructure development could deliver improvements in water conservation and environmental restoration; however billions of dollars have been invested in the existing infrastructure.

### A3.2.4 *Legislative Framework for Urban Water Supply*

In South Australia, the legislative basis for urban water supply systems is the *Waterworks Act* 1932. The original Act was designed with powers to compel property owners within certain urban areas to receive water supply services provided by the State Government. These Acts continue to provide SA Water (a government business enterprise) with significant market power. The combined effects of the monopoly powers bestowed by legislation to SA Water and widespread political pressure to keep water charges affordable (under the uniform pricing policy) have conspired to discourage new entries to the residential water supply market.

In South Australia, three different water rating systems operate in South Australia, one for each category of customer using the public water supply. The categories of customers are (SA Water 1999):

- residential properties (including vacant land and supply by measure agreements)
- business properties (including industry, mining and quarrying, medical and health services, land used for primary production and country lands) and
- commercial properties (including shops, offices, retailers, wholesalers, business and professional services).

Residential customers dominate the number of connections and represent 88% of the customer numbers but consume only 65% of the water supplied by SA Water. Additional information on the breakdown of SA Water's customer base is provided in Appendix A.

A uniform water price structure for residential customers operates throughout most of the State. One reason for adopting a common schedule is that water pricing must recognise capacity to pay and therefore users should not be required to meet full costs where this would be beyond their capacity (WHO 2003). Under this policy, water customers in the metropolitan, rural and regional areas are charged the same price for reticulated water. This forms part the Government's equity and social justice policy. Some subsidy is inevitable under this pricing approach, primarily because the price is determined on the basis of full cost recovery of the metropolitan water business.

The key adherence to COAG principles is ensuring that the subsidies are transparent (ESCOSA 2004). Consequently, the State government pays a community service obligation (CSO) to SA Water for providing these services. SA Water Annual Reports show the level of CSO funding is around 1% to over 40% for the metropolitan and country water supply businesses respectively. While CSO payments are explicit, efficient costs for regional solutions are not identified (ESCOSA 2004) nor is the level of subsidy received by individual water customers. Under the current CSO policy, these payments are not contestable (ie. available to competitors); consequently there is no incentive for SA Water to seek efficiencies in its country water business

### A3.2.5 *Role of Water Pricing*

Water prices should not be regarded as an instrument for modifying income distribution. Dixon and Baker (1992) found that low water prices are not a suitable way to help low income people or people with large families; rather this is a matter for social welfare policy. The appropriate role of water price is to guide consumers' demands for water towards socially optimal levels.

The key characteristics of an effective water pricing system are (WSAA 1998 and GWT 2003);

| | |
|---|---|
| • Cost reflectivity | charges signal to users the true scarcity value of water and the cost of providing the service; provide incentives for more efficient water use and give investors information on the real demand for any needed service extension, |
| • Environmental protection | encouraging conservation and efficient water use, recognising environmental benefits from leaving water in its natural state (pollution charges), and |
| • Cost recovery | generation of revenues for the efficient operation (and debt service) of the present system and its future maintenance, modernisation and operation |

There are a number of pricing structures that can be adopted but one that charges according to the amount of water used can provide incentive for careful use. It is fundamental that price reflects the cost of providing water to urban centres to create the conditions to bring about optimum use and encourage adoption of measures to maximise efficiency in water use. Efficient water pricing is generally via a two part tariff arrangement whereby the variable component is structured to reflect some measure of the marginal cost of water supply (Graham & Scott 1997; WSAA 1998). If environmental sustainability is to be achieved, recognising the real cost of resource extraction must be a central driver of the next generation of economic reform (COA 2002).

## A3.3 RESIDENTIAL WATER PRICING REFORM

Reform of water pricing towards pay-for-use was initiated in the early 1980s by the State Government (SA Water 1999). The key years of pricing reform in moving from a flat rate to a two part tariff were 1991/92 and 1995/96 (Trevor Govett *pers. comm.*). These reforms were introduced as a gradual transition over a 5 year period. A summary of the water pricing reform for residential customers in moving from water rates based on property value to a two part tariff in South Australia is presented in Table 57.

**Table 57 Summary of Residential Water Pricing Reform in South Australia**

| Structure | Pre 1991/92 | 1991/92 | 1993/94 | 1995/96 |
|---|---|---|---|---|
| **Access** | Minimum charge plus property based (1) | No change | Flat Fee | No change |
| **Allowance** | Access Charge (2) divided by Unit Rate | Fixed 136kL | No change | Abolished |
| **Usage** | Unit Rate | No change | No change | Two Unit Rates |

(1) Actual access charge included minimum fee plus component derived from property value above a predetermined value
(2) Access charge includes property component if applicable

*Sources used to generate table: SA Water (1999) & Trevor Govett (pers. comm.)*

### A3.3.1 *Water Rates Based on Property Value (Pre 1991/92)*

Water pricing was based on a property based access charge with a water allowances calculated on the basis of the improved property value (subject to a minimum charge). Water used in excess of the allowance attracted additional water use charges calculated using the same single price of water. In the early 1980s, the charge per kilolitre of water was progressively increased to reflect the actual cost of collection, chlorination, filtering and distribution as shown in Figure 198.

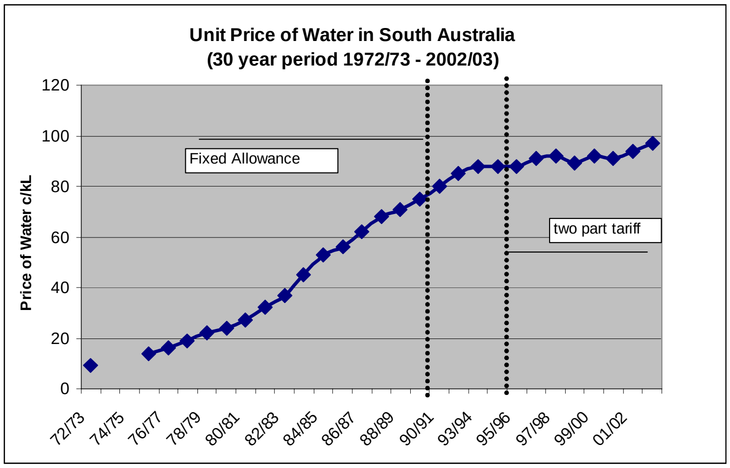


**Figure 198 Presiding Unit Price for Water between 1972/73 to 2002/03**

Increasing the unit water price had the effect of reducing the property based water allowance and causing more customers to exceed the remaining allowance (SA Water 1999). By the late 1990s, approximately 65% of domestic property owners were using and paying for 'excess water', in other words payment for water actually used as shown in Figure 199.

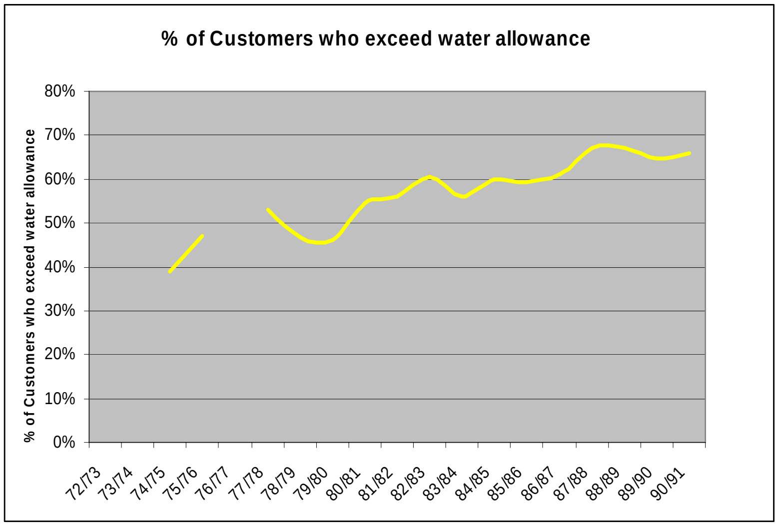


**Figure 199 Percentage of Customers Exceeding Water Allowance to 1990/91**

In 1990, Mr Hugh Hudson undertook a major review of water and sewerage charges.

### A3.3.2 *Transition to Two Part Tariff (1991/92 to 1996/97)*

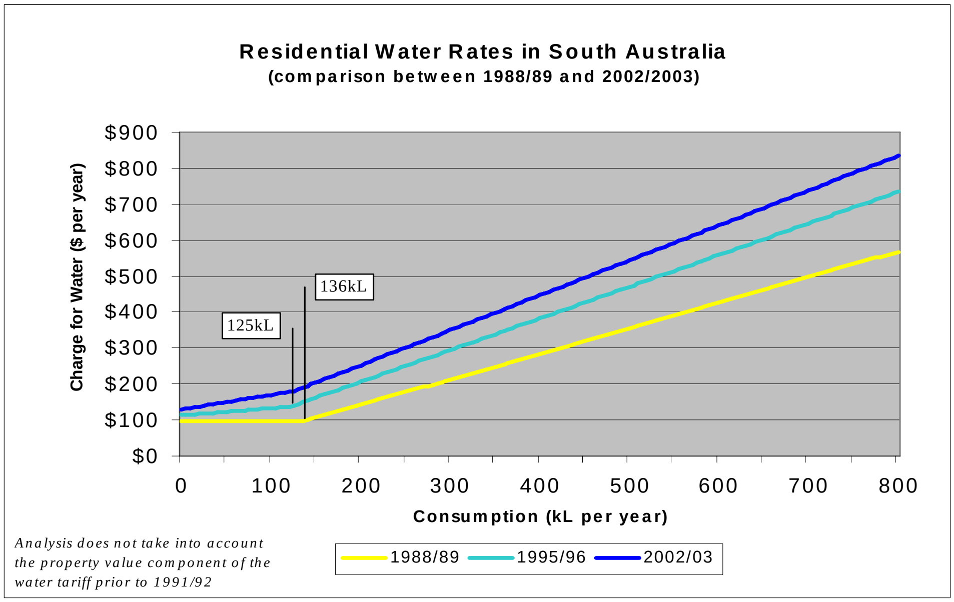
The "Hudson" pricing reform was introduced in 1991/92 saw the first major structural reform toward 'user pays' water pricing. Water allowances for residential customers were fixed at 136kL, that is, no longer dependent on the value of the property being served. The access charge remained linked to the property value until 1993/94 when flat fee (access charge) was introduced. Further substantial change occurred in 1995/96, when residential customers paid from the first kL of water used. This change converted the price structure to a two part tariff; consisting of an access charge and water use charges.

The variable water use charges had two blocks: a low unit rate for all consumption up to 136kL, and higher unit rate for all consumption greater than 136kL. The point at which the second tier water price applied was adjusted downwards to 125kL in 1996/97. ESCOSA (2004) found that the decision by the State government to provide a lower first block tariff for residential customers constitutes a transparent cross subsidy and to be consistent with the COAG water reform principle, on the assumption that the variable charge for the second block is the true cost reflective charge.

Continued application of the lower first block tariff may not provide the correct signal to guided customers towards socially optimum levels. Rabone (in prep) found that the average indoor water use for households in New Haven Village (an experimental residential project north of Adelaide) was around 100kL per annum over the period 1999/00 to 2002/03. In situations where dual water supply service is offered and the lower first block tariff is less than the unit price set for recycled water, then low water use customers may seek to use potable water in preference to recycled water to minimise their water bill (ie 100kL to 125kL). This scenario is apparent in the residential development (Mawson Lakes) where recycled water is currently priced at 75c/kL compared to 44c/kL for the first 125kL of potable water (S Rose *pers. comm.* 2004).

## A3.4 FINANCIAL IMPACT ON CUSTOMERS

While tariff structure has an important role to play in achieving overall economic efficiency (ESCOSA 2004) the impact of the water pricing on annual residential water bills will vary according to the customers total water usage. The expected outcome of the pricing structure reform is that low water users will be rewarded by lower bills, high water users will face higher bills if they maintain their consumption levels, and median water users will face a moderate increase if their consumption is unchanged. By using the rate structure to control water use, excess use is discouraged through increased rates and water conservation becomes voluntary. Using financial year 1988/89 as the pre water reform baseline, Figure 200 presents the transition of the water tariff structure to the current two part tariff. Figure 200 was constructed using the minimum access charge (ignoring the property value component) and the calculated the annual water bill for a given volume based on the price structure for the given year. Appendix B contains a summary of the residential water price structure for the 15 year period 1988/89 to 2002/03.



*Analysis does not take into account the property value component of the water tariff prior to 1991/92*

**Figure 200 Structure of Water Price Tariff in South Australia**

Figure 201 plots the impact of the water price reform in South Australia on annual residential water bills over the 15 year period from 1988/89 (pre reform baseline) to 2002/03 compared with the increase in Consumer Price Index (CPI). Figure 201 shows the increase in annual residential water bill above CPI during the water pricing reform varies according to the total water usage.

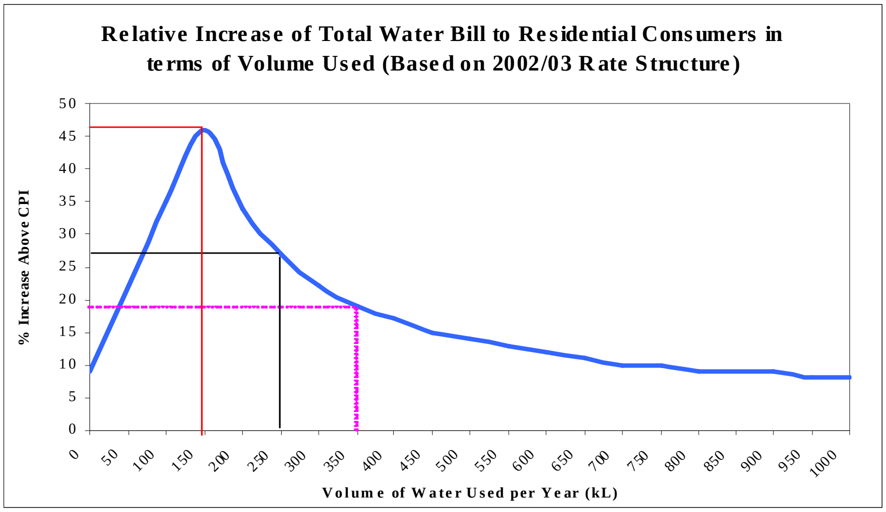


**Figure 201 Comparison of Residential Water Bill & Consumer Price Index**

High water use households (greater than 600kL) faced a moderate increase in water rates above CPI from 10% to 15%; however low water use households faced an increase of greater than 45%. The impact for the low water use customers is first and foremost a result of the introduction of the lower unit water rate when the water allowance was abolished in 1995/96. That is, the relative size of the contribution of cost of water from 1 to 125kL to the total annual bill.

### A3.4.1 *Distribution of Customers by Water Use*

The distribution of residential customers by water use can be used to determine the impact of the proposed water rates on the total increase in annual water bill as well as the impact on the majority of residential customers. Table 58 shows the impact of residential pricing reform in terms of the size of the annual bill using the 1988/89 pre reform baseline.

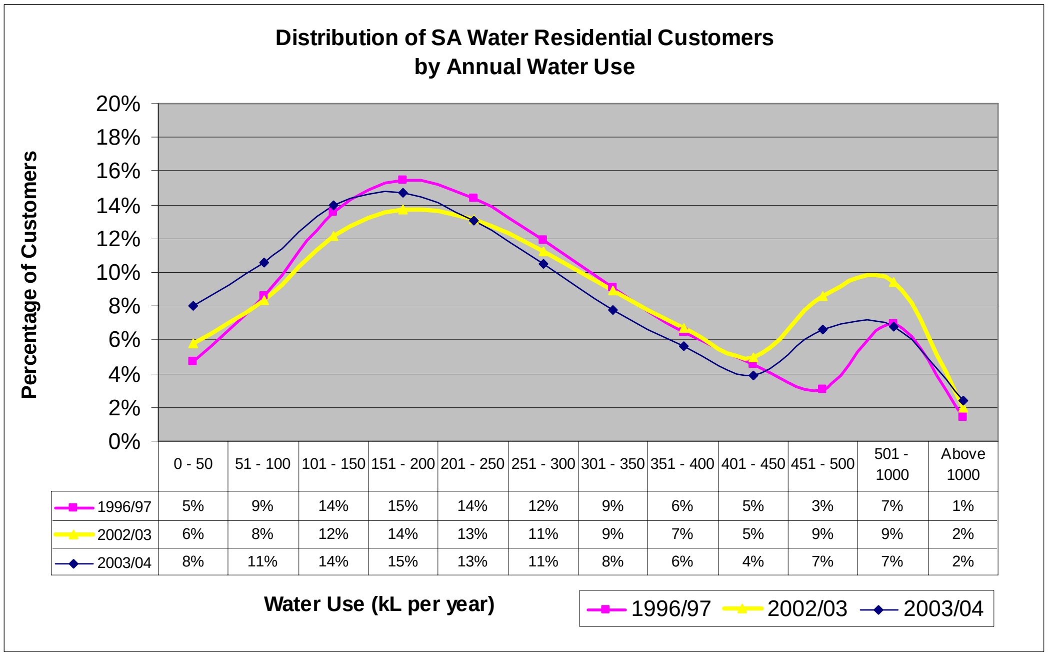
**Table 58 Impact of Prices on Annual Residential Water Bill by Water Use**

| Water Usage (kL per year) | 1988/89 | | 2002/03 | |
|---|---|---|---|---|
| | Actual ($) | % of Customers | Actual ($) | Increase ($) |
| 0 - 50 | $ 96.00 | 5% | $ 141.00 | $ 45.00 |
| 51 – 100 | $ 96.00 | 9% | $ 161.00 | $ 65.00 |
| 101 – 150 | $ 96.00 | 14% | $ 181.00 | $ 85.00 |
| 151 – 200 | $ 123.00 | 15% | $ 228.00 | $ 105.00 |
| 201 – 250 | $ 159.00 | 14% | $ 276.00 | $ 117.00 |
| 251 – 300 | $ 194.00 | 12% | $ 325.00 | $ 131.00 |
| 301 – 350 | $ 230.00 | 9% | $ 373.00 | $ 143.00 |
| 351 – 400 | $ 265.00 | 6% | $ 422.00 | $ 157.00 |
| 401 – 450 | $ 300.00 | 5% | $ 469.00 | $ 169.00 |
| 451 – 500 | $ 333.00 | 3% | $ 518.00 | $ 185.00 |
| 501 – 1000 | $ 530.00 | 7% | $ 783.00 | $ 253.00 |
| Above 1000 | $ 1,062.00 | 1% | $ 1,510.00 | $ 448.00 |

*Absolute increases $ of the day relative to 1988/89 (minimum charge in lieu of property value)*
*The impact was calculated using the mid-point of water usage, 1500kl for above 1000.*

Unfortunately, water use data for years prior to and during the major water pricing reforms (ie. before 1991/92 to 1995/96) is unavailable. This is a consequence of historical data from previous systems not being transferred to the current customer services information system (CSIS) introduced in 1996 (Kym Sichler pers comm. 2004). In the absence of this data, an analysis of the customer distribution was undertaken to identify any post pricing reform shift that may have occurred.

The distribution of customers for the years 1996/97 and 2002/03, that is, while the two part tariff has been in place is shown in Figure 202. The distribution for 2003/04 when permanent water use regulations were introduced has also been plotted. There is a level of uncertainty associated with the distribution for any given year particularly with respect to the influence of weather conditions on discretionary water use. The uncertainty associated with weather conditions might be reduced by adopting a distribution based on a rolling average.



| | 0 - 50 | 51 - 100 | 101 - 150 | 151 - 200 | 201 - 250 | 251 - 300 | 301 - 350 | 351 - 400 | 401 - 450 | 451 - 500 | 501 - 1000 | Above 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996/97 | 5% | 9% | 14% | 15% | 14% | 12% | 9% | 6% | 5% | 3% | 7% | 1% |
| 2002/03 | 6% | 8% | 12% | 14% | 13% | 11% | 9% | 7% | 5% | 9% | 9% | 2% |
| 2003/04 | 8% | 11% | 14% | 15% | 13% | 11% | 8% | 6% | 4% | 7% | 7% | 2% |

**Figure 202 Distribution of SA Water Residential Customers**

A comparison of the distribution curve for 1996/97 and 2002/03 suggests there has been a movement towards increased water use (ie. decreased peaks in the low water use groups and the increased peak in the higher water use groups) which may be the result of reallocation of water through the current system of prices in accordance with market demand. A reverse movement in the distribution peaks was observed when the permanent water use regulations were introduced in 2003/04 (in comparison to 2002/03).

## A3.5 IMPACT ON WATER USE

The price of water provides the clearest message to customers and allows them to achieve an appropriate balance between the benefits and costs of usage of water services (WSAA 1998 and SA Water 1999). The extent to which customers adjust their consumption of water in response to price changes is termed the price elasticity.

Overall, the introduction of user pays pricing, universal water metering, and various demand management policies and educational campaigns under the COAG water reform has had a significant impact on per capita consumption in Australia (COA 2002). The price of water provides a signal to customers and allows them to achieve an appropriate balance between the benefits and costs of usage of water services (WSAA 1998 and SA Water 1999).

### A3.5.1 *Annual Total Water Use*

In South Australia, pricing reform has had an impact on average residential consumption as well as the pattern of water use. Figure 203 below shows the total water consumption by SA Water customers as well as the number of customers being supplied for each financial year since 1977/78.

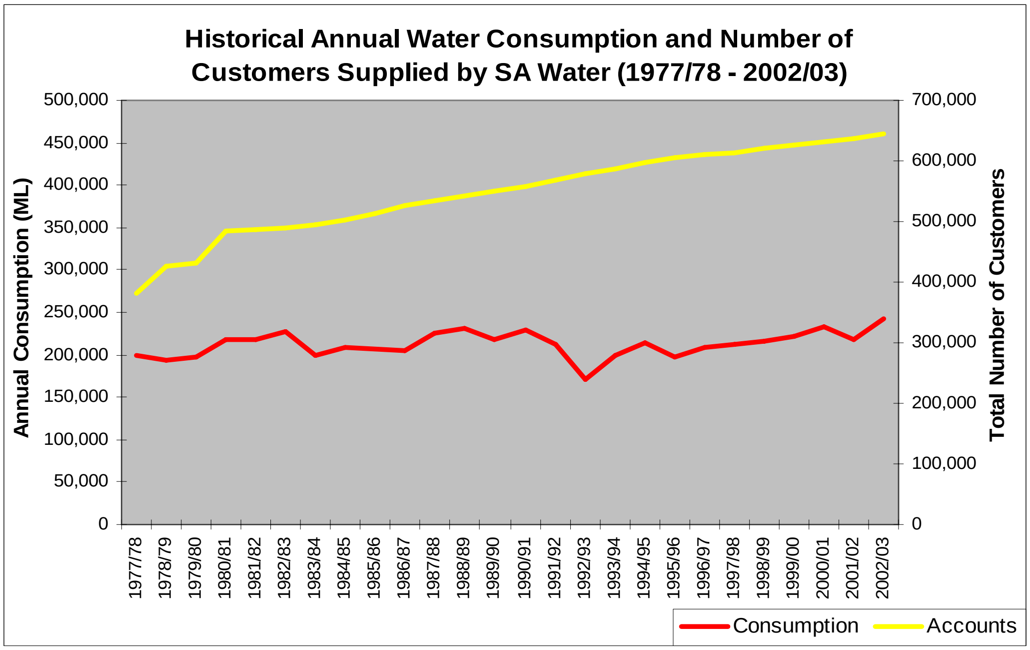
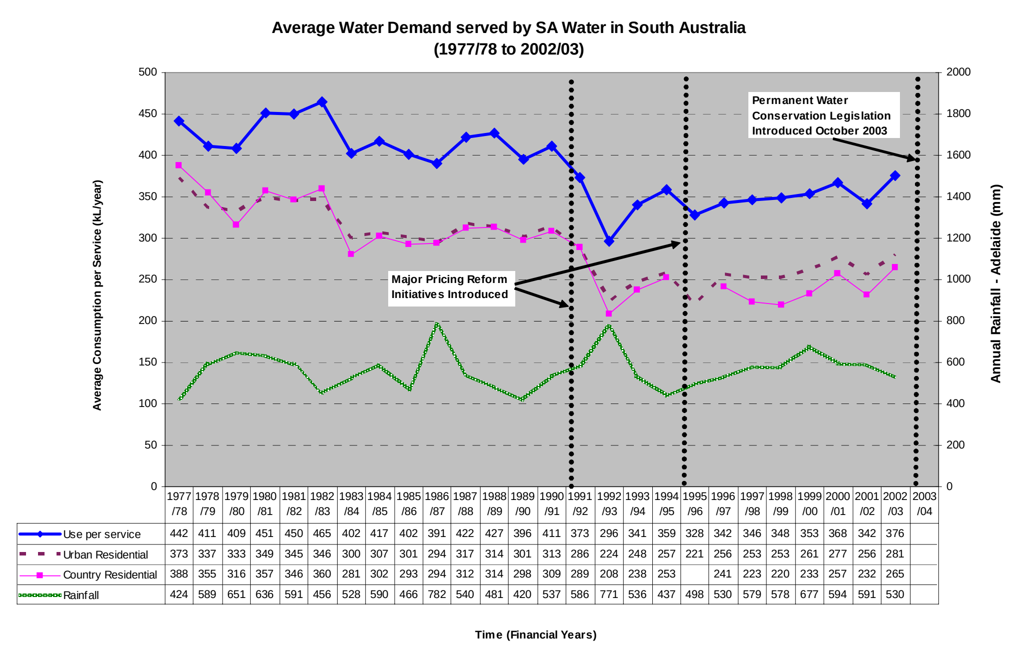


**Figure 203 Annual Water Use by SA Water Customers**

There has been a 22% increase (less than 1% per annum) in the total annual water demand by urban water customers over the 26 year period compared to the 69% growth (approx 2.5% per annum) in the number of properties supplied over the same period.

### A3.5.2 *Average Annual Water Use by Service*

Figure 204 shows the average annual water use as well as residential water use for metropolitan and country water businesses the same period. The plot shows a decreasing trend in the average annual consumption per service (all customer classifications).



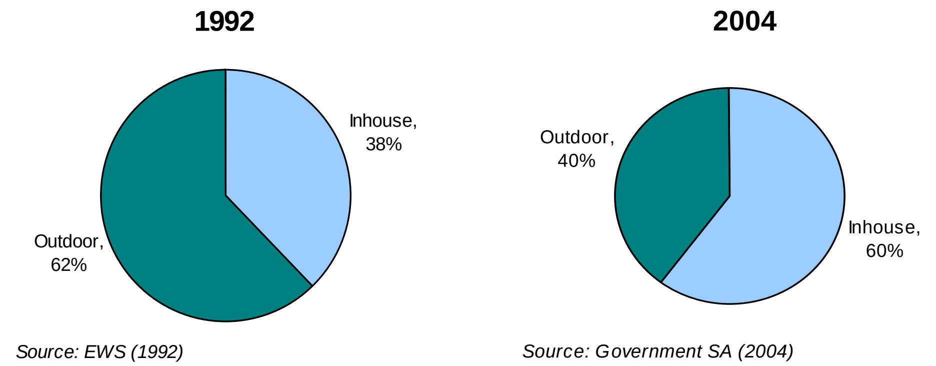
| | 1977 /78 | 1978 /79 | 1979 /80 | 1980 /81 | 1981 /82 | 1982 /83 | 1983 /84 | 1984 /85 | 1985 /86 | 1986 /87 | 1987 /88 | 1988 /89 | 1989 /90 | 1990 /91 | 1991 /92 | 1992 /93 | 1993 /94 | 1994 /95 | 1995 /96 | 1996 /97 | 1997 /98 | 1998 /99 | 1999 /00 | 2000 /01 | 2001 /02 | 2002 /03 | 2003 /04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use per service | 442 | 411 | 409 | 451 | 450 | 465 | 402 | 417 | 402 | 391 | 422 | 427 | 396 | 411 | 373 | 296 | 341 | 359 | 328 | 342 | 346 | 348 | 353 | 368 | 342 | 376 | |
| Urban Residential | 373 | 337 | 333 | 349 | 345 | 346 | 300 | 307 | 301 | 294 | 317 | 314 | 301 | 313 | 286 | 224 | 248 | 257 | 221 | 256 | 253 | 253 | 261 | 277 | 256 | 281 | |
| Country Residential | 388 | 355 | 316 | 357 | 346 | 360 | 281 | 302 | 293 | 294 | 312 | 314 | 298 | 309 | 289 | 208 | 238 | 253 | | 241 | 223 | 220 | 233 | 257 | 232 | 265 | |
| Rainfall | 424 | 589 | 651 | 636 | 591 | 456 | 528 | 590 | 466 | 782 | 540 | 481 | 420 | 537 | 586 | 771 | 536 | 437 | 498 | 530 | 579 | 578 | 677 | 594 | 591 | 530 | |

**Figure 204 Average Annual Water Use per Service, 1977/78 to 2002/03**

The reduction was around 16% in average water consumption per service and 16% for metropolitan and country residential customers as the unit rate for water price was progressively increased from 1980 to 1990. The introduction of two part tariff over the year period from 1991/92 to 1996/97 resulted in further reductions of 14%, 15% and 17% in the average water consumption per service, metropolitan residential and country residential customers respectively. Post tariff reform, the average water consumption per service and for metropolitan residential customers has remained stable up to 2001/02, while over the same period the average annual consumption per service for country residential customers continued to drop by 7%. These reductions in water use have meant that total water use has only marginally increased despite the significant population increase. Despite these achievements, there is a concern that total water consumption is now trending upwards.

### A3.5.3 *Pattern of Residential Water Use*

The pattern of urban domestic water use is subject to uncertainty and is influenced by many factors including population growth, consumer behaviour (culture), household formation rates and density, business activity, and climate. A notable feature of residential water use in Australia's cities is the relatively large amounts of water used for gardening (COA 2002). With residential water use, a distinction can be made between that used for indoor purposes and garden or allotment uses. Certain categories of water use are considered to be relatively unresponsive to price changes. For example, most indoor water use is a necessity without much room for elasticity, but as water consumption becomes more discretionary - irrigation, car washing, recreation - demand becomes more price elastic. Market prices which represent the value of water in the economy will ensure that the current and future demands for water resources are achievable. Figure 205 shows that pricing reform has had a significant impact on average residential consumption and contributed to changing the way South Australian households use water.



*Source: EWS (1992)*

*Source: Government SA (2004)*

**Average Residential Use = 300 kL/house**  **Average Residential Use = 271 kL/house**

*Note: The 3 year average annual residential water consumption is used for this discussion.*

**Figure 205 Typical Residential Water Use in Adelaide (Rabone in prep)**

## A3.6 CONCLUSIONS

All but 2% of the South Australia's population have access to reticulated water supplies that can be used for all purposes provided (on behalf of the State Government) by either SA Water or United Water (under contract to SA Water). The combined effects of the monopoly powers bestowed by legislation to SA Water and widespread political pressure to keep water charges affordable (under the uniform pricing policy) have conspired to discourage new entries to the domestic water supply market.

Development and equity considerations have led governments to encourage the development of more extensive infrastructure networks than can be financed with the tariffs. Changes in water infrastructure development could deliver improvements in water conservation and environmental restoration; however billions of dollars have been invested in the existing infrastructure. A fully functioning water market is expected to ensure that future public investment is properly targeted and that water is put to higher value and more efficient uses.

Pricing reform has had a significant impact on average residential consumption and contributed to changing the way South Australian households use water, particularly outdoor water use. Despite these achievements, there is a concern that total water consumption is now trending upwards, prompting the introduction of permanent water use regulations in 2003/04.

The appropriate role of water prices is to guide consumers' demands for water towards socially optimal levels. Water prices should not be regarded as an instrument for modifying income distribution; rather this is a matter for social welfare policy. Designing and implementing pricing reforms is a complicated process affected by various forces, many of which are difficult to define and model. The impact of the water pricing on annual residential water bills will vary according to the customers total water usage.

## A3.7 APPENDIX A – CHARACTERISTICS OF CUSTOMER BASE

An appreciation of the nature of the water supply customer base can be obtained by subdividing it into the metropolitan and country water businesses or alternatively into the individual customer classifications. The customer classifications used by SA Water are quite broad being based principally on land classifications (SA Water 1999). For example, residential customers include vacant land and holiday homes.

### A3.7.1 *By Metropolitan & Country Water Business*

Figure 206 shows the ratio of customers between the metropolitan and country water business has remained stable at around 72% over the period 1988/89 to 2002/03.

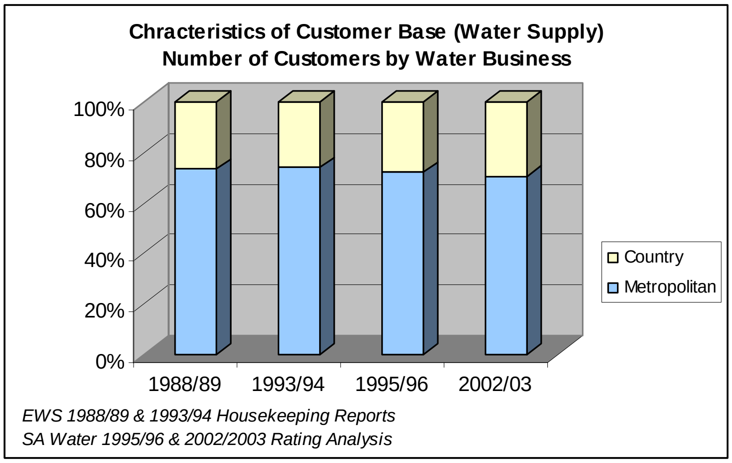


**Figure 206 Number of Customers by Water Supply Business**

Figure 207 shows the split of total water use between the metropolitan and country water businesses. This remained stable at 72% over the period 1988/89 to 1995/96. The 5% increase in demand from country water supply in 2002/03 coincides with growth in the off peak bulk water transportation business (commenced around 1998).

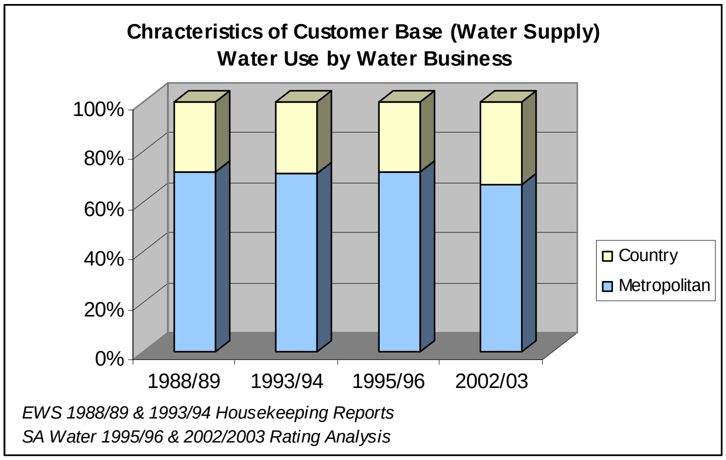
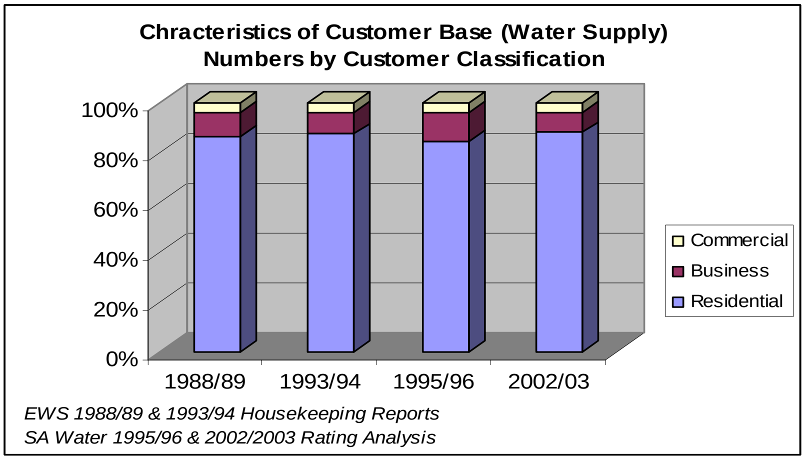


**Figure 207 Water Use by Water Supply Business**

### A3.7.2 *By Customer Classification*

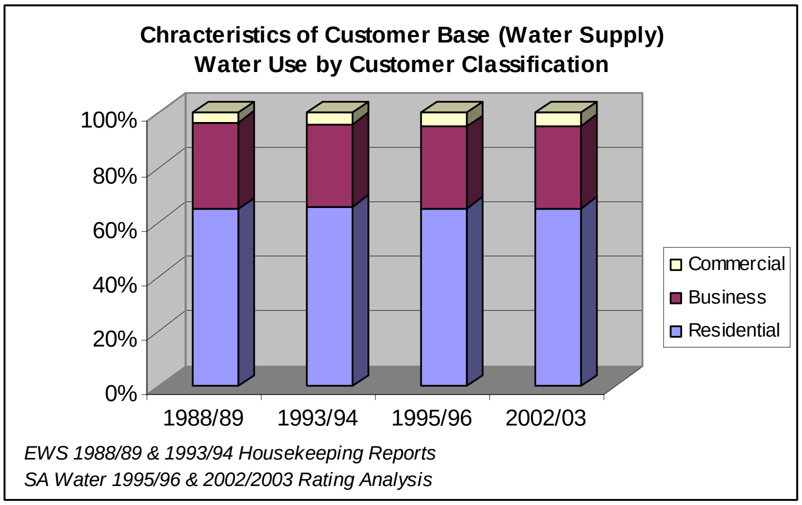
The key observation from Figure 208 is that an overwhelming majority of the customer base is residential accounting for 88% of the number of customers.



*EWS 1988/89 & 1993/94 Housekeeping Reports*
*SA Water 1995/96 & 2002/2003 Rating Analysis*

**Figure 208 Numbers of Customers by Customer Classification**

Figure 209 shows the ratio of water use by residential customers has remained stable at around 65% over the period 1988/89 to 2002/03.



*EWS 1988/89 & 1993/94 Housekeeping Reports*
*SA Water 1995/96 & 2002/2003 Rating Analysis*

**Figure 209 Water Use by Customer Classification**

## A3.8 APPENDIX B - RESIDENTAL WATER PRICING HISTORY

| **Financial Year** | | **88/89** | **89/90** | **90/91** | **91/92** | **92/93** | **93/94** | **94/95** | **95/96** | **96/97** | **97/98** | **98/99** | **99/00** | **00/01** | **01/02** | **02/03** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Supply Charge** | | $96 (1) | $102 | $110 | $116 (2) | $120 | $120 (3) | $120 | $113 (4) | $118 | $131 | $119 | $123 | $121 | $125 | $130 |
| **Water Price ($/kL)** | | | | | | | | | | | | | | | | |
| **from** | **to** | | | | | | | | | | | | | | | |
| **0** | **125** | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.20 | $0.22 | $0.25 | $0.35 | $0.36 | $0.36 | $0.38 | $0.40 |
| **126** | **136** | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.20 | $0.89 | $0.90 | $0.89 | $0.92 | $0.91 | $0.94 | $0.97 |
| **137** | **400** | $0.71 | $0.75 | $0.80 | $0.85 | $0.88 | $0.88 | $0.88 | $0.88 | $0.89 | $0.90 | $0.89 | $0.92 | $0.91 | $0.94 | $0.97 |
| **401** | **500** | $0.71 | $0.75 | $0.80 | $0.85 | $0.88 | $0.88 | $0.88 | $0.88 | $0.91 | $0.92 | $0.89 | $0.92 | $0.91 | $0.94 | $0.97 |
| **>501** | | $0.71 | $0.75 | $0.80 | $0.85 | $0.88 | $0.88 | $0.88 | $0.88 | $0.91 | $0.92 | $0.89 | $0.92 | $0.91 | $0.94 | $0.97 |

(1) Minimum access charge shown. Actual access charge included component derived from property value above a predetermined value. Water allowance equalled supply charge divided by presiding water price (linked to property value).

(2) Access charge shown is the minimum applied for the financial year. Actual access charge included component derived from property value above a predetermined value. Water allowance fixed and no longer linked to property value.

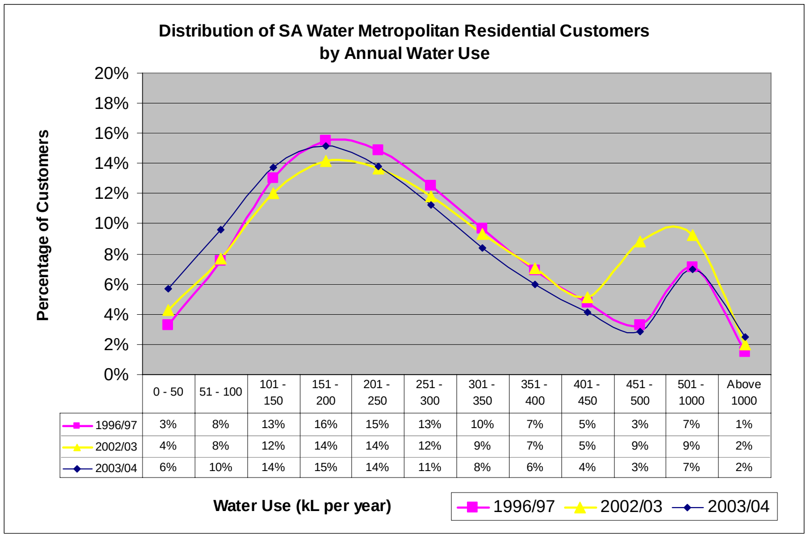
(3) Fixed access charge and fixed water allowance.

(4) Water allowance abolished.

*Sources used to generate table: SA Water (1999), SA Water Rating Policy & Trevor Govett (pers. Comm.)*

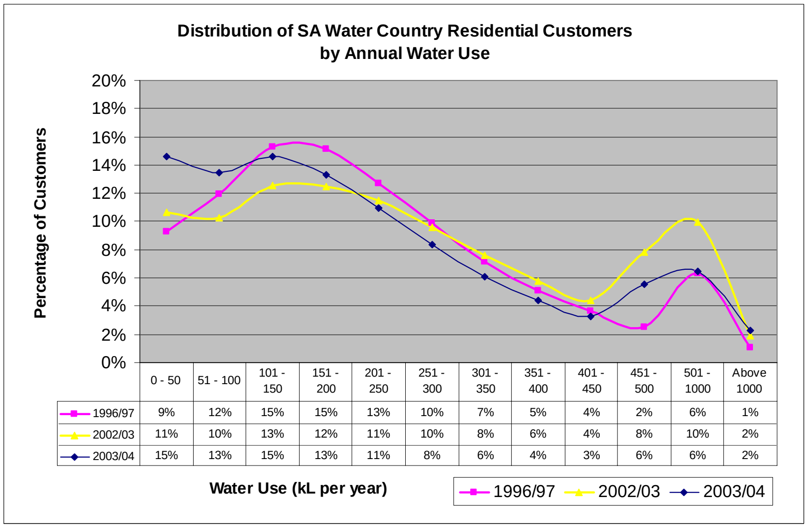
## A3.9 APPENDIX C – DISTRIBUTION OF CUSTOMERS

A distribution of household water use by South Australian households (residential customers) has been constructed from data provided by SA Water. An analysis of the customer distribution was undertaken to identify any shifts in the water use distribution in between 1996/97 and 2002/03 as well as in 2003/04 when permanent water use regulations were introduced in South Australia. Figure 210, Figure 211 and Figure 212 below provide a comparison the distribution of residential customers by water use for the metropolitan, country and total (combined) water business for a given financial year. The first observation is the difference in the distribution of metropolitan and country residential customers, particularly in 0-100 kL water use group (refer Figure 210 and Figure 211).



| | 0 - 50 | 51 - 100 | 101 - 150 | 151 - 200 | 201 - 250 | 251 - 300 | 301 - 350 | 351 - 400 | 401 - 450 | 451 - 500 | 501 - 1000 | Above 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ■ 1996/97 | 3% | 8% | 13% | 16% | 15% | 13% | 10% | 7% | 5% | 3% | 7% | 1% |
| ▲ 2002/03 | 4% | 8% | 12% | 14% | 14% | 12% | 9% | 7% | 5% | 9% | 9% | 2% |
| ◆ 2003/04 | 6% | 10% | 14% | 15% | 14% | 11% | 8% | 6% | 4% | 3% | 7% | 2% |

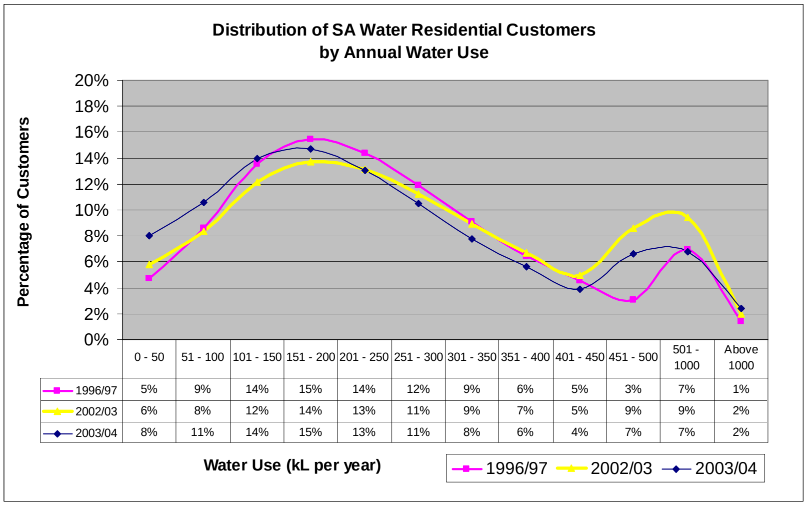
**Figure 210 Distribution of SA Water Metropolitan Residential Customers**



| | 0 - 50 | 51 - 100 | 101 - 150 | 151 - 200 | 201 - 250 | 251 - 300 | 301 - 350 | 351 - 400 | 401 - 450 | 451 - 500 | 501 - 1000 | Above 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ■ 1996/97 | 9% | 12% | 15% | 15% | 13% | 10% | 7% | 5% | 4% | 2% | 6% | 1% |
| ▲ 2002/03 | 11% | 10% | 13% | 12% | 11% | 10% | 8% | 6% | 4% | 8% | 10% | 2% |
| ◆ 2003/04 | 15% | 13% | 15% | 13% | 11% | 8% | 6% | 4% | 3% | 6% | 6% | 2% |

**Figure 211 Distribution of SA Water Country Residential Customers**

The difference may the consequence of a number of factors including; higher use of rainwater tanks in regional areas for drinking and cooking (Heyworth et. al. 1998), declining regional population (ie. lower occupancy rates/ increased number of vacant dwellings), inclusion of holiday homes with seasonal occupancy (particularly in country coastal regions). Secondly, the distribution curve for 1996/97 compared to 2002/03 suggests there has been a movement towards increased water use (ie. decreased peaks in the low water use groups and the increased peak in the higher water use groups) which may be the result of allocation of water through the current system of prices in accordance with market. It is interesting to note the reverse movement in the distribution peaks in the 2003/04 includes the introduction of permanent water use regulations compared to the 2002/03 distribution



| | 0 - 50 | 51 - 100 | 101 - 150 | 151 - 200 | 201 - 250 | 251 - 300 | 301 - 350 | 351 - 400 | 401 - 450 | 451 - 500 | 501 - 1000 | Above 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996/97 | 5% | 9% | 14% | 15% | 14% | 12% | 9% | 6% | 5% | 3% | 7% | 1% |
| 2002/03 | 6% | 8% | 12% | 14% | 13% | 11% | 9% | 7% | 5% | 9% | 9% | 2% |
| 2003/04 | 8% | 11% | 14% | 15% | 13% | 11% | 8% | 6% | 4% | 7% | 7% | 2% |

**Figure 212 Distribution of SA Water Residential Customers**

## A3.10 ACKNOWLEDGEMENTS

Kristen Kulesza, Communications Advisor, SA Water

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Steve Rose, Water Proofing Adelaide Project, SA Water

# Appendix 4

# Overview of the Murray-Darling Basin

The information in this Appendix discusses the issues facing the Murray-Darling Basin and the potential effect it has on the availability and quality of water for South Australia.

## A4.1 INTRODUCTION

The Murray-Darling Basin shown in Figure 213 below encompasses Australia's largest river systems includes the three largest rivers in Australia: the Darling at 2740 km; the Murray at 2530 km; and the Murrumbidgee at 1690 km. It drains one seventh of Australia's mainland (MDBC 2004). Even on a global scale the Basin is large, being ranked 15th in terms of length and 21st in terms of area (COA 2004).

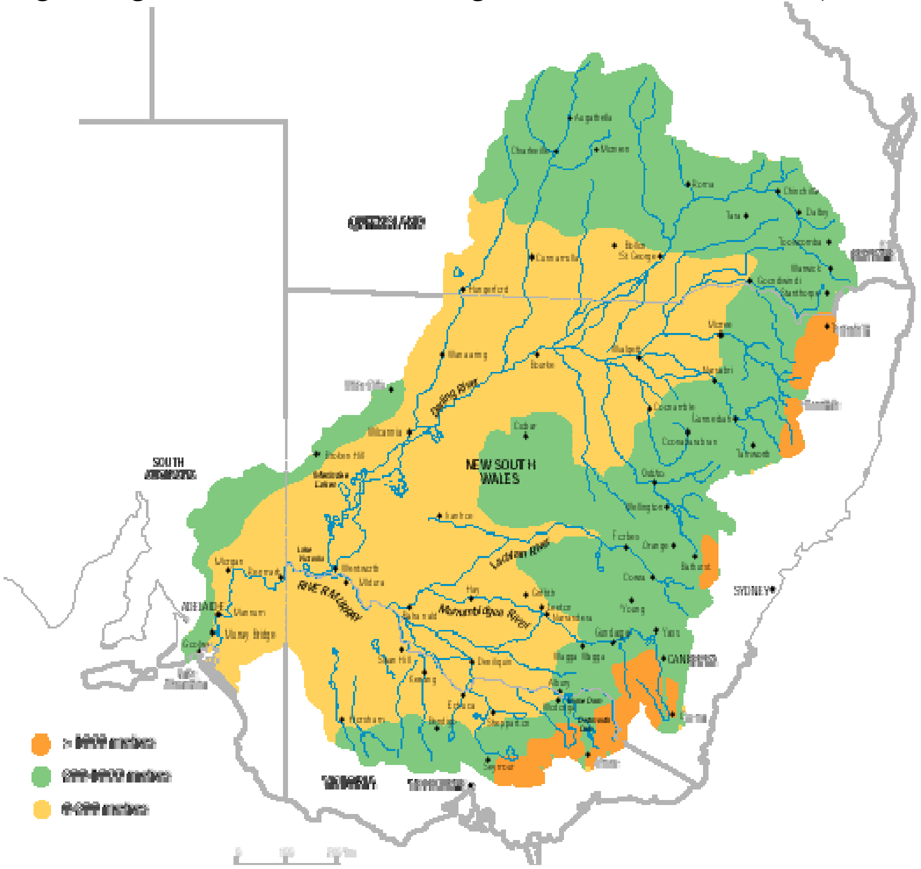


**Figure 213 The Murray-Darling Basin (MDBC 2004)**

The Murray-Darling Basin is located in the south-east of Australia, covers 1,061,469 square kilometres, which is equivalent to 14% of the country's total area, and is defined by the catchment areas of the Murray and Darling Rivers and their many tributaries (MDBC 2004). With the exception of the Great Dividing Ranges in the north and east, most of the Basin consists of extensive plains and low undulating areas (MDBC 2004). The flat terrain, low rainfall and high evaporation combine to concentrate salt in the soil profile and groundwater, while the limited rainfall and the low gradient precluded flushing accumulated slats from the Basin. An important consequence of the extent of the Basin is the great range of climatic conditions and natural environments, from the rainforests of the cool and humid eastern uplands, the temperate mallee country of the south-east, the sub-tropical areas of the northeast, to the hot, dry semi-arid and arid lands of the far western plains (MDBC 2004). There are some 30 000 wetlands in the Basin, of which 12 have been listed under the international Ramsar Convention on Wetlands (COA 2004). At the time of European settlement, about 28% of Australia's mammal species, about 48% of its birds and some 19% of its reptiles were found within the Basin (COA 2004). However, the ‘development’ of the resources of the Murray-Darling Basin followed the traditional path of optimistic exploitation of the available water with little regard for the ecological consequences (Jensen *et al.* 2000). Today, the Basin has at least 35 endangered bird species and 16 endangered mammal species with 20 mammal species now extinct (COA 2004) as well as 11 introduced species of fish (MDBC 2004).

Following regulation of river flows, many schemes have been developed to divert the water for productive uses. Irrigated agriculture has been a feature of the Murray River since the early 1900s when the first dams and irrigation channels were constructed. There are many urban and industrial uses of the water including 1.4 million people in towns and districts along the main tributaries, and over a million people in Adelaide and rural South Australia who rely on this water supply (SA Water 1999d; Jensen *et al.* 2000). While, the Murray-Darling Basin is home to approximately two million people it also supports a quarter of the cattle herd, half of the sheep flock, half of the crop land and almost three quarters of the irrigated agriculture in Australia (Marohasy, 2003). The value of the Basin’s agricultural production exceeds $8.5 billion per annum, which represents 41% of the national output from rural industries (Marohasy, 2003).

Another consequence of the size of the Basin is that it extends across four States, New South Wales, Victoria, South Australia, and Queensland, as well as including the entire area of the Australian Capital Territory (MDBC 2004). Collaborative arrangements for regulation and sharing of water within the Basin have existed between the Commonwealth, New South Wales, Victorian and South Australian governments since 1914, when the first River Murray Waters Agreement was signed (GSA 1999). Since then, the agreement has been revised many times, the most recent revision being in 1992 (GSA 1999). The current Murray-Darling Basin Agreement provides the institutional framework for the management of the Basin's natural and environmental resources (MDBC 2004). In accordance with the Agreement, at least 1850GL per year flows into South Australia, except in years of serious water shortage, which are expected to occur in less than 1 year in 20 (GSA 1999). Only through the cooperative efforts of the States, river operators, water users, community interests and environmental groups can a balance be struck to achieve a sustainable River Murray (MDBC 2004).

## A4.2 THE RIVER MURRAY SYSTEM

The River Murray system is highly modified as a consequence of engineering works over the past 100 years to 'drought proof' the region (Marohasy, 2003). Aside from being the major source of surface water for significant irrigation undertakings, the River Murray has been developed as South Australia's primary water resource, providing water to over 90% of the State's population (GSA 1999). In its natural state, the Murray River could not provide for Adelaide's water needs and it could not support the irrigation industries that flourish along its length (Marohasy, 2003).

Figure 214 shows the River Murray system, which is a subsystem within the Murray-Darling Basin. The River Murray system includes the main course of the River Murray, its anabranches and tributaries as well as the Darling River downstream from Medindee Lakes (MDBC 2004). It also includes the significant engineering works such as Menindee Lakes, Dartmouth Dam, Hume Dam, Yarrawonga Weir, Lake Victoria storage, weirs and locks and the barrages near the mouth of the River Murray (see Figure 215). These structures have been used to maintain a continuous flow throughout the length of the Murray since the early 1940s. Without the storages and regulation, the Murray would almost certainly have ceased to run during the droughts of 1938-39, 1944-45, 1967-68, 1982-83, 1997-98 and 2002-03 (MDBC 2004).

**Figure 214 The River Murray System (MDBC 2004)**

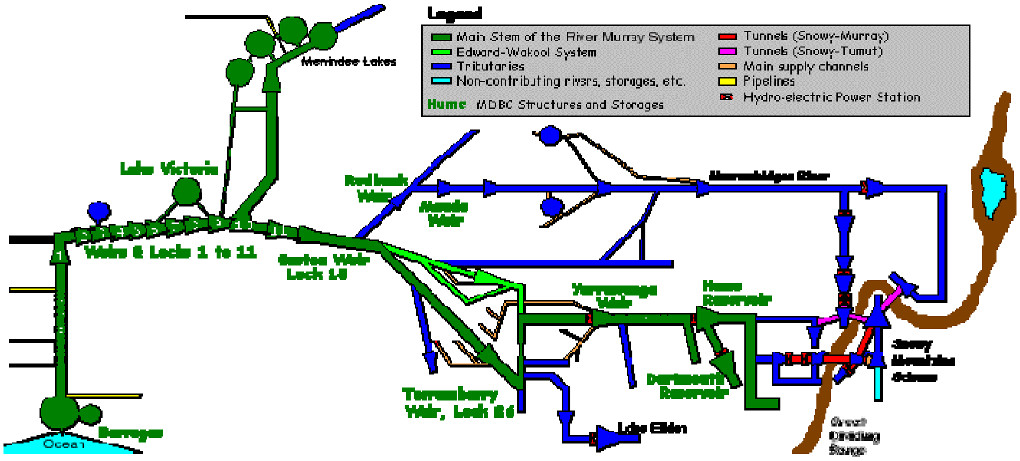


**Figure 215 Schematic of Structures to Regulate the River Murray (MDBC 2004)**

However, increasingly scientific reports question how the River Murray is being managed, including CSIRO (2003 cited in Marohasy 2003), which states:

> *Over the last 100 years, the flow of water through the River Murray system has changed. Most of this is due to dams, locks and levies which were constructed to provide water for irrigation, drinking and industry. The alteration to the system's water flow has caused changes to the environment. Water quality has dropped, some wetlands have become dry, native fish are struggling to survive and some areas of land have become salt affected*

Marohasy (2003) asserts that the available data does not suggest that indicators of river health show general decline, with the exception of native fish stocks. The issues of reduction of river flow, changes in seasonal flows and salinity as they relate to sustainable water use in South Australia are discussed in turn below.

## A4.3 REDUCTION OF RIVER FLOW

The River Murray flows through a semi-arid landscape and there will inevitably be periods of drought. A dry river bed and dry river mouth are natural parts of the Australian landscape during drought (Marohasy 2003). In its natural state the River Murray was quite different, for example during severe droughts the Murray could be reduced to a chain of saline waterholes. Also, in South Australia, sea water could be present a considerable distance upstream from the mouth. Figure 216, a historic photograph, shows the River ran dry well upstream of Adelaide before the construction of the Hume Dam (completed in 1936) and the barrages (completed in 1940).

**Figure 216 Low Flow in the River Murray prior to Locks & Weirs (c. 1914)**

Without dams, locks and weirs, the river flow (and level) would fluctuate wildly between gushing and then running dry. This reflected the highly variable nature of the Basin's climate (Marohasy 2003). For example, inflow to the River Murray system can vary from 2,500GL to 40,000GL each year, but in an average year, under current conditions, total inflow is 12,067GL (Marohasy 2003).

The Murray-Darling Basin Commission (MDBC) has developed a computer model that estimates the total water balance for the Murray River system based on a hypothetical average year under natural conditions (ie. without any dams), and also under current conditions (ie. with dams, locks and levy banks). The results of the water balance for an average year in the River Murray are set out in Table 59 below. Of the water that would have originally reached the sea from the Murray-Darling Basin, about 24% of this is lost from the system through evaporation and transmission, and 34% is diverted (mostly for irrigation). Average outflow from the Murray to the sea has been reduced to as low as half of natural flow expected in an average year. In dry years the differences in the figures are even higher.

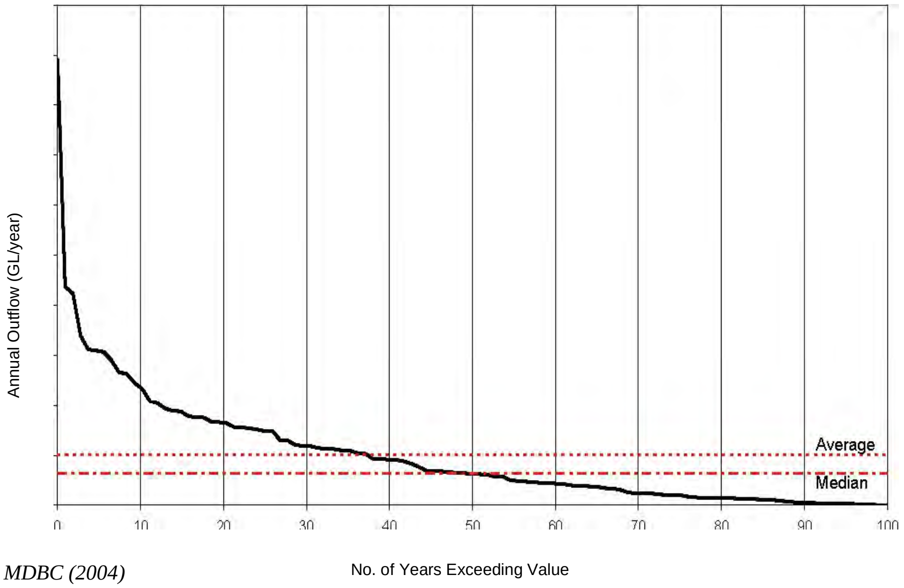
**Table 59 Water Balance for an Average Year in the River Murray System**

| **Water Balance** | **Current (1)** | | **Natural (2)** | |
|---|---|---|---|---|
| | **GL/year** | **%** | **GL/year** | **%** |
| **Inflow (4)** | | | | |
| Inflow | 12607 | 100 | 17052 (3) | 100 |
| **Outflow (4)** | | | | |
| Losses | 3044 | 24 | 3458 | 20 |
| Diversions | 4328 | 34 | 0 | 0 |
| Flow to Sea | 5235 | 41 | 13594 | 80 |
| Total Outflow | 12607 | 100 | 17052 | 100 |

(1) 'Current' is post development with dams, locks and levy banks.
(2) 'Natural' assumes the river is in a state unmodified by human intervention.
(3) Under natural conditions the inflow is shown as greater than under current conditions as on-farm dams and levies will prevent water that under natural conditions may have flowed into the Murray River from reaching the river.
(4) Mean inflows, losses and diversions are for the period from 1891 to 1992

*Source: Murray-Darling Basin Commission 1998 in Marohasy( 2003 ).*

Marohasy (2003) notes that the information is rarely presented in this form, primarily as average figures are influenced by the large flood events. Because much of the flow occurs in relatively few flood years, some people prefer to consider the median annual flow rather than the average since the median corresponds to a 'typical' year (MDBC 2004). The median annual flow is the flow in the year which has the same number of years with greater flow as it has years with less flow. Figure 217 shows the difference between the average and median values for the annual outflow from the Murray-Darling Basin to the sea.



*MDBC (2004)*

**Figure 217 Average and Median Outflows to the Sea (MDBC 2004)**

One significant result of the reduced flows throughout the Basin is that the rivers are now in a state of drought (as defined by river levels) for more than 61 years in every 100 compared to 5 years per 100 under natural conditions (MDBC 1995 in MDBC 2004). This is a particular issue on the lower reaches of the river system, especially for the Coorong and the mouth of the River Murray. On the other hand, regulation has eliminated most of the extreme flows.

## A4.4 CHANGES TO SEASONAL FLOWS

Historically, flows in the River Murray were unpredictable, though seasonal patterns predominated. Typically, high flows occurred most often in spring and early summer whilst low flows were typical in autumn and winter similar to that shown in Figure 218. This figure also shows that with development came the need to deliver more water during summer and autumn to satisfy peak demand, when under natural conditions, the riverine system would be experiencing much lower flows (MDBC 2004).

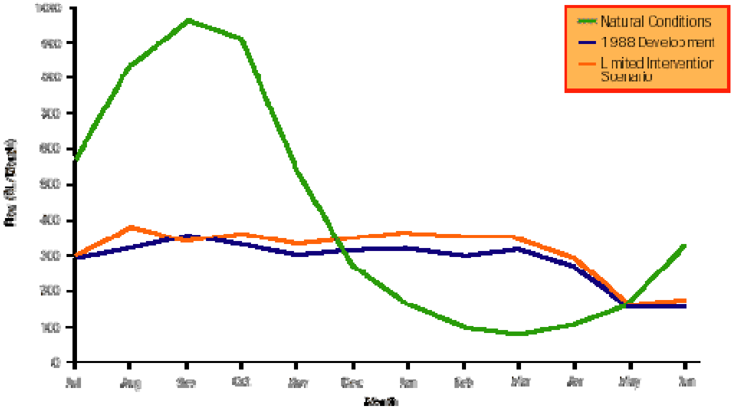


**Figure 218 Median Flow D/s Yarrawonga Dam (MDBC 1995 in MDBC 2004)**

Interestingly, by the time the River Murray reaches the barrages at the mouth, there is little difference in the patterns of flow regimes under regulated and natural conditions as Figure 219 illustrates. However, the critical difference is the reduction of flows, the effect of which is particularly significant in dry years.

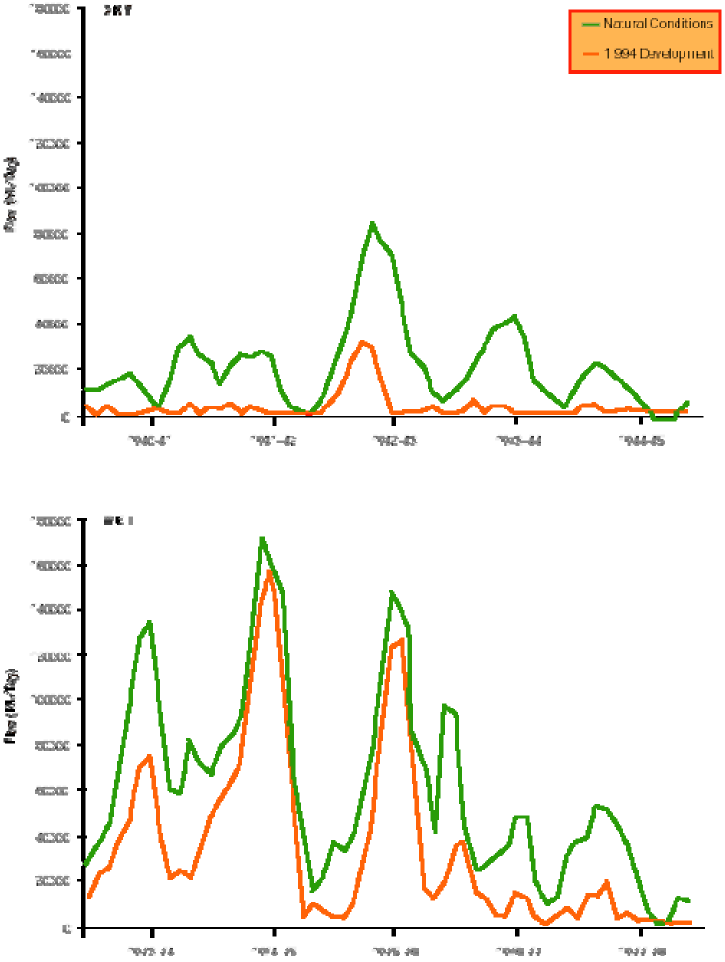


**Figure 219 River Murray flow over the barrages (MDBC 1995 in MDBC 2004)**

The River Murray mouth region is progressively silting up as a result of the changed flow regime. The mouth closed over during low flows in May 1981, the first time since European settlement, although it would be an occasional possibility under the natural flow regime (Jensen *et al.* 2000; Marohasy 2003). Without timely intervention the mouth would again have closed in 2003 for the second time (Carter *pers comm*. 2004). An important consequence of mouth closures is the likelihood of flooding of all townships and fringing lands as far as Wellington (Jensen *et al.* 2000).

The changes brought about by development have resulted in artificial drought conditions coupled with constant unnaturally high pool levels and severe fluctuations in flow following a moderate to high flow event (Jensen *et al.* 2000).

## A4.5 SALINITY LEVELS

The quality of water in the River Murray is characterised by high turbidity, especially when flows are derived mainly from the Darling River. Salt is a natural feature of the Basin and has accumulated over geological time (Blackmore *et al.* 2002; Forward 2004). The flat terrain, low rainfall and high evaporation combined to concentrate salt in the soil profile and groundwater. Limited rainfall and low river gradients have precluded flushing of the accumulated salts from the basin. The level of salinity in a river at any time is a consequence of the salt load and the flow (Pigham 1986; Blackmore *et al.* 2002).

Increasing regulation of river flows and the abstraction of water for consumptive uses resulted in a general increase in the salinity of the water which is a particularly relevant issue to water users. The significance of salinity is in terms of the uses to which water is put and the quality of water required varies depending upon the intended use. For example, the World Health Organisation standard for salinity level for desirable drinking water quality is 800 EC. As the salinity exceeds this level, irrigation management becomes increasingly difficult and at 1500 EC the options for consumptive use become limited. Susceptible crops cannot be grown and direct adverse biological affects are likely to occur in river land wetlands (Blackmore *et al.* 2002).

During periods of low flow the salinity level of the river water can be high enough to cause considerable production losses when used to irrigate horticultural crops (Marohasy 2003; Forward 2004). The need for salinity management was recognised as much as 50 years ago with the installation of the comprehensive drainage schemes (CDS) in Berri, Barmera and Loxton (Forward *pers comm*. 2004). Figure 220 is a plot of the mean daily recorded salinity level at Morgan and clearly shows the salinities levels well over 800 EC for extended periods during the mid-1960s and 1970s. At this time the rising salinity levels associated with irrigated agriculture, particularly in terms of land and water salinisation was recognised as a critical issue facing the Murray-Darling Basin (MDBC 1997; GSA 1999).

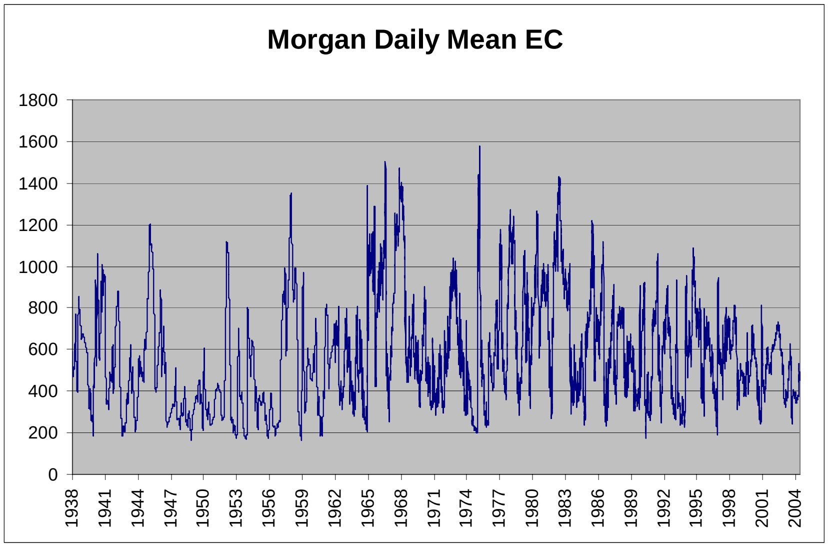


**Figure 220 Recorded Daily Mean Salinity Levels at Morgan (Forward 2004)**

The salinity at Morgan is the main long-term benchmark used by the MDBC for modelling and assessing the impact of actions that increase or decrease salinity in the River Murray (Forward 2004). Figure 221 shows the slow background rise in salinity (about 1.5 EC per year) evident from 1920 until about 1970 when the delayed salinity impacts of irrigation developments started to become noticeable in the river. Without intervention it was estimated that the average salinity at Morgan, a town on the River Murray upstream of the water off-takes to Adelaide, would approach the 800 EC by 2020 (Blackmore *et al.* 2002).

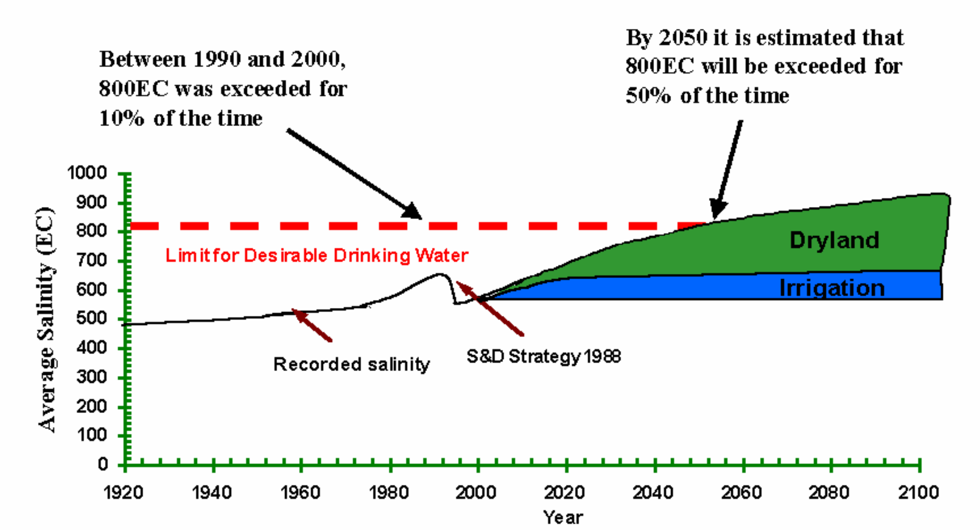


**Figure 221 Salinity Level Forecast in River Murray at Morgan (Forward 2004)**

A number of policy and management responses to tackle this issue have been in place for 20 years, supported by major funding programs from Commonwealth and State governments. The responses included; engineering intervention in the form of major salt interception schemes, land care initiatives, and the release of additional flows (over South Australia's entitlement) to maintain salinity levels at Morgan – a key site just upstream from the extraction point for Adelaide – at less than 800 EC for 95% of the time. Figure 222 shows that the implementation of the 1988 Salinity and Drainage Strategy caused a temporary dip (bought some time) through the impact of changed river flow management and the reductions in salt inflows achieved by the interception schemes (Forward 2004). Despite this achievement, the uptrend is still evident and is now estimated at as much as 4 EC per year.

Recorded salinity levels at Morgan since the implementation of the intervention strategy indicated the measures to manage the salinity levels at Morgan have been successful in reducing the rate of increase (Blackmore *et al.* 2002; Marohasy 2003). The improvement of long term average salinity levels in the River Murray at Morgan since 1980 is shown in Figure 222 below.

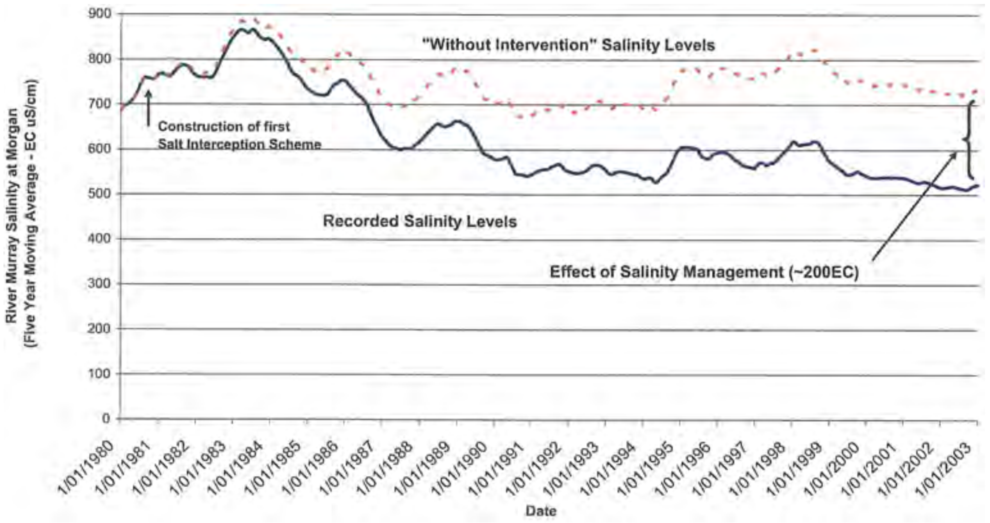


**Figure 222 Effect of Salinity Management - Morgan, South Australia (MDBC 2003)**

The effect of the intervention schemes appears to be the deferral of the predicated approach to the 800 EC threshold of the average salinity at Morgan from 2020 to 2050. Marohasy (2003) points out that salinity levels are generally improving, groundwater levels falling and nitrogen, phosphorus and turbidity levels stabilising should not be surprising given the billions of private and public dollars spent on land care initiatives over the past two decades. On the other hand, the fact that salinity levels continued to improve during the recent drought surprised many people (Marohasy 2003) tends to indicate that the initiatives are robust.

Over the next 50 years, dry land salinisation will increasingly add salt to the rivers at their headwaters. However, approximately 50% of the salt load increase in the River Murray will still be caused by the inflow of saline groundwater in South Australia (MDBC 1999b). The two interrelated problems land and water salinisation threaten the viability of irrigated agriculture in South Australia which currently accounts for 80% of the water use in South Australia (Thompson 1996). All irrigation waters contain salts, and many soils on which irrigation is desired contain significant amounts or are underlain by salty substrata. Salinisation as a result of land clearing and irrigation practices has emerged as the most pressing problem of land and water resource management in Australia.

As well as being a major source of supply for Adelaide, the Murray provides water for the domestic, industrial, livestock and irrigation requirements of the towns and farmlands both along its banks and further a field (SA Water 1999d). Adelaide is not in the Murray Darling Basin, but water piped from the River Murray typically supplies about half of Adelaide’s water needs and in dry years, the reliance on the Murray water can increase to as much as 90% of needs (GSA 2000; Marohasy, 2003). Without the present system of river regulation, the population of Adelaide and many other cities and towns in the Murray Valley would be considerably smaller than they are today (MDBC 2004).

# Appendix 5

# Willingness to Pay – Bottled Water Demand

## A5.1 BOTTLED WATER

The packaged water industry in Australia was in its infancy when this research commenced and was studied in passing to demonstrate a '*willingness to pay for drinking water*' by consumers. However over the period of research, it has become the fastest growing segment in the beverage industry in Australia, providing consumers with another choice to reticulated water, rainwater and other beverages (i.e. soft drinks, juices, and beer). Enter any supermarket in Australia and one of the first things to strike you is the profusion of brands and choice - and the variety of pack sizes. "*More people are seeing spring water as a cheap investment in their health*" (Anon. 1992). If this is what people think, then sadly they are mistaken because bottled non-carbonated water is neither cheap nor any greater investment in health than drinking common scheme tap water (Anon. 1992).

The origin of the packaged water industry was in the supply of water to remote homesteads and urban residential districts that were did not have access to reticulated water or to which the quality of the reticulated water was not suitable for drinking (Holloway 2000). According to Heyworth *et. al.* (1998) in their article "Who Drinks What?" as many as 14% of South Australians choose packaged water as their primary refreshment drink. This level of use of bottled water coincides with a growing awareness in the community of the link between drinking water and a healthy lifestyle. In addition, while packaged water is not available 'on tap' like scheme water it is conveniently available 'en route' and without variation in taste, which often occurs in reticuated water depending on the local source of supply. It has reached a point where suppliers of reticulated water are considering entering the packaged water market.

## A5.2 DEFINITIONS OF BOTTLED WATER

Packaged water is considered a food (Hidell III, 2000) and bottled water companies are required to use approved sources. There are two types of sources from which bottled water can be drawn being:

- natural sources (i.e. springs and wells), and
- approved potable municipal supplies.

Bottled water companies that use these sources reprocess the water using methods such as distillation, reverse osmosis, deionisation and filtration. This ensures the finished product is very different, in both composition and taste, from the original source water.

The bottled water industry has two main segments that reflect the size of the package and method of delivery. These are;

- Retail - packaged water (sparkling and still) with pack sizes ranging from 500mL up to 10 litres purchased by consumer in shops; and
- Bulk - home and office delivery of packaged water (still) to consumers with pack sizes over 10 litres.

The Sydney water crisis in 1998 gave the bulk bottled water home and office delivery the opportunity to gain and retain thousands of new domestic clients (Holloway 2000). Available Australian records indicate that bottled water has never been responsible for an outbreak of waterborne illness (ABWI, Undated).

## A5.3 WILLINGNESS TO PAY

Accurate information on this rapidly expanding market has generally been piecemeal and difficult to obtain. However, the increase in sales from a single Coles supermarket at St Agnes of 280 litres in 1993 to 5020 litres by 1998 represents more than a 1000% increase in volume sold at this one location. Figure 223 provides an indication of the market share of the retail andf bulk bottled water industry at the time of the two surveys. It should be noted that the purschasing patterns of bottled water in 1998 at the time of the second survey may be been influenced by the water quality scare that had recently occured in Sydney.

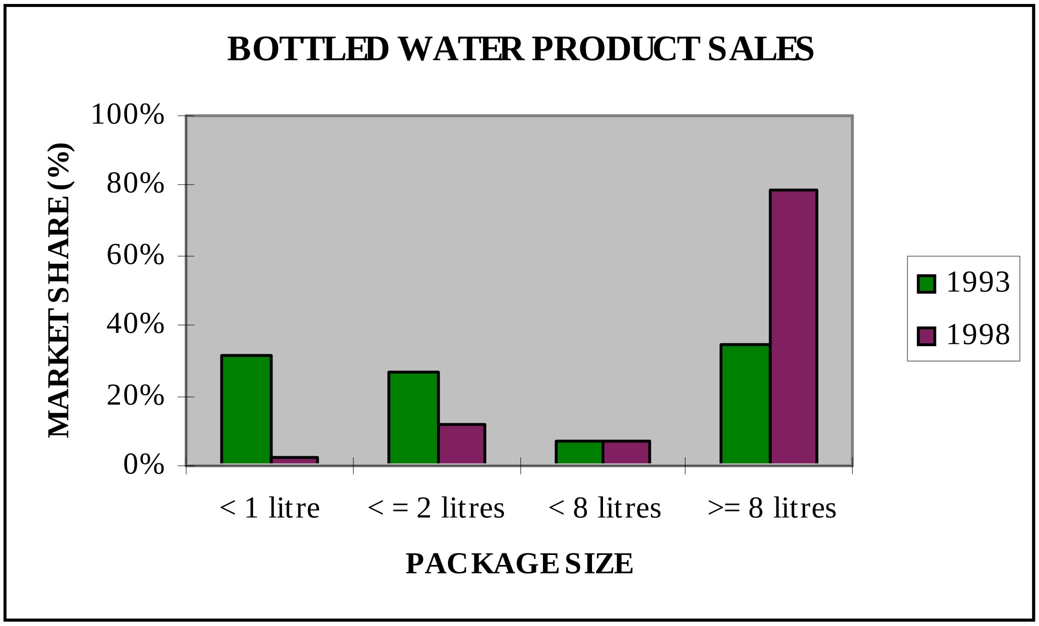


**Figure 223 Change in Bottled Water Products Sold at Coles (St Agnes)**

The cost of bottled water over the five year period from 1993 to 1998 appears to be driven by the demand for the relative products (coefficient of elasticity). Figure 224 shows the change in retail price of the various sizes of packaged water over the five year period from 1993 to 1998.

Figure 224 shows the cost of convenient sized bottled water (less than 1 litre) has increased by 7% over the same period and the sales (market share) of this size of bottled water from the supermarket have decreased by 30% (Figure 223 above). This is not to say this is a general trend across the bottled water industry, because the cost and number of bottles sold at convenience stores and gym has not been studied.

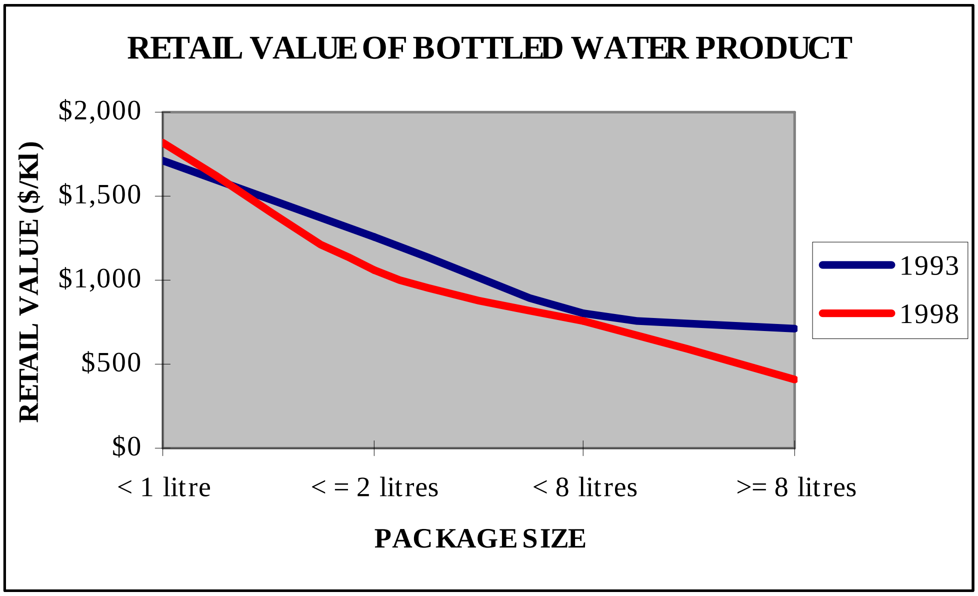


**Figure 224 Change in Retail Value of Bottled Water from 1993 to 1998**

Bottled water has yet to find its price point, but there are signs that this is fast approaching (Holloway 2000). While the cost to of bulk packaged water (greater than 8 litres) as decreased by 42% it still costs consumers an average of $415 per kilolitre compared with the cost of $0.92 per kilolitre (in 1998) for mains water of drinkable quality as shown in Figure 31. Clearly, people are willing to pay for water services that are perceived to be of high quality.

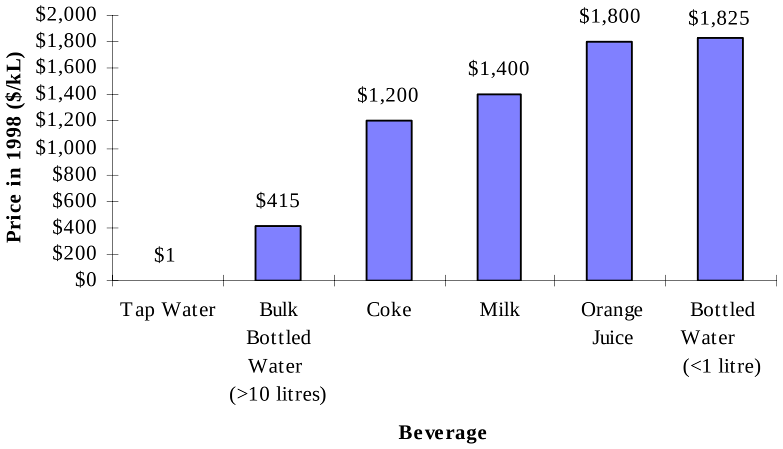


**Figure 32 Comparison of Costs for Drinks**

The amount of money spent on resold and vended water shows that among consumers there is ability and willingness to pay for reliable water service (Katko 1991).

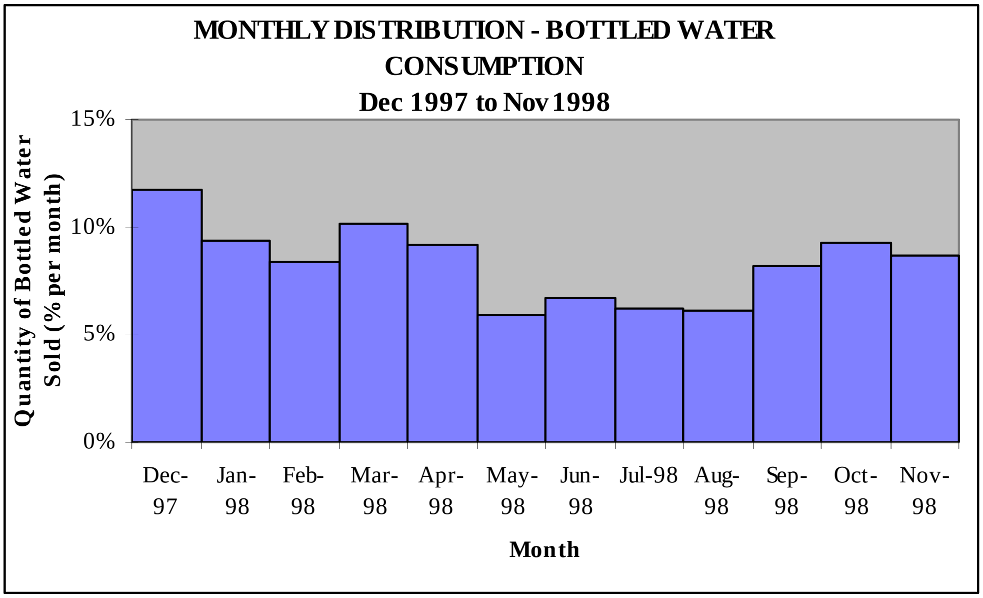


**Figure 225 Monthly Distribution of Bottled Water Consumption**

## A5.4 AUSTRALIAN BOTTLED WATER INDUSTRY (ABWI)

Until recently the reselling and vending of water in the developing world has largely been ignored by utilities, governments, and external support agencies. Vendors transport water door-to-door or sell it wholesale. Reselling and vending indicate consumers' ability and willingness to pay for water service (Katko 1991). In spite of its wide use in developing countries, vending is often ignored by water authorities.

The bottled drinking water industry is an advanced form of reselling. Although the amount of bottled water consumed per capita is low, the unit price per litre and the total money flow can be considerable. At least it shows that people are willing to pay a substantial amount for groundwater perceived to be of good quality (Katko 1991).

The ABWI (1999) reports a 20% growth in the bottled water market each year since 1996, with over 400 million litres of bottled water sold in 1999. Drinks share of throat in Australia - indicates that soft drinks are the driver of market growth and shows within soft drinks it is bottled water that stands out (Holloway 2000). But no segment can match the bottled water surge, with 167% or 19 litres per person since it was added in 1993 (Holloway 2000).

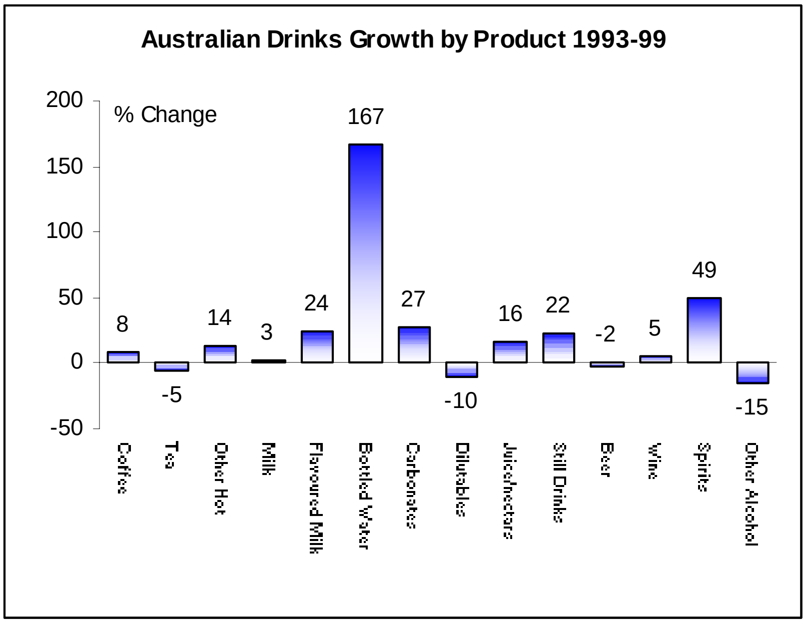


**Figure 226 Australian Drinks Growth by Product 1993-99**

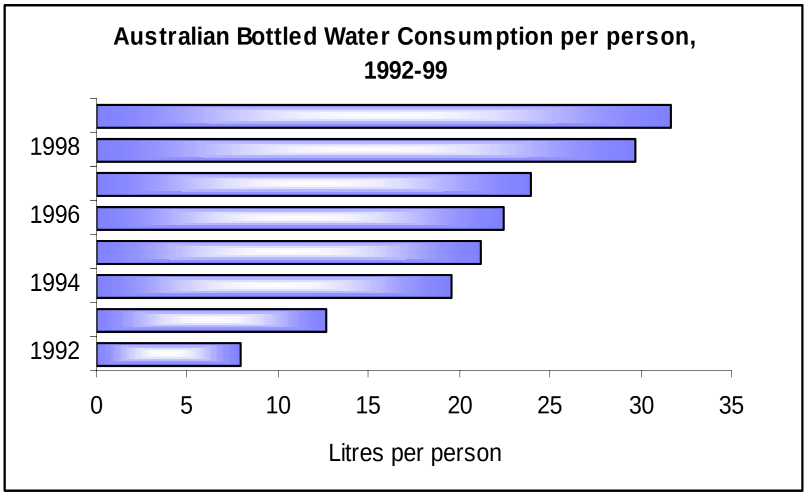


**Figure 31 Australian Bottled Water Consumption per person 1992-99**

Add the expected boost provided to soft drink and water sales by their exemption from the new Goods and Services Tax, introduced earlier this year and the prospects for the market begin to look rosier still (Holloway 2000). It may be that the 50% growth forecast for the years between 2000 and 2005 for the bottled water sector will prove to be only a modest proposition. After all, 900 million litres of sales would only be equivalent to around 45 litres per person per year (Holloway 2000).

Another factor that has contributed to the advance of the bottled water industry has been the success of home and office delivery, especially home delivery. For a market of only 600 ML, Australia has a high bulk penetration (compared with other countries), with pack sizes over 10 litres accounting for 45% of the total (Holloway 2000).

## A5.5 CASE STUDIES

### A5.5.1 *Bottling the Basin*

The small rural community of Mitchell in western Queensland like many others in Australia is wrestling with the problems associated with a declining population and low economic growth. However, there is a feeling that the rural town will survive after the Booringa Shire Council embarked on its ambitious spa complex and water bottling projects, despite the sceptics (Landline 2000). Mitchell has established itself as a tourist stop with its salty artesian spas which are said to have therapeutic qualities. The Council and local grazier are getting behind a project to harvest, package and sell artesian drinking water under the label of: "*Great Artesian Water: from the water that dripped off a dinosaur's back*" (Landline 2000). This project is in its infancy, with the water manually bottled and labelled, but is moving towards full automation with a $50,000 grant from the National Network of Area Consultative Committees. The raw Great Artesian Basin water is sourced from a property not far out of town. It is extracted from a depth of 231 metres by bore, and is of good quality meeting the National Health Medical Research Council parameters of water suitable for human consumption (Landline 2000). The grazier is licensed to take 1 ML/year from the bore. Currently, the bottled water is being sold to the local market with a view to expanding into the large international market. Although, the project is not making money yet it is expected that it will only a matter of time given the world wide growth in the bottled water industry.

### A5.5.2 *Rain Farm*

A Queensland farmer has developed what most farmers only dream of, a crop that costs nothing to grow, is simple to harvest and profitable: harvesting rain, bottling it and selling. Rain Farm is producing about 250,000 litres of bottled water a week and sells to Coles, Woolworth's, Franklins and a large base of distributors, quite a feat in the competitive bottled water market, which is dominated by big companies, like Coca-Cola (Landline 2000b). Rain Farm water sells for $1.20 for a 1.5-litre bottle in the supermarket, while that money is not all profit for Rain Farm, there is definitely room for some healthy returns. The business has grown threefold since Rain Farm was set it up two years ago and it is still expanding. The initial set-up costs were quite high, with the fully automated production plant, equipped with machinery worth more than $500,000, but once the initial capital costs are paid for, the crop will be free. After attracting a few investors, the developer bought prime farming land west of Innisfail, in far north Queensland which is one of the wettest spots in Australia, receiving on average 3.5 metres of rain each year. Rain Farm is selective about the rain that is harvested, it can't be cyclonic rain, as it has a high salt content and storm water is no good as it contains foreign matter, such as grass and insects. The purest water comes from the south-east and it is this rain that is collected. The rain collectors are inverted only when it rains from the south-east. In other words, they're in the upside-down position at all times except when it rains from the south-east. The water harvested is fed from the collectors through 10 micron filters and the water fills up storage tanks ready for bottling.

# Appendix 6
# History of the Provision of Water Services in South Australia

The story of the provision of water supply in South Australia has been a triumph of adaptation and experimentation, in the face of disease, engineering trial and error and changing public attitudes (Hammerton 1986). Although the early water technology of South Australia was largely derivative, it was characterised by skilful adaptation, which was essential for the survival of the first settlements (AATCE 1988). Past endeavours can provide a rich source of learning for contemporary political and social leaders. The spirit of adaptation and striving for improvement has persisted and deserves consideration in the planning and development of water harvesting and reuse projects in the country towns of South Australia today.

In this regard, South Australia is fortunate to have a comprehensive history of the development of public water and wastewater services provided by the government for 1836 to 1984 in the form of the book *Water South Australia*, authored by Marianne Hammerton (1986). This section draws heavily on material published in Hammerton's book which provides contains an account of important water-related issues as well as an insight into the evolution of water services in this State.

Settlement in South Australia in 1836 was unusual in that, unlike the other colonies, it was settled by free people and the colony had no financial backing from the British government. The first permanent European settlers came from a green and pleasant land, with rivers flowing throughout the year with good quality water and with no extreme variations between summer and winter flows. They brought a corresponding sense of water values to Australia, not realising that Australia was a very different land to that with which they were familiar (AATCE 1988). For a time, early water technology, imported largely from the United Kingdom, proved to be inadequate.

## A6.1 WATER SUPPLY

### A6.1.1 *Survival of a Colony (1836 – 1900)*

Wells were randomly sunk but the major water supply was the River Torrens. The river was used for watering stock, bathing, refuse disposal, and as a water supply. Oxen and horses soon conveyed water via specially constructed vehicles (water carts) or people hauled their own supplies (Hammerton 1986). Rich and poor paid the same amount for carted water, which was determined by the distance they lived from the Torrens (Hammerton 1986). However, water carters took no responsibility for the quality of water delivered. In 1839, after an epidemic of dysentery killed five children in one day Governor Gawler took the first step towards controlling the quality of the Torrens (Hammerton 1986). He prohibited people from bathing, washing clothes, and throwing dead animals into the stream within 1 mile of the town, but each summer the epidemic recurred and the complaints persisted. Despite these hardships, there were about 30 satellite villages outside Adelaide by the early 1840s.

Three separate schemes to improve Adelaide's water supply were promoted by enterprising individuals in 1846, 1847 and 1848, but failed to raise the necessary capital to implement their projects (Hammerton 1986). Citizens who could afford wells or cartage charges were not interested in expensive alternatives, while the poorer people lacked the capital and the voice to support them. During this period, the first public water supply scheme in the colony had been completed at Port Elliot and provides a good example of how organised communities can find innovative solutions to local problems. Water from springs was collected by galvanised iron imbedded in concrete and brick channels, which drained into a large covered tank. Domestic water was then pumped and shipping supplied by a 2 inch cast iron pipe to the jetty Hammerton (1986).

For the first 24 years of colonisation, Adelaide's settlers relied on shallow wells, rainwater tanks and water carted from the nearest permanent water hole in the River Torrens (Clark *et al.*1997). This did not change until the government stepped in and built South Australia's first reservoir at Thorndon Park and water finally flowed into Adelaide in 1860 (SA Water 1999d). In 1861 the Colonial authorities extended water supply to Port Adelaide and suburban townships, and introduced a uniform charge for service pipes to houses. Hammerton (1986) notes that demand for the service was hesitant at first; however the public did not remain uninvolved when the convenience of piped water supply became a reality. By 1867 more than 20,000 consumers in Adelaide and Port Adelaide had been connected to the system and although the supply was intended for domestic purposes, the arrival of the practice of watering gardens led to frequent water shortages.

Private individuals and government agencies provided water services for smaller, more isolated groups on a less complicated scale. Tanks constructed were of three types: the simple excavated dam; circular or rectangular masonry or concrete tanks into which natural runoff was diverted by means of drains and embankments; and tanks with artificial catchments of galvanised iron fastened to timber framework above the ground. Sometimes, efforts to maintain water supplies to small or isolated communities were not always successful. For example, a reservoir constructed to capture diverted surface water for the township of Kapunda never filled. While residents of Kapunda appreciated the efforts they were unwilling to be rated for the water supply until the quantity (reliability) of water improved. Likewise, the townships of Moonta, Kadina and Wallaroo also experienced frequent water shortages and suffered widespread outbreaks of typhoid fever (Hammerton 1986).

By 1888, 130 reservoirs and twenty-four tanks had been excavated, 62 wells and 22 well borings made, 150 station dams had been resumed and 21 tanks and wells had been improved. Government departments involved suffered as achievements were thwarted by shrinking and variable local freshwater reserves, which would soon become a major limitation to colonial development. Country water districts lodged petitions for fairer sharing of water. Providing water to regional South Australia presented challenges, given the vast distances involved and the extremely limited natural water resources (SA Water 1999d).

The public saw the advantages in government provision of water and waste water services, despite the financial failure of a number of government experiments and community-run water supply projects in this area. During this period other communities, with constraints including accumulated financial problems, abundant petty squabbling and schemes requiring improvement and supervision, also saw advantages in a central organisation of water as opposed to a local one (Hammerton 1986).

Managing the River Murray became a problem for the colonies of New South Wales, Victoria and South Australia when conflict developed between the use of the river for navigation and irrigation in the 1880s (MDBC 1997). A series of conventions were attended by representatives from every colony during the 1890s, to draft the Australian Constitution (COA 1999). The impending Federation prompted a review of the central provision of water services, which confirmed public works and services were attractive to politicians and citizens. This approach appeared to solve many problems including unemployment, water shortages and the development of the colony's rural potential (Hammerton 1986).

### A6.1.2 *Watering the State (1901 to 1970)*

Before 1900, Australia was a collection of six self-governing British colonies. The Australian Constitution of 1901 established a federal system of government (COA 1999), which distributed powers between the federal government (the Commonwealth) and the six state governments (the three Territories having self-government arrangements). However, the responsibility for water resource management remained firmly a power of the state government (Pigham 1986). The extensions of the railways through Eyre Peninsula and the consequent rapid opening of the country to settlement made the problem of water supply a matter of grave concern to the Government (EWS 1973). In 1912 it was proposed that shed tanks should be built by the Government on newly surveyed land to encourage settlers to take up the land (EWS 1984). Within 4 years over 200 farm sheds and rain tanks had been erected. The shed tanks initiative continued for over 20 years and when it ceased in 1934 a total 750 tanks had been installed on the Eyre Peninsula (EWS 1984). Figure 227 provides a good example of this early water technology which is still is use today in remote and isolated areas of the state.

**Figure 227 Early Water Supply: The Lady Kinard Shed Tank (EWS 1987)**

A vital breakthrough in the area of water management for South Australia occurred in 1914, when the first Murray-Darling Basin Agreement was signed (MDBC 1997) after a series of conferences held between 1903 and 1908. It provided for cost sharing of construction works and its water sharing formula guaranteed South Australia a minimum flow throughout the year (GSA 1999; MDBC n.d.). This agreement provided the state with much needed security for its commercial farmers and residential users (Pigham 1986; Competition Commissioner 1997). With the provision of water security came one of the biggest challenges facing the South Australian government - the control and use of the River Murray to best serve South Australia's needs, in cooperation with partner States (Hammerton 1986).

The use of the River Murray as a source of water for Adelaide was considered for many years, but was not possible until barrages at the river mouth were constructed preventing saline water entering the lower reaches of the river (SA Water 1999d). From the earliest days of settlement along the lower reaches of the river there were strong representations from landowners for the construction of barrages, to keep the water fresh in the lower reaches of the River Murray, as well as Lake Albert and Lake Alexandrina, originally for navigation and agriculture (Jensen *et al.* 2000). The barrages were constructed between 1935 and 1940, in their current location to keep Lakes Alexandrina and Albert fresh while maintaining tidal conditions in the Coorong. The barrages, linked by earthen causeways, create a barrier 7.6 km long (Jensen *et al.* 2000). The level of the River Murray below Blanchetown and the ingress of seawater are controlled by five barrages near the Murray Mouth.

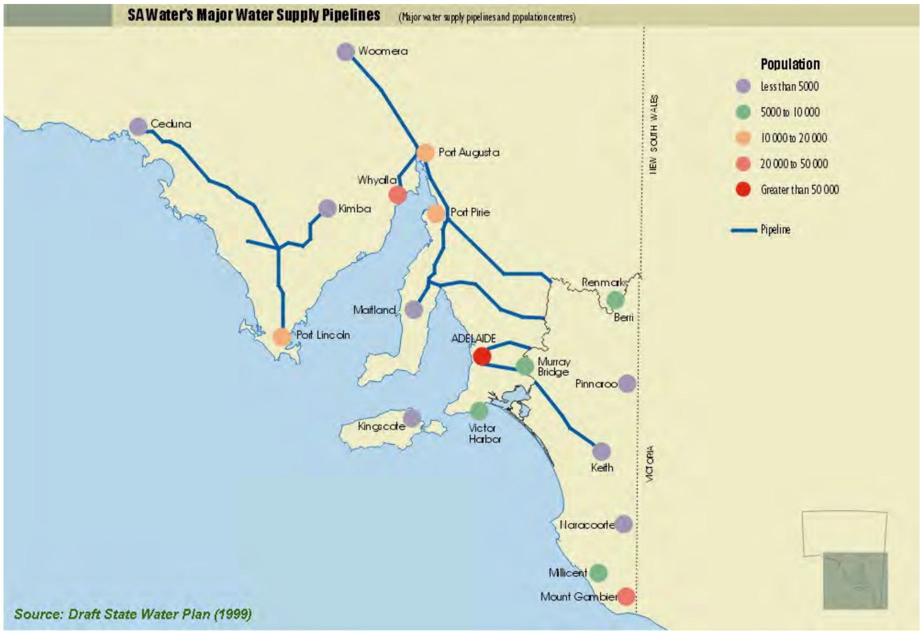
**Figure 228 General View of Goolwa Barrage (SA Water Photo Catalogue)**

Once the state had access to the water it needed to open the way for development. Pipelines were built to transport water from the River Murray to remote regions of the state (SA Water 1999d) and in due course the original local water supply schemes were abandoned in favour of reticulated water systems. The fastest growth in South Australia's history occurred in the years 1945 to 1965. The provision of reliable water supply was a key requirement of the government's industrial program and involved extending reliable water supplies to as much of the State as possible, as well as meeting the increasing demand from the areas already supplied (Hammerton 1986). Rapid suburban expansion and increased water use by households, generally associated with reticulated water systems, meant that water restrictions became a regular occurrence. The public saw these restrictions as a sign of service failure, rather than as an attempt to prevent failure (Hammerton 1986).

The first major pipeline built from the River Murray to the city was the Mannum-Adelaide Pipeline (SA Water 1999d). In the summer of 1954, the newly completed pipeline was able to balance the effects of a dry winter and meant that Adelaide was the only Australian capital city without water restrictions that summer (Hammerton 1986). In fact, Adelaide residents have not experienced water restrictions for over 50 years until the recent 2002/03 drought when permanent water use regulations were introduced.

**Figure 229 MAPL - First pipe en-route to Mannum (SA Water Photo)**

By 1965 the proportion of the population receiving water by State reticulation schemes was 97%; the highest for all Australian States, which included more than forty towns and country regions (Hammerton 1986). At the same time, local water supply schemes ranging from water retention structures on surface streams, bores pumping groundwater from aquifers and rainwater tanks to store roof runoff were abandoned in favour of the major regional pipelines. The state had been watered and the government accomplished its objective to extend a reliable water supply to stimulate development to much of the State, as illustrated by Figure 230.



Source: Draft State Water Plan (1999)

**Figure 230 Major Water Supply Pipelines Serving South Australia (GSA 1999)**

Most of the state, including Adelaide, relies on water from the River Murray through five major water supply pipelines to support communities. Country, rural and remote communities rely on a wide variety of water sources including ground water, small local dams and water piped over many kilometres in regional pipeline systems (SA Water 1999d). For example, the Eyre Peninsula is served by a system which relies on storage of surface water in the Tod Reservoir, and significant groundwater supplies located near Port Lincoln (SA Water 1999d). Water delivered to Adelaide comes mainly from two sources - the Adelaide Hills Catchment area and via large pipelines from the River Murray (SA Water 1999d). However, problems associated with remote communities were not so easily solved and places such as Andamooka and Kimba faced endless carting of water and continuous restrictions.

These systems provided a safe and reliable water supply to most South Australians at an affordable price largely as a result of the Government's uniform price policy. By the mid-1960s, the government become conscious that fixed rate charges without metered charges for water consumed was discouraging economical use and defeating their own ends (Hammerton 1986). In addition, water quality issues became more apparent and complaints about smelly and unpalatable water resulted in Hope Valley Reservoir being dosed with copper sulphate, a practice that continues today. Chlorination was used to address water quality problems and to ensure safe drinking water at all metropolitan reservoirs and at an increasing number of country water supplies. On the other hand, country residents remained more concerned with regularity of a water supply for commercial use than its quality and also began to make increasing demands including requests for assistance to develop local sewerage schemes (Hammerton 1986).

### A6.1.3 *Improving Quality of Supply (1970 – 2000)*

Unfiltered supplies in South Australia, particularly from the River Murray, have always had problems associated with physical appearance, taste and odour (Heyworth *et al*. 1998). The quality of water in the River Murray is characterised by high turbidity, especially when flows are derived mainly from the Darling River, so that the waters are aesthetically unacceptable. Once the pipelines brought Murray water to Adelaide, public attention focused on quality and in the early 1970s the demand for filtered water intensified when an outbreak of amoebic meningitis was traced back to the Morgan Whyalla pipeline (Hammerton 1986).

The decision to filter Adelaide's water supply in the mid-1970s was primarily a response to improve the quality of the source waters (Hudson 1990). The government agreed with the proposal for seven treatment plants for Adelaide's water supplies to be built over a ten year period; however, mobilising funding for the non-earning exercise continued to be a problem throughout the program (Hammerton 1986). From about 1975 to 1992, funding was directed predominantly to the more cost effective projects that would benefit the largest proportion of the population. Distribution of filtered water began in September 1977 with the commissioning of the Hope Valley Water Filtration Plant (Heyworth *et al*. 1998). This situation is primarily the result of urban areas having an advantage over their rural counterparts, because they possess a stronger revenue base. At the completion of this program of works, 85% of South Australians benefited from filtered water (SA Water 1999d).

By the 1980s rising salinity levels associated with irrigated agriculture, particularly in terms of land and water salinisation, were recognised as one of the most critical issues facing the Murray-Darling Basin. Of greater long-term significance are accessions of salt to the River Murray from surface and subsurface drainage of irrigated land and the associated cost in additional treatment to providing water to communities that meets standards set by the Australian Drinking Water Guidelines. The significance of the Murray-Darling Basin and associated issues to South Australia are discussed separately in more detail in Appendix 4.

The government's next goal was to extend the delivery of filtered water to residents living outside the metropolitan area. However, the provision of an assured quality of filtered water to rural South Australia presented additional problems, including those associated with the distance, the small size of the communities, and lack of good quality local sources of water (Heyworth *et al*. 1998; SA Water 1999d). In fact, the only area outside Adelaide to receive filtered water was the Iron Triangle region until 1997. With the completion of the ten Riverland plants in September 1999, 95% of South Australians are supplied with filtered water which meets or exceeds standards set by the Australian Drinking Water Guidelines (SA Water 1999d).

The remaining country population, totalling less than 30,000 services or about 5% of the state, receive mains water that is generally not sufficiently protected against microbiological contamination. A small proportion of country communities also receive water with some chemical concentrations exceeding 1996 Australian Drinking Water Guideline values (SA Water 1996). These quality deficiencies are primarily a consequence of the poor quality and limited availability of source waters. Many challenges to the successful implementation of these types of schemes remain.

## A6.2 WASTEWATER SERVICES

Wastewater is an inevitable product of human settlements, necessitating treatment, frequently of a complex nature, in the interest of public health and the environment (AATCE 1988). However, there was little concerted interest in matters of sanitation until in 1848, twelve years after settlement, when Adelaide's first firm of night soil men appeared (Hammerton 1986). Still, the mortality from diseases such as typhoid which were directly related to the use of polluted water continued to increase. In the 1870s people came to agree that public health was government business, that Adelaide needed deep drainage, and that the government should provide it (Hammerton 1986). The issues of public health and sewerage were the main political concerns of the colony.

Gathering consensus, strengthened by knowledge of Adelaide's high mortality rate, resulted in the passing of the first Public Health Act in 1874 and the first Sewer Act in 1878 (Hammerton 1986). Chadwick had developed the notion of an arterial system of town drainage, utilising gradients and the sewer and motivated by water supply (Hammerton 1986). Provision of water supply and sewerage works complemented each other as a proportion of fresh water used by households connected to the water supply is returned to sewers from household toilets, sinks and showers (AATCE 1988). Sewage is 99.9% water, with the remaining 0.1% being material dissolved or suspended in it (SA Water 1999d). The sewerage system works silently and unseen 24 hours a day, seven days a week collecting and transporting wastewater and providing a vital community health service (SA Water 1999d).

South Australia's sewerage authorities, coming late into the field had the advantage of being able to select the most appropriate technologies from those in use elsewhere (AATCE 1988). Originally, the emphasis was to convey sewage as cheaply and efficiently as possible beyond urban boundaries with the primary objective the protection of public health (Clark *et al.* 1997).

From January 1881, all sewerage that had previously run into the Torrens was taken by main sewer to the first sewerage farm at Islington. At this time, land application of domestic sewage and effluent was not motivated by a need for irrigation or a desire to use effluent as a resource, but as a means of disposing of it (Polin 1977). It was South Australia's first attempt at water reuse but sadly, dairy and orchard activities were abandoned under the weight of public prejudice against their produce by 1888. Figure 231 shows the grazing and fattening stock using effluent water that continued for many years.

**Figure 231 Cattle at the Sewerage Farm in Adelaide 1901 (SA Water Photo)**

The effects of government provision of sewerage and water supply were far-reaching in terms of the colony's health and growth. After only five years Adelaide's mortality rates dropped from 23.5 per 1000 in 1881 to 14.3 per 1000 (Hammerton 1986). In 1916, the first sewers were constructed in the Port Adelaide area and the sewage collected was pumped to the sewerage farm at Islington (Sickerdick *pers comm*. 2004). With advances in wastewater treatment technology, interest in land applications waned as water could be easily disposed of in waterways (Polin 1977).

In 1932 Adelaide's first wastewater treatment plant at Glenelg was opened. While a majority of treated effluent discharged into Gulf St. Vincent, a portion of treated effluent has been used to irrigate public areas including golf courses, sports fields and parklands since. In 1935, the Port Adelaide wastewater treatment plant was the second plant in the Adelaide area to be commissioned (the plant was extended in 1954 and again in 1960 to increase its capacity).

After approximately 55 years, problems in the sewerage system became evident, including inflows of sand and water and the deterioration and collapse of concrete sewers. The concrete pipes used are subject to severe corrosion from the by-products of hydrogen sulphide generated in raw sewage.

Figure 232 shows a reinforced concrete sewer pipe in Grand Junction Road, Islington that had saltwater disintegration in 1936.

**Figure 232 Deterioration of Sewers, Islington 1936 (SA Water Photo Collection)**

In 1961 work began on Adelaide's largest sewage treatment works at Bolivar forty years after it was first suggested. The plant at Bolivar was commissioned in three stages between 1964 and 1969 (SA Water 1999d). Sewage was diverted to Bolivar from the sewage farm at Islington in 1966 (Sickerdick *pers comm*. 2004). Since completion, some effluent from Bolivar has been used for irrigated agriculture in the Northern Adelaide Plains with the majority being discharged into Gulf St. Vincent (until the commissioning of the Virginia pipeline in 1999).

Despite setbacks, the achievements in provision of sewerage services in South Australia between 1945 and 1965 were remarkable. For example, in 1947 around 1,000 miles of sewer had been laid in the metropolitan area and in less than twenty years that figure had doubled (Hammerton 1986). By 1965, nearly 100% of Adelaide was served by sewerage whereas no other Australian city had more than 75% of its population served by sewerage (Hammerton 1986). The Governments goal was to extend the service to residents living outside the metropolitan area.

In the meantime, the coalfield town of Leigh Creek was the first country town in South Australia to be served by sewerage in 1946. Figure 233 is a photograph of the first small town sewage treatment plant in South Australia. In response, other country towns such as Renmark, Victor Harbour and Naracoorte, began to seek departmental assistance to develop local sewerage schemes (Hammerton 1986). Over a thirty year period from about 1961, the government directed funding to the provision of conventional sewerage services to a number of rural centres in South Australia. During this period, Christies Beach became the newest of the four metropolitan wastewater treatment plants and was opened in 1971 (with further extenions in 1981).

**Figure 233 Leigh Creek Sewage Treatment Plant, 1946 (SA Water Photo)**

Many country towns have common effluent schemes and some have sewage treatment works. Again as with the provision of water supply, funding was directed predominantly to the most cost-effective projects that would benefit the largest proportion of the population, for example, towns with the largest populations, existing public health issues associated with septics or located within the water catchments to protect quality of water supply sources (Sickerdick *pers comm*. 2004). Between 1961 and 1990 the provision of conventional sewerage systems and small wastewater treatment systems was delivered to the 19 towns listed below (SA Water 1999d): Angaston, Bird-in-Hand, Finger Point (Mt Gambier), Gumeracha, Hahndorf, Heathfield, Mannum, Millicent, Mount Burr, Murray Bridge, Myponga, Nangwarry, Naracoorte, Port Augusta (East and West plants), Port Lincoln, Port Pirie, Victor Harbor, and Whyalla.

The pace of sewering towns was slow, a result of limited funds, and since 1972 septic tank effluent disposal schemes (STEDS) have been provided to most South Australian towns instead of conventional sewerage schemes as an interim measure (Palmer *et al*. 1999; Sickerdick *pers comm*. 2004). The provision of STEDS in South Australia has been a partnership between the State Government and Local Government in a cost sharing arrangement to speed up the delivery of sewerage services (LGA 2003).

STEDS were initially regarded as “temporary” drains to convey septic tank effluent to a central treatment facility (typically an oxidation lagoon), with the expectation that a "permanent" sewerage scheme will replace it in the future. Figure 234 shows these schemes have offered an affordable alternative to sewerage and have been retained for the majority of towns in South Australia (Palmer *et al.* 1999).

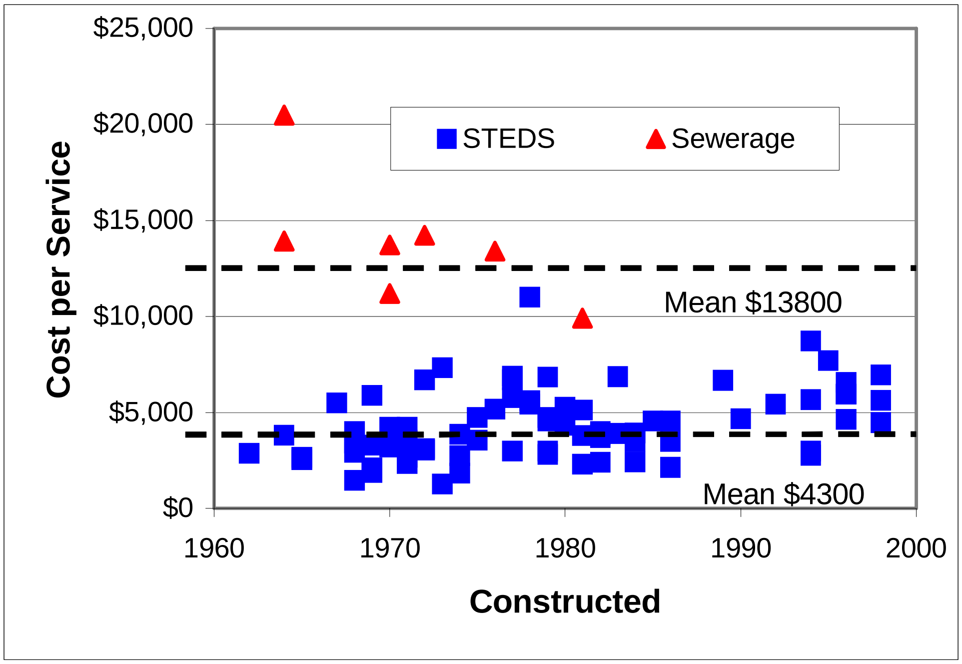


**Figure 234 Construction Costs for Sewerage and STEDS (Palmer *et al.* 1999)**

STEDS provide approximately 10% of all public wastewater services in South Australia (LGA 2003). Around 130,000 South Australian residents have their wastewater treated and their local environment and public health have improved, the majority of which have been constructed within the STEDS Program which commenced in 1972 (Lightbody & Endley 2002). A further 68,000 people currently meet the trigger criteria for connection to similar communal wastewater services (Lightbody & Endley 2002). There remains a very substantial funding requirement to satisfy the expectations and demand for new STEDS, and also the replacement and upgrading of existing schemes. In some townships treated effluent is already being used for oval watering and there is potential for more reuse in these areas.

## A6.3 STORMWATER SERVICES

Stormwater is an inevitable by-product of urban development. As well as the water supply and health problems, the issue of drainage had to be addressed as the roads were often riddled with bog patches (Hammerton 1986). The combination of horse drawn traffic and unsealed roads meant that urban runoff was highly polluted (Clark *et al.* 1997). Because alternative sources of better quality water where readily available stormwater was traditionally deemed a nuisance without value and drains were constructed, discharging the stormwater as cheaply and efficiently as possible beyond urban boundaries (Clark *et al.* 1997; Newman & Mouritz 1992; Fleming 1999; Langford 2003).

At this time, local councils managed the stormwater. South Australia's wastewater system is managed completely separately from the stormwater system, which caters for rainfall run-off from roads, roofs and gutters (SA Water 1999d). It is apparent that the responsibility for stormwater management in Adelaide falls between State and Local Government with an unclear boundary. It is also evident that the State

Government has a strategic interest in stormwater management, and that the transition in thinking from nuisance to resource will only occur if the State Government provides the lead (GSA 1999).

There is increasing recognition that major drainage systems offer significant environmental and economic opportunities within a catchment management framework. Treatment of stormwater in wetlands and storage in groundwater aquifers are two relatively new technologies which can assist reuse of stormwater (GSA 1999).

## A6.4 IRRIGATION SERVICES

The history of irrigation in South Australia is largely the history of irrigation in Australia, that is, a form of security to protect against the variability of the Australian climate. The earliest developments were by individual farmers in numerous locations in all of the original colonies (MDBC 1997), such as along the River Murray in South Australia. The earliest method of watering orchards and vineyards was by furrow irrigation. Together with some early attempts at group or collective schemes, they provided indications of what might be possible with irrigation. Out of these came the support of the colonial governments for the establishment of irrigation as a means of encouraging people to settle in inland Australia. Of particular note was the role of the South Australian and Victorian governments in supporting the Chaffey Brothers in founding Renmark and Mildura irrigation settlements (MDBC 1997).

Renmark was one of the first irrigation settlements established by the Chaffey Brothers in 1887, with the support of the South Australian government (Hammerton 1986). Financial difficulties resulted in the operations being transferred to the Renmark Irrigation Trust in 1893, which along with Mildura is one of the oldest of the privately operated irrigation schemes in Australia (Hammerton 1986). During this time, however, there was little knowledge about crops' water requirements. As there was initially no shortage of water, the volume applied was very much a matter of trial and error (AATCE 1988).

The South Australian government established a number of communal village settlements along the Murray in 1894, of which Lyrup is the sole survivor (MDBC 1997). After World War I, a number of soldier settlement schemes were established in South Australia, such as Berri, Cadell, Cobdogla, Ral Ral and Waikerie. Many of these were expansions of earlier small developments, which also included Kingston and Moorook (MDBC 1997). Between 1948 and 1955, further irrigation areas were established by the Commonwealth Government as War Service Land Settlement Schemes in the Riverland, such as Cooltong, Loveday and Loxton in South Australia (MDBC 1997). Apart from group schemes, there are small irrigation operation farmers throughout who pump their own water directly from rivers. The irrigation schemes established and run by state government agencies have been the dominant component of the irrigation industry (MDBC 1997).

The privately operated irrigation schemes range from the long established Renmark and Mildura Irrigation Trusts to a number of schemes of varying sizes, most of which date from the 1960s. Many of them are located along the South Australian section of the River Murray (MDBC 1997). In the Riverland region water has to be lifted from the river by pumping as they are located on "high land" sandy mallee soils, well above the level of the River Murray. Along with the Loveday Division of the Cobdogla Irrigation Area (near Renmark), Loxton was the first to use overhead sprinklers which made the scheme possible (MDBC 1997). This partly explains the emphasis in these irrigation areas on higher value horticultural crops in this region. Along the lower reaches of the Murray in South Australia, meanwhile, former swamp and wetland areas have been drained and used for pasture and fodder production. Being below the level of the river, these areas are flood irrigated. The region supports a major part of the South Australian dairy industry, particularly for the supply of fresh milk to Adelaide (MDBC 1997).

Irrigation still plays an important role in South Australia's economy and currently accounts for 80% of water use in South Australia. Since the early 1970s South Australia has taken a leading role nationally, by encouraging efficient irrigation water use as part of a total property management planning approach. As a result South Australian irrigators are amongst the most efficient in Australia and in many areas of the State grow predominantly high value crops. For example, typical farm gate returns per ML of water used in South Australia range from $5000/ML for apples, $1500/ML for potatoes, $1000/ML for grapes and $750/ML for olives, compared with returns of $400/ML for cotton and $200/ML for rice grown in upstream States (GSA 1999).

The South Australian government is proud of the State's record in producing high value crops and efficient irrigation practices (GSA 1999). However, in some parts of the State, especially the South East, large volumes of water continue to be used for irrigation of pasture with returns typically about $200/ML (GSA 1999). Interestingly, here the State government argues that pasture irrigation is the most effective use of the available water given the nature of the agricultural enterprises in the region and in some cases the quality of the water in those districts. Clearly, there is potential to increase returns through use of higher value crops in these areas.

Admittedly, some of the water resources used for irrigation are of poorer water quality and are not suitable for use on higher value (often salt sensitive) crops. The significance of salinity in water resources is in terms of the intended use. As the salinity level exceeds 800EC, irrigation management becomes increasingly difficult and at 1,500 EC options become limited. At this level, susceptible crops cannot be grown and direct adverse biological affects are likely to occur in river land wetlands (Blackmore *et al.* 2002). Two interrelated problems land and water salinisation threaten the viability of irrigated agriculture in South Australia which (Thompson 1996). Policy and management responses to tackle this issue, supported by major funding programs from Commonwealth and State governments, have been in place for 20 years. During the mid-1990s, the state government moved out of the operation (and in some cases the ownership) of most of the irrigated schemes as part of the COAG water reform (discussed separately in Appendix 2).

# Appendix 7
# Water Resources of South Australia

South Australia has a State Water Plan that sets out the policies for achieveing the objectives of the *Water Resources Act* 1997. The information contained in this Appendix is an inventory of the water resources and issues according to the water management regions set out in the State Water Plan (SWP) as shown in Figure 44.

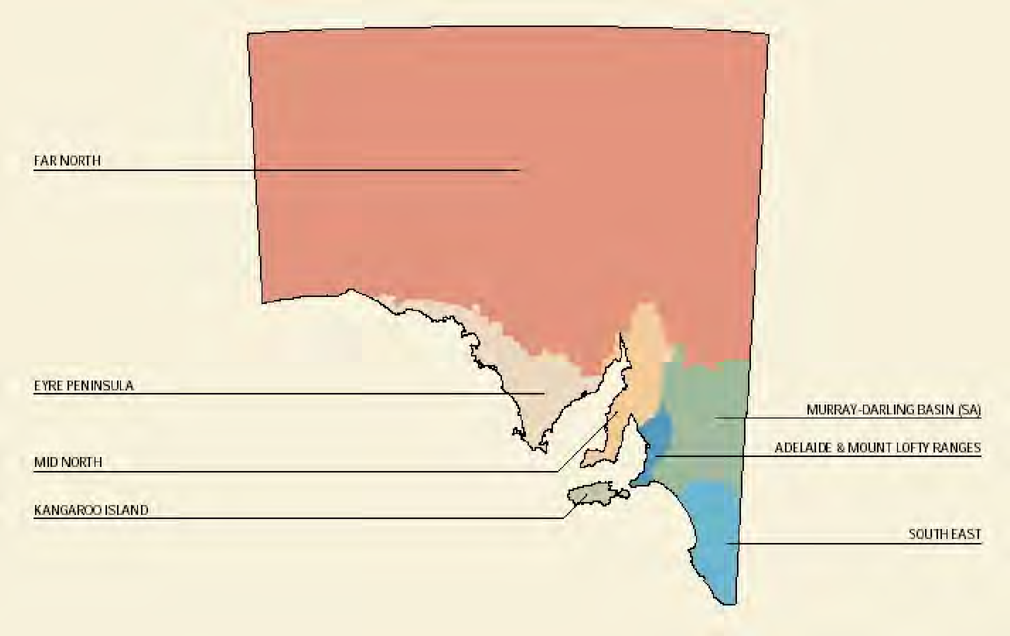


**Figure 44State Water Resources Management Regions (SWP 2000)**

In the sections that follow, a summary of the quantity and level of use for the major water resources for each region are provided.

## A7.1 ADELAIDE AND MOUNT LOFTY RANGES REGION

The Adelaide Region with the surrounding Mount Lofty Ranges is the most intensively settled area of the State. The region is of significance for agricultural production, given the close proximity to Adelaide, the productive nature of the landscape and the availability of water. It is estimated that the value of agricultural commodities produced is $250 million per year (GSA 2000). Both surface and groundwater are used for irrigation, stock and domestic supply. Table 60 below shows the use limits and current levels of use for the region as a whole.

**Table 60 Adelaide & Mt. Lofty Ranges Region Water Quantity Limits & Use**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| Surface water resources (SR) | 84 (1) | 130 (2) |
| Groundwater resources (GW) | 74 | 61 |
| Stormwater resources (SW) | 110 | 21 |
| Treated Effluent (TE) | 79 | 17 |
| Total - Regional Estimate (rounded) | 350 | 230 |
| River Murray Surface water – imported (RM) (3) | 130 (4) | 110 |

Notes:
(1) Surface resources use limit has been derived using the standard methodology applied to all SR figures in the SWP. On this basis, use exceeds use limit.
(2) The bulk of the SR use is water extracted from local catchments for Adelaide water supply. Environmental water needs have not been assessed for this region.
(3) RM water is imported into this region to supplement local water supply systems.
(4) The use limit for RM is the nominal annual cap.

*Source: State Water Plan (2000)*

The uses of water resources within the Mount Lofty Ranges include (GSA 2000):

- drinking water supplies for metropolitan Adelaide,
- bottled water supply,
- agriculture industries (both stock and irrigated horticulture),
- recreation and rural living, and
- water for the environment.

The Mount Lofty Ranges catchment areas are a major source of Adelaide's reticulated water supplies. Water collected within the Mount Lofty Ranges contributes a significant component (approximately 60% in an average year) of the total supply needs of Adelaide (GSA 2000). This is augmented with water from the River Murray which can supply up to 90% of the State's water needs in drought years. Surface water quality has deteriorated because of urban development and intensive land use. Rapid expansion of irrigation has increased development of farm dams and groundwater extractions.

## A7.2 MURRAY-DARLING BASIN REGION

The region consists of the catchments of the River Murray within South Australia. Almost all the surface water originates in the upstream States of Victoria, New South Wales and Queensland. The region supports significant South Australian economic activity based on irrigation, farming and tourism. The total irrigated area is approximately 55,000 ha, of which two thirds is in the Riverland area above Blanchetown (GSA 2000). More than 70% of the economic activity is based on the irrigation industry which, together with tourism, generates nearly $750m per annum (GSA 2000). The river is central to the social and economic development of the

State and region (GSA 1999). Table 61 below shows the water balance in the Murray-Darling Basin Region.

**Table 61 Murray-Darling Basin (SA) Water Quantity Summary**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| River Murray Surface water (RM) | 704 (1) | 600 |
| Surface water resources (SR) | 22 | 4 |
| Groundwater resources (GW) | 67 | 27 |
| Stormwater resources (SW) | 4 | <1 |
| Treated Effluent (TE) | 4 | 1 |
| Region Estimate (rounded) | 800 | 630 |

*Source: State Water Plan (2000)*

(1) The RM use limit is the maximum permissible under the River Murray Cap

The River Murray has long been South Australia's primary water resource. It provides water to over 90% of the State's population and is the major source of surface water for significant irrigation undertakings (GSA 1999). Adelaide is not in the Murray-Darling Basin, but water piped from the Murray typically supplies about half of Adelaide’s water needs. Adelaide is therefore able to present itself as an English-style city of roses and churches, despite being the capital of the driest state in the world’s second driest continent (Marohasy 2003). In dry years, the reliance on the River Murray water can increase to as much as 90% of needs.

In accordance with the Murray-Darling River Basin Agreement, at least 1850 GL per year flows into South Australia, except in years of serious water shortage. Shortages are expected to occur in less than one year in twenty. Median flow to sea, important to sustaining the Coorong, has been reduced to a fifth of the natural rate mostly as a result of regulation of the river and irrigation development in upstream States (GSA 1999). Appendix 4 contains a discussion of these changes.

Water use from the River Murray has been limited to licensed allocations since 1968 with most of the water devoted to irrigation and reticulated water supply. Allocations can be bought, leased and amalgamated in water allocation transfer market, subject to conditions to promote sustainable use of the water. Prices paid for permanent transfer of water allocations have typically increased from up to $500/ML a decade ago to $1500-$2000/ML more recent years, indicating water is much more highly valued now (GSA 1999).

River salinity is an issue. An increased withdrawal of water mainly for irrigation has reduced the dilution of natural salt inputs (GSA 1999). Salinity mitigation schemes throughout the basin have been constructed, but an underlying gradual increase continues (GSA 1999). Recent studies also indicate that increases in salinity in the River Murray over the next 50 to 100 years will be greater than previously expected due to the impact of spreading dryland salinity in the upper catchments of the Basin. Salinity at Morgan, for example is expected to rise by 200EC units over the next 50 years if no action is taken (GSA 1999).

The Angas-Bremer groundwater resource is fully allocated. River Murray water transferred into the area is replacing groundwater use and enabling development to occur. As previously over-committed groundwater resources have recovered, water logging in low lying areas has emerged as a management issue (GSA 1999).

## A7.3 SOUTH EAST REGION

The unconfined and confined groundwater resources of the South East provide South Australia's largest volume of water available for economic development, with a total of 1180GL per year being potentially available on a sustainable basis. About 280GL per year is extracted from the twin aquifer system supporting a rapidly expanding irrigation industry, reticulated supplies for towns and independent supplies for domestic and stock water (GSA 1999).

**Table 62 South East Region Water Quantity Summary**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| Surface water resources (SR) | 85 | 0 |
| Groundwater resources – unconfined (GWU) | 1010 | 250 |
| Groundwater resources – confined (GWC) | 140 | 26 |
| Stormwater resources (SW) | 5 | 2 |
| Treated Effluent (TE) | 4 | <1 |
| Region Estimate (rounded) | 1240 | 280 |

*Source: State Water Plan (2000)*

Throughout the region the unconfined aquifer is the primary resource used supporting 90% of extractions. The often shallow water table and the quantities available make this resource accessible to many of the water users. The quality of the unconfined aquifer varies significantly through the area. In the south, groundwater is abundant, fresh and near the surface. However, salinity increases progressively to marginal and brackish to the north and west of this region (GSA 1999).

In comparison the confined aquifer contains high quality water. Poorly constructed or maintained wells have been identified as being possible sources of contamination with water from the generally poorer quality upper aquifer. Due to the higher quality of water, the lower yields and higher costs for access, use of this aquifer has generally been reserved for high return activities such as town water supplies and industrial use. Where the upper aquifer is unsuitable for irrigation the lower aquifer has been accessed for irrigation (GSA 1999). The yield of this aquifer is estimated to be 10% of the upper aquifer. The majority of the groundwater resources in the South East region are prescribed within five distinct areas as they are full allocated. Groundwater in the north western area of this region is considered unsuitable for most irrigation activities due to the high salinity levels. Land salting has been an increasing problem in the north of the region (GSA 1999).

Irrigation activities account for over 90% of consumptive water use, the remainder for industrial, recreational or environmental purposes. Irrigation is not metered and allocations are based on the area of crops grown. Usage is determined from an estimated water requirement for each crop, irrespective of the actual water applied (GSA 1999). In practical terms, the water resources of the Naracoorte Ranges, Padthaway, and Tatiara prescribed areas, are fully allocated. However, throughout these areas it is estimated that less than two thirds of the allocated water is actually used. A transfer market for water licenses is available and allows water to be bought and sold for new developments.

The region has experienced rapid development and significant changes in the land use and land management practices. Vineyards and other higher value crops have replaced irrigated pasture, bringing improved irrigation management. The South East Catchment Water Management Board was established in 1988. Its present focus is to develop water allocation plans for the five prescribed areas in the region. When this has progressed, it will turn its attention to a comprehensive Catchment Water Management Board and its implementation (GSA 1999).

Natural surface drainage is limited in this region because of flat terrain and this is reflected by numerous wetlands throughout the area. Over the last 50 years an extensive artificial drainage system has been constructed and has enabled vast wetlands to be used for primary production. The South East Drainage Board continues to manage the region's extensive drainage scheme (GSA 1999).

## A7.4 MID NORTH REGION

Local water resources in the north Mount Lofty Ranges and the southern Flinders Ranges have been developed for small-scale irrigation and to supplement dry land farming. Water from the SA Water is piped from the River Murray to Whyalla, Port Pirie and Port Augusta and to other regional areas to supplement irrigation storages (SA Water 1999d). Rapid expansion of vineyards and associated development is placing stress on the available water resources in Clare Valley and neighbouring areas. Table 63 below shows the water balance in the Mid North Region.

**Table 63 Mid North Region Water Quantity Summary**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| Surface water resources (SR) | 12 | 5 |
| Groundwater resources (GW) | 15 (1) | 12 |
| Stormwater resources (SW) | 4 | <1 |
| Treated Effluent (TE) | 9 | 1 |
| Region Estimate (rounded) | 40 | 20 |

*Source: State Water Plan (2000)*

(1) The groundwater use limit for the Clare Valley Prescribed Water Resources Area is not included in the regional total as it is under assessment.

The majority of groundwater resources within the Mid North are found in fractured rock aquifers which are scattered, highly variable and dependent on local recharge. The aquifers in the area have a low yield and their storage capacity is variable. The salinity of the groundwater ranges from 500mg/L to 7000mg/L. Large-scale irrigation takes place in the Clare Valley and in 1996 it was prescribed to protect the water resources (GSA 2000).

## A7.5 FAR NORTH REGION

The region is predominantly used for pastoral activities, mining, tourism, nature conservation and large areas of land to the north and west have been granted to Aboriginal people. Approximately 55% of the region is devoted to pastoralism with 331 pastoral leases being divided among 220 stations. Mining is significant, particularly at Olympic Dam and Roxby Downs where copper, uranium and other minerals are mined. Natural gas is extracted at Moomba and Gidgealpa and coal from an open cut mine at Leigh Creek. Opal is mined at Coober Pedy, Andamooka and Mintabie (GSA 1999a).

Table 64 below shows the current levels of use for the region as a whole and for the Great Artesian Basin, which is the most significant water resource in the region.

The Far North supports a range of important waterways, mound springs and wetlands. Although arid areas of the State can have significant surface water resources, their potential for development requires new methods of harvesting, treatment and storage such as aquifer storage and recovery, sealed catchments, desalination and rainwater tanks (GSA 2000). Most arid streams are turbid through natural processes. At Innamincka very deep waterholes provide a reliable supply from the Cooper Creek (GSA 1999a). Because of the high variability of the region's surface waters the Great Artesian Basin (GAB) is used as a reliable supply for townships, grazing and mining.

**Table 64 Far North Region Water Quantity Summary**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| Surface water resources (SR) | Highly Variable | Not Assessed |
| Groundwater resources (GW) | 110 | 76 |
| Stormwater resources (SW) | <1 | <1 |
| Treated Effluent (TE) | 18 | <1 |
| Region Estimate (rounded) | 130 | 80 |

*Source: State Water Plan (2000)*

Notwithstanding the large quantities of available groundwater in the GAB, current extraction rates through artesian bores are unsustainable and aquifer pressures have declined in a number of regions throughout the basin (GSA 1999a). Natural outflows from mound springs are estimated to have declined by 30% over the last 100 years and some have ceased to flow altogether. As a result, many free-flowing bores have been capped over the past 23 years (GSA 1999a). Groundwater quality in the region is variable. However water in artesian aquifers underlying half of the region has a TDS concentration of less than 1000 mg/L and is suitable for all classes of stock and domestic purposes (GSA 1999a) despite being hot (up to 98°Celsius) when it emerges from bores. The cost of developing water resources is relatively high and the resulting drop in well pressure is increasing these costs and may restrict future use (GSA 1999a).

## A7.6 EYRE PENINSULA REGION

Development of Eyre Peninsula has been closely allied to the availability of water (GSA 1999a). A lack of surface water limited early settlement of Eyre Peninsula. The introduction of the Water Conservation Act 1936 was recognition of the importance of securing supplies and this was attempted through a system of bores, tanks, wells and small reservoirs (GSA 1999a). The scheme did not supply adequate water for the growing population and a more reliable scheme was subsequently developed with a reservoir using the Tod River and tapping into various groundwater basins (GSA 1999a).

Many of the region's water sources are isolated and small, which imposes difficulties on determination of sustainable levels of use and potentially exposes the resource to overuse and consequent degradation (GSA 1999a). The spatial distribution of the water resources and the small scattered population has led to high operating costs throughout the region. Table 65 below shows the water balance in the Eyre Peninsula Region.

**Table 65 Eyre Peninsula Region Water Quantity Summary**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| Surface water resources (SR) | 4 (1) | 3 (1) |
| Groundwater resources (GW) | 37 | 12 |
| Stormwater resources (SW) | 1 | <1 |
| Treated Effluent (TE) | 1 | <1 |
| Region Estimate (rounded) | 40 | 20 |

*Source: State Water Plan (2000)*

(1) Surface water tesource estimate is based on catchment yield analysis. Rainfall is spatially and temporally dispersed. Avaialbility can not be guaranteed for use.

Annual rainfall in the region ranges from 200mm to 500mm and occurs mostly during the winter months. Surface drainage is not well developed and there are few useful surface water resources (GSA 1999a). The major surface water development is a water supply system based on a reservoir that is provided with water from the Tod River catchment. The salinity of this resource is highly variable and the fresher groundwater resources of the region are used to reduce the salinity to acceptable levels (GSA 1999a). The Yeldulknie, Ullabindinie and Ulbana reservoirs constructed in the 1900s have been abandoned as sources of domestic water because of poor quality, siltation and low yield. They are still used for stock watering, recreational and environmental purposes (GSA 1999a).

Groundwater predominates in the west and south coasts where rainfall is highest and thin soils over limestone allow high recharge to aquifers. The water occurs in thin unconfined freshwater lenses that are delineated either by geographical features or adjacent waters of higher salinity (GSA 1999a). Groundwater levels decline as a result of natural discharge and water supply extraction. The availability of water from the freshwater lenses is very dependent on the rate of recharge during the previous season. Several communities on the Eyre Peninsula are supplied from these freshwater lenses (GSA 1999a).

There are two prescribed well areas (PWA) in the region, these being Southern Basins PWA and County Musgrave PWA. Both were prescribed in 1987. This was done with the specific objective of conserving the groundwater resources for public water supply and stock and domestic use. Almost all water extracted from these basins is used by SA Water for reticulated water supplies. SA Water is exempt from licensing (GSA 1999a). Drawdown of the watertable could affect vegetation condition and the viability of springs. Dryland salinisation is estimated to affect 50,000 hectares on Eyre Peninsula and is increasing (GSA 1999a). Aquifers are shallow and are recharged from local sources, which places them at risk of pollution from surface-based activities that are not carefully managed (GSA 1999a).

An estimated 30% of the rural population relies solely on rainwater, private surface water collection and/or groundwater for their domestic and stock supplies (GSA 1999a). The current use of alternative reuse water supplies from stormwater and more efficient use of water supplies has permitted further development of the township. For example, a management program at Streaky Bay in 1982 resulted in a 23% reduction in annual water use (GSA 1999a). Innovative approaches to small local water resources, alternative supplies and effluent reuse can provide limited local water supplies. Additional supplies of saline and brackish water are available from Tertiary sediments of the Polda Trough (GSA 1999a).

## A7.7 KANGAROO ISLAND REGION

Kangaroo Island has an area of 4350 square kilometres with steep cliffs on the north coast and a central plateau, while the southern coastline is dominated by sand dunes. The northern edge has a significant stream network from which domestic water supplies are collected (GSA 1999a). South Australia's first official settlement was in 1836 at Nepean Bay (now Kingscote) which was all but abandoned soon after settlement due to poor soils and lack of water (GSA 1999a).

After World War II, the War Service Settlement Scheme (up to 1962) resulted in 174 new farms, and a new town Parndarna. During the first ten years of the scheme 70% more land was cleared than in the previous 100 years. Salinity and waterlogging problems quickly developed after the massive clearing program (GSA 1999a). Between 1982 and 1991, there was a 27% decrease in the number of farms and 25% of the island was dedicated to conservation. Other uses include sheep, dairies, aquaculture, cropping (canola and grains) and viticulture (GSA 1999a).

**Table 66 Kangaroo Island Region Water Quantity Summary**

| Water Resource | Use Limit GL/y | Use GL/y |
|---|---|---|
| Surface water resources (SR) | 16 | <1 |
| Groundwater resources (GW) | <1 | Not Assessed |
| Stormwater resources (SW) | <1 | 0 |
| Treated Effluent (TE) | <1 | <1 |
| Region Estimate (rounded) | 20 | 1 |

*Source: State Water Plan (2000)*

Kingscote and Parndana derive water from a reservoir at Middle River. In the past, Penneshaw's water requirement was met by two privately owned dams operated by SA Water. However, these have now been taken out of commission due to the installation of a new seawater desalination plant. The rest of the island’s rural settlements derive their water from dams and rainwater tanks (GSA 1999a). Clearing of land for agricultural activities has led to extensive and severe dryland salinity. Salinisation has also affected stream conditions (GSA 1999a). Water supply to industries is a limiting factor in development, both for water quality and infrastructure (Kingscote abattoir). Aquaculture is a developing industry and is an opportunity for economic growth (GSA 1999a).

The Kangaroo Island Integrated Catchment Water Management Group is monitoring to determine the extent and source of elevated nutrients in Nepean Bay. One action has seen the establishment of a community-operated gauging station on the Cygnet River. The gauge will continuously monitor flow and random grab samples will be taken to determine nutrient levels (GSA 1999a). Dry land salinity continues to spread and water supplies are limited due to declining water quality (GSA 1999a). Large-scale revegetation will move toward re-establishing the water balance and minimise effects of salinisation (GSA 1999a).

# Appendix 8

# Average Monthly Rainfall Data for Towns in South Australia

Table 67 presents an alphabetical listing of the ‘*average monthly and annual rainfall*’ for 220 towns in South Australia developed Kevin Burrows of the Bureau of Meteorology in 1987. The information provides an understanding of the prevailing pattern of rainfall, however, it should be noted that the actual rainfall can deviate widely from the average monthly and annual figures. Variability is measured by the ‘coefficient of variation’ which is statistical measure of the standard deviation to the mean. In South Australia the coefficient range for rainfall is 0.2 to 0.8 (EWS 1987).

**Table 67 Average Monthly Rainfall Data for Towns (Burrows 1987)**

**Estimated Average Monthly Rainfall (mm)**

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adelaide | 20 | 21 | 24 | 44 | 68 | 72 | 67 | 62 | 51 | 45 | 31 | 26 | **531** |
| Alawoona | 19 | 20 | 14 | 21 | 31 | 28 | 30 | 29 | 27 | 29 | 20 | 16 | **284** |
| Aldinga | 17 | 19 | 22 | 40 | 63 | 73 | 69 | 60 | 54 | 42 | 26 | 21 | **506** |
| American River | 17 | 19 | 16 | 39 | 60 | 79 | 86 | 72 | 54 | 39 | 25 | 21 | **527** |
| Andamooka (Est) | 22 | 25 | 17 | 14 | 20 | 15 | 13 | 14 | 14 | 19 | 13 | 21 | **207** |
| Angaston | 21 | 23 | 23 | 45 | 64 | 71 | 69 | 71 | 62 | 51 | 34 | 27 | **561** |
| Appila | 19 | 20 | 19 | 29 | 38 | 42 | 40 | 43 | 42 | 38 | 28 | 25 | **383** |
| Ardrossan | 14 | 17 | 16 | 30 | 41 | 43 | 40 | 43 | 36 | 32 | 22 | 17 | **351** |
| Arno Bay | 12 | 20 | 16 | 26 | 35 | 38 | 37 | 36 | 35 | 30 | 21 | 19 | **325** |
| Auburn | 26 | 25 | 26 | 45 | 69 | 74 | 75 | 76 | 68 | 53 | 36 | 27 | **600** |
| Balaklava | 19 | 20 | 18 | 34 | 44 | 44 | 43 | 44 | 40 | 36 | 24 | 20 | **386** |
| Barmera | 17 | 19 | 12 | 18 | 23 | 21 | 23 | 19 | 22 | 27 | 21 | 15 | **237** |
| Beachport | 23 | 22 | 31 | 67 | 76 | 99 | 119 | 106 | 74 | 53 | 44 | 32 | **746** |
| Berri | 19 | 19 | 12 | 22 | 27 | 20 | 25 | 24 | 28 | 32 | 25 | 16 | **269** |
| Birdwood | 26 | 24 | 26 | 55 | 82 | 100 | 101 | 100 | 82 | 64 | 38 | 31 | **729** |
| Blackrock | 19 | 18 | 15 | 19 | 31 | 34 | 30 | 36 | 32 | 27 | 24 | 21 | **306** |
| Blanche Town | 17 | 18 | 16 | 23 | 28 | 25 | 23 | 25 | 23 | 27 | 19 | 17 | **261** |
| Blyth | 20 | 20 | 18 | 34 | 51 | 52 | 49 | 50 | 47 | 40 | 26 | 23 | **430** |
| Booborowie | 19 | 23 | 15 | 30 | 48 | 45 | 55 | 55 | 47 | 43 | 28 | 21 | **429** |
| Boolero Centre | 21 | 21 | 17 | 27 | 40 | 47 | 42 | 45 | 40 | 37 | 27 | 23 | **387** |
| Borda | 16 | 18 | 23 | 47 | 81 | 110 | 105 | 87 | 55 | 43 | 27 | 21 | **633** |
| Bordertown | 21 | 23 | 20 | 40 | 53 | 58 | 57 | 57 | 53 | 45 | 34 | 28 | **489** |
| Bridgewater | 31 | 30 | 37 | 79 | 128 | 153 | 154 | 145 | 111 | 88 | 50 | 40 | **1046** |
| Brinkworth | 18 | 22 | 17 | 29 | 46 | 50 | 47 | 49 | 44 | 38 | 26 | 22 | **408** |
| Bruce | 18 | 19 | 13 | 15 | 26 | 30 | 25 | 27 | 24 | 25 | 21 | 20 | **263** |
| Buckleboo | 21 | 21 | 14 | 20 | 32 | 31 | 36 | 36 | 33 | 28 | 25 | 18 | **315** |
| Bundaleer | 23 | 23 | 20 | 37 | 59 | 71 | 70 | 71 | 64 | 54 | 34 | 27 | **553** |
| Bute | 17 | 20 | 17 | 32 | 46 | 53 | 48 | 47 | 41 | 36 | 24 | 18 | **399** |
| Caliph | 22 | 21 | 15 | 23 | 30 | 26 | 28 | 30 | 25 | 32 | 22 | 19 | **293** |
| Callington | 20 | 19 | 19 | 30 | 38 | 42 | 41 | 43 | 41 | 36 | 25 | 21 | **375** |
| Ceduna | 10 | 17 | 18 | 21 | 41 | 34 | 39 | 36 | 29 | 26 | 23 | 18 | **312** |
| Clare | 26 | 25 | 25 | 48 | 75 | 80 | 81 | 78 | 72 | 58 | 36 | 29 | **633** |
| Claredon | 27 | 26 | 35 | 71 | 100 | 118 | 110 | 104 | 84 | 67 | 43 | 36 | **821** |
| Claypans | 19 | 22 | 17 | 25 | 31 | 27 | 31 | 30 | 29 | 33 | 22 | 20 | **306** |

### Estimated Average Monthly Rainfall (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cleve | 16 | 24 | 19 | 30 | 41 | 46 | 45 | 48 | 43 | 37 | 28 | 22 | **399** |
| Cockburn | 19 | 18 | 15 | 16 | 22 | 19 | 13 | 14 | 15 | 19 | 18 | 17 | **205** |
| Coober Pedy (Est) | 18 | 25 | 11 | 7 | 15 | 14 | 7 | 10 | 9 | 16 | 12 | 13 | **157** |
| Cook | 10 | 13 | 16 | 16 | 14 | 18 | 12 | 15 | 12 | 17 | 15 | 14 | **172** |
| Cooke Plains | 17 | 20 | 20 | 30 | 40 | 45 | 41 | 44 | 41 | 37 | 26 | 23 | **384** |
| Coomandook | 17 | 21 | 21 | 30 | 49 | 51 | 50 | 50 | 44 | 41 | 30 | 24 | **428** |
| Coonalpyn | 20 | 20 | 21 | 37 | 50 | 54 | 54 | 55 | 48 | 44 | 30 | 24 | **457** |
| Copeville | 16 | 21 | 16 | 21 | 31 | 30 | 29 | 31 | 31 | 30 | 22 | 20 | **298** |
| Corny Point | 13 | 17 | 15 | 36 | 54 | 67 | 66 | 59 | 43 | 33 | 23 | 18 | **444** |
| Cowell | 14 | 20 | 17 | 27 | 31 | 29 | 25 | 27 | 28 | 28 | 20 | 16 | **282** |
| Cradock | 20 | 22 | 15 | 19 | 26 | 34 | 35 | 27 | 24 | 22 | 20 | 19 | **283** |
| Crystal Brook | 19 | 21 | 17 | 32 | 43 | 50 | 45 | 46 | 43 | 40 | 26 | 22 | **404** |
| Cummins | 10 | 16 | 13 | 26 | 52 | 64 | 73 | 63 | 45 | 33 | 22 | 18 | **435** |
| Curramulka | 15 | 17 | 18 | 34 | 50 | 60 | 57 | 54 | 45 | 38 | 23 | 19 | **430** |
| Darke Peak | 14 | 23 | 14 | 26 | 42 | 49 | 48 | 52 | 44 | 33 | 24 | 21 | **390** |
| Denial Bay | 8 | 18 | 18 | 22 | 39 | 42 | 42 | 43 | 26 | 24 | 20 | 17 | **319** |
| Edithburgh | 14 | 17 | 17 | 34 | 50 | 58 | 56 | 53 | 42 | 34 | 23 | 18 | **416** |
| Elliston | 10 | 14 | 15 | 28 | 55 | 75 | 71 | 60 | 39 | 30 | 20 | 15 | **432** |
| Ernabella | 41 | 35 | 25 | 20 | 20 | 17 | 13 | 15 | 11 | 24 | 22 | 29 | **272** |
| Eudunda | 21 | 22 | 20 | 33 | 47 | 51 | 50 | 55 | 47 | 41 | 29 | 24 | **440** |
| Eurelia | 22 | 20 | 16 | 21 | 33 | 36 | 33 | 38 | 31 | 29 | 26 | 20 | **325** |
| Farrell Flat | 22 | 21 | 18 | 35 | 54 | 59 | 58 | 62 | 54 | 44 | 27 | 24 | **478** |
| Fowlers Bay | 8 | 12 | 13 | 22 | 42 | 52 | 43 | 37 | 22 | 21 | 16 | 11 | **299** |
| Frances | 21 | 24 | 24 | 39 | 55 | 59 | 63 | 64 | 57 | 51 | 36 | 28 | **521** |
| Freeling Railway | 20 | 21 | 19 | 37 | 51 | 55 | 53 | 56 | 49 | 42 | 28 | 24 | **455** |
| Gawler Railway | 19 | 17 | 24 | 44 | 57 | 65 | 56 | 57 | 51 | 43 | 28 | 22 | **483** |
| Georgetown | 20 | 22 | 19 | 36 | 52 | 57 | 56 | 57 | 53 | 46 | 30 | 24 | **472** |
| Geranium | 18 | 23 | 20 | 30 | 45 | 43 | 45 | 49 | 43 | 39 | 28 | 24 | **407** |
| Gladstone | 20 | 20 | 18 | 32 | 43 | 48 | 48 | 49 | 47 | 41 | 30 | 23 | **419** |
| Glen Osmond | 24 | 21 | 24 | 54 | 79 | 89 | 86 | 76 | 63 | 54 | 35 | 29 | **634** |
| Glenelg | 17 | 19 | 21 | 37 | 58 | 61 | 57 | 54 | 45 | 38 | 27 | 22 | **456** |
| Goolwa | 20 | 20 | 22 | 38 | 55 | 60 | 60 | 54 | 48 | 39 | 28 | 21 | **465** |
| Greenock | 22 | 23 | 22 | 46 | 61 | 64 | 64 | 68 | 60 | 51 | 32 | 26 | **539** |
| Gulnare | 21 | 24 | 16 | 32 | 52 | 57 | 57 | 57 | 52 | 44 | 32 | 24 | **468** |
| Hallet | 18 | 21 | 17 | 30 | 48 | 54 | 55 | 55 | 54 | 43 | 30 | 23 | **448** |
| Hamely Bridge | 20 | 20 | 18 | 35 | 47 | 51 | 49 | 50 | 45 | 40 | 27 | 24 | **426** |
| Hammond | 17 | 18 | 15 | 19 | 26 | 30 | 26 | 30 | 26 | 24 | 19 | 19 | **269** |
| Hawker | 20 | 20 | 15 | 20 | 32 | 41 | 33 | 33 | 27 | 23 | 23 | 19 | **306** |
| Hoyleton | 21 | 19 | 19 | 37 | 51 | 53 | 53 | 55 | 49 | 42 | 28 | 23 | **450** |
| Inman Valley | 29 | 29 | 26 | 66 | 90 | 98 | 108 | 97 | 75 | 65 | 40 | 31 | **754** |
| Iron Knob | 17 | 23 | 13 | 15 | 21 | 19 | 20 | 19 | 21 | 21 | 15 | 15 | **219** |
| Jamestown | 21 | 21 | 19 | 32 | 47 | 54 | 55 | 56 | 52 | 46 | 34 | 27 | **464** |
| Kadina | 15 | 19 | 20 | 35 | 49 | 51 | 48 | 45 | 38 | 34 | 22 | 18 | **394** |
| Kapunda | 21 | 21 | 23 | 39 | 56 | 58 | 59 | 61 | 54 | 47 | 30 | 25 | **494** |
| Karoonda | 17 | 21 | 15 | 25 | 37 | 35 | 33 | 37 | 35 | 33 | 24 | 22 | **334** |
| Keith | 19 | 23 | 21 | 35 | 55 | 52 | 54 | 57 | 51 | 45 | 32 | 26 | **470** |
| Kimba | 16 | 23 | 15 | 24 | 37 | 39 | 41 | 42 | 36 | 31 | 23 | 18 | **345** |
| Kingscote | 15 | 17 | 18 | 36 | 59 | 73 | 77 | 64 | 46 | 36 | 24 | 19 | **484** |
| Kingston SE | 20 | 19 | 24 | 47 | 73 | 88 | 91 | 76 | 59 | 45 | 31 | 29 | **602** |
| Koolunga | 19 | 21 | 16 | 29 | 44 | 47 | 45 | 46 | 41 | 37 | 25 | 22 | **392** |
| Kyancutta | 13 | 18 | 13 | 20 | 37 | 40 | 42 | 41 | 33 | 27 | 24 | 19 | **327** |
| Kybybolite | 23 | 25 | 25 | 41 | 58 | 59 | 70 | 67 | 61 | 51 | 37 | 31 | **548** |
| Lameroo | 20 | 24 | 19 | 28 | 43 | 41 | 41 | 43 | 43 | 39 | 27 | 23 | **391** |
| Langhorne Creek | 19 | 20 | 21 | 33 | 42 | 44 | 43 | 43 | 39 | 37 | 27 | 23 | **391** |
| Laura | 21 | 22 | 19 | 35 | 47 | 55 | 53 | 54 | 53 | 45 | 30 | 23 | **457** |
| Leigh Creek (#) | 28 | 24 | 8 | 16 | 21 | 16 | 17 | 18 | 17 | 14 | 11 | 18 | **208** |

### Estimated Average Monthly Rainfall (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lenswood (DOA) | 44 | 39 | 48 | 92 | 117 | 120 | 148 | 138 | 116 | 89 | 49 | 40 | **1040** |
| Lochiel | 15 | 21 | 15 | 27 | 45 | 45 | 43 | 46 | 43 | 36 | 25 | 20 | **381** |
| Lock | 13 | 19 | 15 | 24 | 46 | 54 | 56 | 56 | 42 | 33 | 25 | 21 | **404** |
| Loxton | 18 | 22 | 16 | 17 | 27 | 27 | 25 | 27 | 28 | 28 | 21 | 18 | **274** |
| Lucindale | 23 | 20 | 26 | 49 | 66 | 80 | 88 | 78 | 64 | 51 | 34 | 32 | **611** |
| Lyndoch | 19 | 21 | 21 | 45 | 63 | 76 | 74 | 73 | 64 | 53 | 31 | 25 | **565** |
| Macclesfield | 27 | 27 | 31 | 60 | 81 | 97 | 100 | 96 | 85 | 65 | 43 | 33 | **745** |
| Maggea | 17 | 20 | 12 | 21 | 28 | 25 | 26 | 28 | 25 | 26 | 21 | 20 | **269** |
| Maitland | 17 | 22 | 21 | 44 | 62 | 69 | 66 | 62 | 50 | 43 | 29 | 22 | **507** |
| Mallala | 19 | 18 | 18 | 35 | 48 | 49 | 45 | 46 | 42 | 37 | 25 | 21 | **403** |
| Mannum | 15 | 17 | 18 | 26 | 31 | 31 | 28 | 31 | 30 | 28 | 20 | 18 | **293** |
| Manoora | 19 | 20 | 20 | 36 | 56 | 57 | 57 | 63 | 57 | 47 | 30 | 25 | **487** |
| Marrabel | 21 | 21 | 22 | 40 | 59 | 63 | 63 | 69 | 58 | 49 | 43 | 25 | **533** |
| Marree (Est) | 18 | 21 | 15 | 11 | 14 | 14 | 10 | 10 | 11 | 13 | 11 | 17 | **165** |
| McLaren Vale | 23 | 26 | 20 | 50 | 73 | 74 | 78 | 67 | 51 | 50 | 34 | 27 | **573** |
| Meadows | 30 | 30 | 36 | 72 | 100 | 121 | 120 | 114 | 100 | 77 | 48 | 38 | **886** |
| Melrose | 30 | 26 | 24 | 39 | 67 | 77 | 73 | 71 | 63 | 55 | 36 | 27 | **588** |
| Meningie | 19 | 17 | 22 | 38 | 56 | 61 | 61 | 55 | 48 | 40 | 28 | 23 | **468** |
| Meribah | 17 | 19 | 13 | 22 | 30 | 27 | 29 | 25 | 27 | 29 | 21 | 16 | **275** |
| Milang (EWS) | 22 | 31 | 19 | 35 | 37 | 39 | 43 | 41 | 34 | 36 | 20 | 13 | **370** |
| Mindarie | 17 | 21 | 14 | 21 | 31 | 30 | 30 | 34 | 31 | 32 | 21 | 19 | **301** |
| Minlaton | 14 | 17 | 18 | 36 | 53 | 63 | 59 | 57 | 44 | 37 | 24 | 18 | **440** |
| Minnipa PO (A) | 14 | 21 | 16 | 19 | 39 | 48 | 48 | 46 | 34 | 28 | 22 | 19 | **354** |
| Minarto | 21 | 24 | 22 | 40 | 71 | 75 | 77 | 82 | 71 | 56 | 34 | 28 | **601** |
| Moonta | 14 | 18 | 19 | 35 | 48 | 49 | 46 | 41 | 35 | 31 | 22 | 17 | **375** |
| Morgan | 14 | 18 | 13 | 17 | 25 | 24 | 20 | 22 | 24 | 24 | 17 | 19 | **237** |
| Mt Barker | 28 | 27 | 31 | 61 | 91 | 101 | 105 | 102 | 86 | 70 | 40 | 33 | **775** |
| Mt Bold | 25 | 30 | 26 | 62 | 92 | 91 | 106 | 93 | 71 | 65 | 42 | 34 | **737** |
| Mt Bryan | 19 | 24 | 16 | 27 | 47 | 51 | 54 | 56 | 51 | 41 | 27 | 25 | **438** |
| Mt Burr | 28 | 32 | 34 | 70 | 85 | 97 | 114 | 101 | 78 | 64 | 47 | 39 | **789** |
| Mt Compass | 30 | 30 | 27 | 65 | 105 | 110 | 129 | 110 | 90 | 69 | 42 | 32 | **839** |
| Mt Cooper | 11 | 16 | 17 | 26 | 53 | 60 | 68 | 56 | 46 | 33 | 28 | 19 | **433** |
| Mt Crawford Forest | 24 | 30 | 28 | 59 | 98 | 94 | 112 | 102 | 85 | 68 | 37 | 30 | **767** |
| Mt Gambier (A) | 25 | 31 | 33 | 60 | 72 | 78 | 100 | 90 | 69 | 64 | 49 | 37 | **708** |
| Mt Pleasant | 25 | 26 | 26 | 52 | 76 | 93 | 92 | 91 | 78 | 60 | 36 | 28 | **683** |
| Murray Bridge | 17 | 19 | 20 | 29 | 36 | 36 | 34 | 35 | 36 | 34 | 25 | 21 | **342** |
| Myponga | 24 | 29 | 24 | 59 | 95 | 111 | 114 | 97 | 81 | 61 | 38 | 28 | **761** |
| Nackara | 22 | 23 | 19 | 16 | 27 | 29 | 27 | 27 | 24 | 24 | 22 | 21 | **281** |
| Naracoorte | 23 | 21 | 27 | 45 | 61 | 73 | 75 | 72 | 64 | 53 | 36 | 30 | **580** |
| Nildottie | 19 | 17 | 15 | 19 | 26 | 20 | 24 | 21 | 27 | 32 | 17 | 15 | **252** |
| Nuriootpa | 20 | 21 | 21 | 41 | 58 | 65 | 63 | 66 | 57 | 48 | 31 | 27 | **518** |
| Oodlawirra | 28 | 29 | 15 | 21 | 29 | 30 | 26 | 30 | 26 | 26 | 26 | 23 | **309** |
| Oodnadatta | 28 | 29 | 14 | 11 | 15 | 12 | 10 | 9 | 10 | 13 | 11 | 14 | **176** |
| Orroroo | 26 | 20 | 16 | 23 | 34 | 39 | 35 | 40 | 32 | 29 | 25 | 22 | **341** |
| Owen | 21 | 27 | 18 | 39 | 48 | 45 | 50 | 49 | 43 | 41 | 29 | 21 | **431** |
| Palmer | 19 | 25 | 19 | 31 | 45 | 43 | 49 | 53 | 48 | 39 | 26 | 24 | **421** |
| Parafield AMO (A) | 25 | 21 | 20 | 44 | 47 | 52 | 58 | 53 | 43 | 48 | 30 | 23 | **464** |
| Paratoo | 19 | 21 | 16 | 15 | 22 | 21 | 16 | 18 | 19 | 20 | 20 | 21 | **228** |
| Parawa | 31 | 39 | 34 | 81 | 116 | 132 | 145 | 123 | 91 | 79 | 47 | 36 | **954** |
| Parilla | 19 | 24 | 16 | 26 | 38 | 36 | 35 | 39 | 36 | 35 | 26 | 20 | **350** |
| Parndana | 17 | 22 | 26 | 48 | 76 | 89 | 99 | 85 | 62 | 46 | 28 | 23 | **621** |
| Parrakie | 18 | 23 | 18 | 28 | 41 | 40 | 40 | 46 | 42 | 37 | 26 | 22 | **381** |
| Paruna | 15 | 20 | 13 | 20 | 30 | 28 | 29 | 29 | 27 | 30 | 20 | 17 | **278** |
| Paskeville | 16 | 19 | 17 | 32 | 47 | 52 | 48 | 49 | 39 | 35 | 21 | 18 | **393** |
| Peake | 18 | 23 | 20 | 30 | 44 | 41 | 42 | 46 | 42 | 40 | 26 | 24 | **396** |
| Peebinga | 24 | 18 | 13 | 26 | 32 | 26 | 32 | 30 | 31 | 34 | 29 | 16 | **311** |
| Penneshaw | 18 | 20 | 17 | 40 | 58 | 70 | 80 | 66 | 52 | 40 | 29 | 21 | **511** |

## Estimated Average Monthly Rainfall (mm)

| **Town** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Penola | 26 | 23 | 30 | 49 | 71 | 83 | 87 | 86 | 70 | 58 | 41 | 35 | **659** |
| Penong | 9 | 18 | 16 | 23 | 43 | 45 | 44 | 43 | 29 | 25 | 20 | 15 | **330** |
| Peterborough | 21 | 19 | 16 | 23 | 32 | 35 | 33 | 38 | 33 | 29 | 26 | 22 | **327** |
| Pinnaroo | 17 | 24 | 19 | 23 | 36 | 36 | 34 | 36 | 35 | 34 | 27 | 20 | **341** |
| Point Pass | 22 | 25 | 17 | 31 | 52 | 46 | 54 | 60 | 51 | 43 | 28 | 25 | **454** |
| Policemans Point | 27 | 20 | 24 | 46 | 57 | 60 | 78 | 69 | 45 | 41 | 27 | 27 | **521** |
| Poochera | 10 | 19 | 14 | 18 | 38 | 48 | 47 | 45 | 32 | 24 | 19 | 17 | **331** |
| Port Elliot | 21 | 21 | 22 | 42 | 59 | 65 | 66 | 60 | 53 | 43 | 29 | 23 | **504** |
| Pt Augusta | 15 | 15 | 17 | 19 | 26 | 27 | 20 | 23 | 22 | 23 | 18 | 16 | **241** |
| Pt Broughton | 16 | 19 | 16 | 30 | 43 | 45 | 40 | 38 | 36 | 32 | 21 | 17 | **353** |
| Pt Germein | 19 | 18 | 17 | 27 | 39 | 36 | 31 | 34 | 33 | 32 | 23 | 21 | **330** |
| Pt Lincoln | 13 | 15 | 19 | 37 | 58 | 75 | 77 | 67 | 49 | 35 | 22 | 18 | **485** |
| Pt Pirie | 18 | 19 | 17 | 29 | 40 | 41 | 33 | 35 | 35 | 34 | 23 | 22 | **346** |
| Pt Victoria | 13 | 18 | 16 | 33 | 49 | 52 | 49 | 45 | 37 | 33 | 22 | 18 | **385** |
| Pt Vincent | 13 | 20 | 13 | 26 | 40 | 49 | 45 | 44 | 39 | 32 | 21 | 18 | **360** |
| Pt Wakefield | 17 | 20 | 19 | 30 | 38 | 38 | 36 | 36 | 32 | 30 | 20 | 17 | **333** |
| Quorn | 19 | 21 | 14 | 21 | 35 | 39 | 37 | 41 | 31 | 29 | 22 | 20 | **329** |
| Redhill | 17 | 20 | 18 | 33 | 49 | 55 | 50 | 52 | 44 | 38 | 26 | 21 | **423** |
| Renmark | 16 | 20 | 15 | 19 | 26 | 25 | 23 | 25 | 28 | 28 | 21 | 18 | **264** |
| Riverton | 21 | 21 | 22 | 42 | 60 | 64 | 62 | 67 | 58 | 48 | 33 | 25 | **523** |
| Robe | 21 | 19 | 26 | 48 | 76 | 96 | 104 | 83 | 59 | 45 | 30 | 28 | **635** |
| Roseworthy AG | 20 | 18 | 20 | 38 | 49 | 54 | 51 | 54 | 47 | 43 | 28 | 23 | **445** |
| Roxby Downs | 16 | 21 | 16 | 7 | 17 | 12 | 12 | 12 | 10 | 14 | 11 | 14 | **162** |
| Rudall | 13 | 20 | 15 | 26 | 38 | 38 | 45 | 42 | 36 | 30 | 24 | 21 | **348** |
| Saddleworth | 21 | 22 | 22 | 40 | 57 | 58 | 58 | 62 | 54 | 46 | 31 | 25 | **496** |
| Salisbury | 20 | 19 | 21 | 41 | 56 | 63 | 54 | 56 | 46 | 40 | 28 | 23 | **467** |
| Sandalwood | 19 | 21 | 15 | 23 | 36 | 35 | 33 | 36 | 35 | 32 | 24 | 21 | **330** |
| Sedan | 15 | 18 | 16 | 22 | 32 | 34 | 31 | 35 | 32 | 30 | 19 | 18 | **302** |
| Smithfield | 19 | 20 | 21 | 26 | 57 | 58 | 55 | 56 | 49 | 43 | 29 | 24 | **457** |
| Smokey Bay | 8 | 15 | 13 | 18 | 26 | 45 | 44 | 37 | 26 | 20 | 17 | 14 | **283** |
| Snowtown | 19 | 20 | 17 | 31 | 46 | 51 | 48 | 50 | 42 | 37 | 24 | 20 | **405** |
| Spalding | 18 | 23 | 16 | 28 | 49 | 53 | 53 | 55 | 51 | 42 | 30 | 24 | **442** |
| Stansbury | 15 | 17 | 16 | 31 | 49 | 56 | 55 | 53 | 44 | 36 | 22 | 18 | **412** |
| Stockport | 20 | 20 | 19 | 37 | 49 | 52 | 51 | 54 | 49 | 44 | 30 | 24 | **449** |
| Stockwell | 20 | 21 | 21 | 40 | 55 | 62 | 61 | 63 | 55 | 47 | 31 | 26 | **502** |
| Strathalbyn | 21 | 22 | 24 | 40 | 56 | 58 | 63 | 60 | 53 | 45 | 29 | 24 | **495** |
| Streaky Bay | 10 | 15 | 15 | 25 | 48 | 66 | 60 | 51 | 35 | 26 | 20 | 12 | **383** |
| Sutherlands | 15 | 20 | 15 | 19 | 30 | 30 | 28 | 32 | 30 | 28 | 20 | 19 | **286** |
| Swan Reach | 16 | 20 | 17 | 19 | 29 | 27 | 25 | 27 | 28 | 27 | 18 | 18 | **271** |
| Tailem Bend | 18 | 23 | 21 | 29 | 41 | 39 | 38 | 40 | 39 | 39 | 29 | 26 | **382** |
| Tanunda | 22 | 21 | 23 | 44 | 62 | 72 | 68 | 69 | 60 | 50 | 31 | 26 | **548** |
| Tarlee | 20 | 21 | 20 | 39 | 54 | 54 | 53 | 58 | 50 | 45 | 31 | 24 | **469** |
| Terowie | 21 | 21 | 15 | 22 | 30 | 34 | 34 | 39 | 35 | 31 | 24 | 24 | **330** |
| Tintinara | 18 | 22 | 22 | 38 | 54 | 52 | 54 | 57 | 51 | 44 | 32 | 27 | **471** |
| Torrens Island | 21 | 23 | 17 | 39 | 50 | 54 | 53 | 49 | 43 | 40 | 28 | 25 | **442** |
| Tumby Bay | 11 | 17 | 14 | 25 | 37 | 45 | 49 | 44 | 38 | 30 | 22 | 19 | **351** |
| Two Wells | 19 | 18 | 18 | 35 | 47 | 52 | 46 | 46 | 38 | 36 | 24 | 22 | **401** |
| Ungarra | 11 | 20 | 15 | 27 | 45 | 54 | 63 | 55 | 47 | 34 | 23 | 21 | **415** |
| Uraidla | 35 | 34 | 41 | 86 | 133 | 159 | 156 | 142 | 115 | 90 | 55 | 45 | **1091** |
| Victor Harbor | 22 | 21 | 22 | 43 | 63 | 71 | 74 | 66 | 56 | 46 | 29 | 23 | **536** |
| Virginia | 20 | 19 | 19 | 36 | 51 | 55 | 50 | 51 | 44 | 39 | 27 | 24 | **435** |
| Wallaroo | 15 | 17 | 20 | 32 | 46 | 48 | 42 | 40 | 34 | 31 | 21 | 16 | **362** |
| Wanbi (A) | 16 | 21 | 19 | 23 | 29 | 24 | 33 | 31 | 31 | 33 | 25 | 17 | **302** |
| Warooka | 14 | 17 | 15 | 34 | 56 | 65 | 65 | 59 | 46 | 36 | 22 | 17 | **446** |
| Watervale | 25 | 26 | 27 | 53 | 75 | 83 | 81 | 85 | 73 | 59 | 39 | 31 | **657** |
| Wellington | 16 | 12 | 23 | 34 | 37 | 49 | 39 | 42 | 40 | 37 | 24 | 21 | **374** |

## Estimated Average Monthly Rainfall (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Western River | 17 | 20 | 21 | 49 | 78 | 102 | 115 | 94 | 62 | 46 | 32 | 20 | **656** |
| Whyalla | 19 | 25 | 16 | 19 | 28 | 25 | 22 | 25 | 26 | 27 | 23 | 20 | **275** |
| Whyte Yarcowie | 21 | 21 | 18 | 24 | 33 | 37 | 37 | 40 | 36 | 31 | 24 | 22 | **344** |
| Williamstown | 23 | 22 | 23 | 55 | 79 | 101 | 93 | 91 | 71 | 60 | 37 | 28 | **683** |
| Willowie | 18 | 21 | 16 | 20 | 33 | 35 | 32 | 34 | 33 | 30 | 24 | 21 | **317** |
| Willunga | 21 | 23 | 28 | 52 | 85 | 93 | 91 | 80 | 68 | 55 | 33 | 25 | **654** |
| Wilmington | 24 | 20 | 17 | 32 | 49 | 55 | 54 | 54 | 46 | 38 | 28 | 23 | **440** |
| Wilpena Heat Station | 28 | 26 | 22 | 18 | 40 | 52 | 51 | 40 | 31 | 27 | 22 | 23 | **380** |
| Wirrabra | 21 | 22 | 21 | 35 | 51 | 59 | 58 | 59 | 52 | 46 | 32 | 24 | **480** |
| Wolseley | 20 | 23 | 20 | 40 | 52 | 55 | 58 | 59 | 53 | 47 | 33 | 25 | **485** |
| Woomera (AMO) | 15 | 21 | 15 | 12 | 21 | 16 | 16 | 14 | 16 | 16 | 17 | 14 | **193** |
| Worlds End Creek | 16 | 21 | 14 | 18 | 32 | 33 | 34 | 37 | 36 | 29 | 21 | 20 | **311** |
| Yacka | 17 | 21 | 16 | 31 | 45 | 49 | 47 | 49 | 45 | 37 | 26 | 22 | **405** |
| Yalata | 10 | 12 | 10 | 21 | 43 | 56 | 42 | 36 | 21 | 21 | 15 | 7 | **294** |
| Yankalilla | 19 | 22 | 24 | 44 | 73 | 87 | 81 | 71 | 59 | 47 | 30 | 24 | **581** |
| Yeelanna | 10 | 16 | 13 | 25 | 48 | 59 | 68 | 58 | 43 | 31 | 21 | 18 | **410** |
| Yongala | 21 | 21 | 16 | 26 | 37 | 41 | 39 | 44 | 39 | 34 | 28 | 24 | **370** |

# Appendix 9

# Average Monthly Evaporation Data for Towns

Table 68 presents an alphabetical listing of the '*estimated average monthly and annual evaporation*' for 220 towns in South Australia developed Kevin Burrows of the Bureau of Meteorology in 1987.

**Table 68 Average Monthly Evaporation Data for Towns (Burrows 1987)**

| **Estimated Average Monthly Pan Evaporation (mm)** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Town** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total** |
| Adelaide | 305 | 271 | 201 | 130 | 83 | 63 | 60 | 71 | 99 | 150 | 220 | 283 | **1936** |
| Alawoona | 325 | 285 | 209 | 135 | 88 | 70 | 70 | 84 | 116 | 170 | 242 | 305 | **2099** |
| Aldinga | 250 | 228 | 178 | 125 | 86 | 65 | 60 | 69 | 93 | 135 | 188 | 233 | **1710** |
| American River | 200 | 182 | 144 | 105 | 76 | 62 | 60 | 69 | 88 | 120 | 158 | 190 | **1454** |
| Andamooka (Est) | 440 | 340 | 305 | 215 | 135 | 90 | 100 | 125 | 200 | 305 | 335 | 430 | **3020** |
| Angaston | 310 | 277 | 207 | 135 | 87 | 64 | 60 | 70 | 98 | 150 | 221 | 286 | **1965** |
| Appila | 225 | 212 | 196 | 165 | 122 | 87 | 80 | 108 | 162 | 215 | 241 | 239 | **2052** |
| Ardrossan | 275 | 246 | 189 | 130 | 88 | 67 | 65 | 78 | 108 | 155 | 213 | 261 | **1875** |
| Arno Bay | 290 | 259 | 201 | 140 | 95 | 72 | 70 | 87 | 122 | 175 | 234 | 279 | **2024** |
| Auburn | 320 | 283 | 212 | 140 | 90 | 66 | 65 | 83 | 121 | 180 | 250 | 306 | **2116** |
| Balaklava | 320 | 283 | 212 | 140 | 90 | 66 | 65 | 83 | 121 | 180 | 250 | 306 | **2116** |
| Barmera | 330 | 292 | 219 | 145 | 95 | 72 | 70 | 86 | 122 | 180 | 252 | 313 | **2176** |
| Beachport | 210 | 182 | 130 | 80 | 50 | 39 | 40 | 49 | 69 | 105 | 154 | 197 | **1305** |
| Berri | 330 | 292 | 219 | 145 | 95 | 72 | 70 | 86 | 122 | 180 | 252 | 313 | **2176** |
| Birdwood | 285 | 255 | 193 | 130 | 87 | 68 | 65 | 76 | 103 | 150 | 212 | 267 | **1891** |
| Blackrock | 350 | 312 | 244 | 170 | 113 | 82 | 80 | 105 | 156 | 225 | 295 | 343 | **2475** |
| Blanche Town | 320 | 281 | 207 | 135 | 88 | 69 | 70 | 86 | 120 | 175 | 245 | 304 | **2100** |
| Blyth | 325 | 287 | 217 | 145 | 94 | 71 | 70 | 89 | 130 | 190 | 259 | 313 | **2190** |
| Booborowie | 330 | 290 | 218 | 145 | 94 | 70 | 70 | 91 | 133 | 195 | 265 | 319 | **2220** |
| Booleroo Centre | 340 | 304 | 239 | 170 | 116 | 87 | 85 | 110 | 159 | 225 | 291 | 335 | **2461** |
| Borda | 200 | 179 | 136 | 95 | 70 | 60 | 60 | 65 | 78 | 105 | 146 | 185 | **1379** |
| Bordertown | 270 | 239 | 173 | 110 | 71 | 56 | 55 | 62 | 83 | 125 | 188 | 248 | **1680** |
| Bridgewater | 275 | 246 | 186 | 125 | 83 | 63 | 60 | 71 | 98 | 145 | 205 | 258 | **1815** |
| Brinkworth | 330 | 292 | 223 | 150 | 97 | 72 | 70 | 90 | 133 | 195 | 265 | 318 | **2235** |
| Bruce | 360 | 322 | 255 | 180 | 121 | 88 | 85 | 111 | 164 | 235 | 306 | 353 | **2580** |
| Buckleboo | 345 | 307 | 238 | 165 | 110 | 81 | 80 | 104 | 153 | 220 | 289 | 338 | **2430** |
| Bundaleer | 330 | 292 | 225 | 155 | 102 | 76 | 75 | 99 | 146 | 210 | 277 | 323 | **2310** |
| Bute | 310 | 276 | 212 | 145 | 94 | 67 | 65 | 86 | 129 | 190 | 255 | 301 | **2130** |
| Caliph | 325 | 285 | 209 | 135 | 88 | 69 | 70 | 86 | 119 | 175 | 247 | 308 | **2116** |
| Callington | 275 | 246 | 186 | 125 | 83 | 63 | 60 | 71 | 98 | 145 | 205 | 258 | **1815** |
| Ceduna | 292 | 261 | 214 | 160 | 114 | 87 | 85 | 110 | 158 | 215 | 265 | 292 | **2253** |
| Clare | 325 | 286 | 213 | 140 | 89 | 66 | 65 | 84 | 124 | 185 | 256 | 312 | **2145** |
| Clarendon | 275 | 246 | 186 | 125 | 83 | 63 | 60 | 71 | 98 | 145 | 205 | 258 | **1815** |
| Claypans | 320 | 279 | 203 | 130 | 85 | 68 | 70 | 85 | 116 | 170 | 241 | 303 | **2070** |
| Cleve | 300 | 271 | 213 | 150 | 101 | 74 | 70 | 87 | 125 | 180 | 241 | 288 | **2100** |
| Cockburn | 400 | 352 | 268 | 180 | 116 | 86 | 85 | 112 | 167 | 245 | 329 | 390 | **2730** |
| Coober Pedy (Est) | 470 | 390 | 330 | 225 | 140 | 100 | 125 | 150 | 225 | 150 | 330 | 365 | **3000** |
| Cook | 350 | 311 | 250 | 185 | 134 | 108 | 110 | 140 | 194 | 260 | 319 | 353 | **2714** |

## Estimated Average Monthly Pan Evaporation (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cooke Plains | 260 | 232 | 176 | 120 | 82 | 66 | 65 | 77 | 102 | 145 | 199 | 246 | **1770** |
| Coomandook | 275 | 243 | 181 | 120 | 81 | 65 | 65 | 76 | 101 | 145 | 205 | 258 | **1815** |
| Coonalpyn | 270 | 237 | 175 | 115 | 78 | 64 | 65 | 77 | 102 | 145 | 203 | 255 | **1786** |
| Copeville | 320 | 279 | 203 | 130 | 85 | 68 | 70 | 85 | 116 | 170 | 241 | 303 | **2070** |
| Corny Point | 215 | 195 | 153 | 110 | 80 | 67 | 65 | 73 | 92 | 125 | 167 | 203 | **1545** |
| Cowell | 300 | 270 | 212 | 150 | 103 | 78 | 75 | 91 | 127 | 180 | 240 | 288 | **2114** |
| Cradock | 380 | 337 | 261 | 180 | 118 | 87 | 85 | 112 | 166 | 240 | 317 | 372 | **2655** |
| Crystal Brook | 330 | 294 | 229 | 160 | 108 | 81 | 80 | 102 | 147 | 210 | 276 | 322 | **2339** |
| Cummins | 260 | 233 | 181 | 125 | 84 | 63 | 60 | 73 | 104 | 150 | 204 | 248 | **1785** |
| Curramulka | 250 | 227 | 177 | 125 | 87 | 68 | 65 | 75 | 99 | 140 | 191 | 235 | **1739** |
| Darke Peak | 320 | 285 | 219 | 150 | 101 | 77 | 75 | 93 | 132 | 190 | 256 | 308 | **2206** |
| Denial Bay | 295 | 265 | 215 | 160 | 113 | 86 | 85 | 111 | 161 | 220 | 271 | 298 | **2280** |
| Edithburgh | 190 | 176 | 144 | 110 | 83 | 68 | 65 | 73 | 91 | 120 | 154 | 181 | **1455** |
| Elliston | 255 | 233 | 185 | 130 | 86 | 61 | 55 | 67 | 98 | 145 | 199 | 241 | **1755** |
| Ernabella | 460 | 404 | 318 | 230 | 165 | 134 | 140 | 181 | 253 | 340 | 420 | 465 | **3510** |
| Eudunda | 325 | 287 | 213 | 140 | 92 | 71 | 70 | 85 | 119 | 175 | 246 | 307 | **2130** |
| Eurelia | 360 | 322 | 251 | 175 | 117 | 87 | 85 | 108 | 157 | 225 | 298 | 350 | **2535** |
| Farrell Flat | 320 | 283 | 212 | 140 | 90 | 66 | 65 | 83 | 121 | 180 | 250 | 306 | **2116** |
| Fowlers Bay | 300 | 269 | 217 | 160 | 113 | 86 | 85 | 110 | 156 | 215 | 268 | 300 | **2279** |
| Frances | 260 | 231 | 171 | 110 | 68 | 48 | 45 | 55 | 80 | 126 | 187 | 241 | **1622** |
| Freeling Railway | 315 | 281 | 208 | 135 | 86 | 64 | 60 | 70 | 98 | 150 | 223 | 290 | **1980** |
| Gawler Railway | 320 | 282 | 208 | 135 | 87 | 66 | 65 | 79 | 110 | 165 | 237 | 300 | **2054** |
| Georgetown | 340 | 300 | 229 | 155 | 101 | 75 | 75 | 98 | 145 | 210 | 280 | 332 | **2340** |
| Geranium | 280 | 249 | 187 | 125 | 84 | 66 | 65 | 77 | 104 | 150 | 211 | 263 | **1861** |
| Gladstone | 335 | 300 | 236 | 165 | 109 | 78 | 75 | 99 | 148 | 215 | 282 | 328 | **2370** |
| Glen Osmond | 300 | 265 | 195 | 125 | 78 | 57 | 55 | 67 | 97 | 150 | 219 | 280 | **1888** |
| Glenelg | 300 | 267 | 199 | 130 | 84 | 63 | 60 | 71 | 99 | 150 | 218 | 279 | **1920** |
| Goolwa | 235 | 210 | 160 | 110 | 76 | 61 | 60 | 70 | 92 | 130 | 179 | 222 | **1605** |
| Greenock | 310 | 277 | 207 | 135 | 87 | 64 | 60 | 70 | 98 | 150 | 221 | 286 | **1965** |
| Gulnare | 330 | 291 | 221 | 150 | 99 | 75 | 75 | 96 | 138 | 200 | 269 | 320 | **2264** |
| Hallet | 335 | 295 | 223 | 150 | 98 | 74 | 75 | 97 | 142 | 205 | 275 | 326 | **2295** |
| Hamely Bridge | 325 | 289 | 215 | 140 | 90 | 68 | 65 | 78 | 110 | 165 | 238 | 303 | **2086** |
| Hammond | 360 | 323 | 255 | 180 | 121 | 89 | 85 | 109 | 160 | 230 | 302 | 351 | **2565** |
| Hawker | 390 | 344 | 264 | 180 | 117 | 85 | 85 | 114 | 172 | 250 | 330 | 384 | **2715** |
| Hoyleton | 320 | 278 | 203 | 130 | 83 | 63 | 65 | 84 | 122 | 180 | 251 | 307 | **2086** |
| Inman Valley | 205 | 191 | 159 | 120 | 87 | 66 | 60 | 68 | 91 | 125 | 164 | 194 | **1530** |
| Iron Knob | 360 | 322 | 255 | 180 | 121 | 88 | 85 | 111 | 164 | 235 | 306 | 353 | **2580** |
| Jamestown | 340 | 302 | 232 | 160 | 107 | 81 | 80 | 102 | 146 | 210 | 279 | 330 | **2469** |
| Kadina | 315 | 276 | 202 | 130 | 84 | 65 | 65 | 79 | 111 | 165 | 236 | 297 | **2025** |
| Kapunda | 320 | 282 | 208 | 135 | 86 | 65 | 64 | 79 | 113 | 170 | 242 | 302 | **2066** |
| Karoonda | 300 | 265 | 197 | 130 | 87 | 70 | 70 | 83 | 111 | 160 | 225 | 282 | **1980** |
| Keith | 270 | 238 | 176 | 115 | 76 | 60 | 60 | 71 | 96 | 140 | 200 | 253 | **1755** |
| Kimba | 340 | 303 | 236 | 165 | 110 | 82 | 80 | 103 | 150 | 215 | 283 | 332 | **2399** |
| Kingscote | 210 | 190 | 148 | 105 | 75 | 62 | 60 | 68 | 87 | 120 | 162 | 198 | **1485** |
| Kingston SE | 210 | 191 | 148 | 100 | 64 | 45 | 40 | 47 | 68 | 105 | 152 | 194 | **1364** |
| Koolunga | 325 | 287 | 220 | 150 | 100 | 75 | 75 | 96 | 139 | 200 | 267 | 316 | **2250** |
| Kyancutta | 325 | 289 | 220 | 150 | 100 | 76 | 75 | 93 | 132 | 190 | 258 | 312 | **2220** |
| Kybybolite | 240 | 217 | 165 | 110 | 70 | 50 | 45 | 52 | 74 | 115 | 170 | 220 | **1528** |
| Lameroo | 290 | 258 | 194 | 130 | 86 | 67 | 65 | 77 | 106 | 155 | 218 | 273 | **1919** |
| Langhorne Creek | 250 | 222 | 169 | 115 | 78 | 61 | 60 | 73 | 101 | 145 | 197 | 239 | **1710** |
| Laura | 340 | 303 | 236 | 165 | 110 | 82 | 80 | 103 | 150 | 215 | 283 | 332 | **2399** |
| Leigh Creek (#) | 415 | 347 | 332 | 199 | 118 | 75 | 92 | 144 | 207 | 283 | 348 | 380 | **2940** |
| Lenswood (DOA) | 275 | 246 | 186 | 125 | 83 | 63 | 60 | 71 | 98 | 145 | 205 | 258 | **1815** |
| Lochiel | 320 | 282 | 210 | 140 | 94 | 74 | 75 | 91 | 125 | 180 | 248 | 305 | **2144** |
| Lock | 310 | 276 | 210 | 140 | 89 | 63 | 60 | 77 | 116 | 175 | 243 | 296 | **2055** |
| Loxton | 330 | 293 | 219 | 145 | 95 | 72 | 70 | 85 | 118 | 175 | 248 | 311 | **2161** |

## Estimated Average Monthly Pan Evaporation (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lucindale | 240 | 215 | 161 | 105 | 67 | 49 | 45 | 53 | 75 | 115 | 170 | 221 | **1516** |
| Lyndoch | 315 | 279 | 207 | 135 | 88 | 67 | 65 | 77 | 107 | 160 | 231 | 294 | **2025** |
| Macclesfield | 255 | 228 | 175 | 120 | 81 | 62 | 60 | 73 | 101 | 145 | 199 | 242 | **1741** |
| Maggea | 325 | 287 | 213 | 140 | 92 | 71 | 70 | 85 | 119 | 175 | 246 | 307 | **2130** |
| Maitland | 290 | 257 | 194 | 130 | 86 | 66 | 65 | 80 | 113 | 165 | 227 | 277 | **1950** |
| Mallala | 320 | 284 | 212 | 140 | 92 | 71 | 70 | 84 | 116 | 170 | 240 | 301 | **2100** |
| Mannum | 305 | 271 | 201 | 130 | 83 | 63 | 60 | 71 | 99 | 150 | 220 | 283 | **1936** |
| Manoora | 320 | 283 | 212 | 140 | 90 | 67 | 65 | 81 | 117 | 175 | 246 | 304 | **2100** |
| Marrabel | 320 | 283 | 212 | 140 | 90 | 67 | 65 | 81 | 117 | 175 | 246 | 304 | **2100** |
| Marree (Est) | 475 | 375 | 360 | 225 | 155 | 90 | 110 | 135 | 220 | 330 | 360 | 490 | **3325** |
| McLaren Vale | 260 | 234 | 181 | 125 | 84 | 63 | 60 | 72 | 100 | 145 | 200 | 246 | **1770** |
| Meadows | 250 | 224 | 173 | 120 | 81 | 62 | 60 | 73 | 101 | 145 | 197 | 238 | **1724** |
| Melrose | 340 | 306 | 244 | 175 | 119 | 88 | 85 | 109 | 159 | 225 | 290 | 334 | **2474** |
| Meningie | 240 | 214 | 165 | 115 | 79 | 61 | 60 | 74 | 102 | 145 | 194 | 231 | **1680** |
| Meribah | 325 | 285 | 209 | 135 | 88 | 70 | 70 | 84 | 116 | 170 | 242 | 306 | **2100** |
| Milang (EWS) | 230 | 204 | 158 | 110 | 74 | 56 | 55 | 70 | 102 | 145 | 191 | 224 | **1619** |
| Mindarie | 325 | 285 | 209 | 135 | 88 | 70 | 70 | 84 | 116 | 170 | 242 | 306 | **2100** |
| Minlaton | 250 | 225 | 173 | 120 | 84 | 67 | 65 | 74 | 96 | 135 | 187 | 234 | **1710** |
| Minnipa PO (A) | 344 | 289 | 242 | 160 | 109 | 67 | 75 | 101 | 134 | 196 | 262 | 333 | **2312** |
| Minarto | 325 | 285 | 212 | 140 | 91 | 70 | 70 | 88 | 126 | 185 | 255 | 312 | **2159** |
| Moonta | 310 | 277 | 202 | 130 | 86 | 68 | 65 | 70 | 90 | 135 | 207 | 280 | **1920** |
| Morgan | 330 | 290 | 214 | 140 | 91 | 70 | 70 | 87 | 122 | 180 | 253 | 313 | **2160** |
| Mt Barker | 275 | 246 | 186 | 125 | 83 | 63 | 60 | 71 | 98 | 145 | 205 | 258 | **1815** |
| Mt Bold | 260 | 237 | 186 | 130 | 88 | 65 | 60 | 70 | 96 | 140 | 195 | 243 | **1770** |
| Mt Bryan | 330 | 291 | 221 | 150 | 99 | 75 | 75 | 96 | 138 | 200 | 269 | 320 | **2264** |
| Mt Burr | 225 | 197 | 143 | 90 | 58 | 45 | 45 | 53 | 73 | 110 | 162 | 209 | **1410** |
| Mt Compass | 230 | 210 | 167 | 120 | 84 | 64 | 60 | 70 | 96 | 135 | 181 | 218 | **1635** |
| Mt Cooper | 300 | 269 | 207 | 140 | 90 | 64 | 60 | 76 | 113 | 170 | 235 | 286 | **2010** |
| Mt Crawford Forest | 310 | 274 | 201 | 130 | 85 | 66 | 65 | 77 | 104 | 155 | 225 | 289 | **1981** |
| Mt Gambier (A) | 217 | 197 | 151 | 82 | 54 | 35 | 44 | 59 | 79 | 110 | 140 | 198 | **1366** |
| Mt Pleasant | 300 | 266 | 198 | 130 | 86 | 66 | 65 | 77 | 105 | 155 | 222 | 281 | **1951** |
| Murray Bridge | 275 | 245 | 185 | 125 | 82 | 62 | 60 | 73 | 102 | 150 | 210 | 260 | **1829** |
| Myponga | 235 | 215 | 169 | 120 | 84 | 65 | 60 | 67 | 88 | 125 | 174 | 218 | **1620** |
| Nackara | 360 | 319 | 247 | 170 | 112 | 81 | 80 | 106 | 159 | 230 | 303 | 353 | **2520** |
| Naracoorte | 240 | 217 | 165 | 110 | 70 | 50 | 45 | 52 | 74 | 115 | 170 | 220 | **1528** |
| Nildottie | 315 | 276 | 202 | 130 | 83 | 64 | 65 | 81 | 115 | 170 | 240 | 299 | **2040** |
| Nuriootpa | 310 | 277 | 207 | 135 | 87 | 64 | 60 | 70 | 98 | 150 | 221 | 286 | **1965** |
| Oodlawirra | 360 | 319 | 246 | 170 | 114 | 85 | 85 | 111 | 161 | 230 | 302 | 353 | **2536** |
| Oodnadatta | 508 | 420 | 375 | 249 | 167 | 120 | 140 | 189 | 258 | 360 | 426 | 502 | **3714** |
| Orroroo | 365 | 325 | 252 | 175 | 117 | 87 | 85 | 108 | 156 | 225 | 299 | 354 | **2548** |
| Owen | 325 | 287 | 213 | 140 | 92 | 71 | 70 | 85 | 119 | 175 | 246 | 307 | **2130** |
| Palmer | 300 | 267 | 199 | 130 | 84 | 63 | 60 | 71 | 99 | 150 | 218 | 279 | **1920** |
| Parafield AMO (A) | 335 | 290 | 234 | 139 | 91 | 56 | 63 | 92 | 121 | 159 | 241 | 319 | **2140** |
| Paratoo | 370 | 329 | 255 | 175 | 114 | 83 | 80 | 105 | 157 | 230 | 306 | 361 | **2565** |
| Parawa | 195 | 179 | 147 | 110 | 80 | 63 | 60 | 70 | 92 | 125 | 161 | 188 | **1470** |
| Parilla | 300 | 265 | 197 | 130 | 85 | 66 | 65 | 79 | 109 | 160 | 226 | 283 | **1965** |
| Parndana | 240 | 213 | 158 | 105 | 73 | 60 | 60 | 67 | 84 | 120 | 172 | 222 | **1574** |
| Parrakie | 280 | 249 | 187 | 125 | 84 | 66 | 65 | 77 | 104 | 150 | 211 | 263 | **1861** |
| Paruna | 325 | 285 | 209 | 135 | 88 | 70 | 70 | 84 | 116 | 170 | 242 | 306 | **2100** |
| Paskeville | 310 | 275 | 209 | 140 | 91 | 67 | 65 | 82 | 118 | 175 | 242 | 296 | **2070** |
| Peake | 275 | 245 | 185 | 125 | 84 | 66 | 65 | 77 | 104 | 150 | 209 | 259 | **1844** |
| Peebinga | 320 | 280 | 203 | 130 | 85 | 69 | 70 | 83 | 113 | 165 | 237 | 301 | **2056** |
| Penneshaw | 210 | 190 | 148 | 105 | 75 | 62 | 60 | 68 | 87 | 120 | 162 | 198 | **1485** |
| Penola | 235 | 209 | 155 | 100 | 64 | 47 | 45 | 53 | 75 | 115 | 169 | 218 | **1485** |
| Penong | 300 | 272 | 225 | 170 | 122 | 93 | 90 | 114 | 162 | 220 | 271 | 300 | **2339** |
| Peterborough | 350 | 308 | 235 | 160 | 106 | 80 | 80 | 105 | 153 | 220 | 292 | 343 | **2432** |
| Pinnaroo | 300 | 265 | 197 | 130 | 85 | 66 | 65 | 79 | 109 | 160 | 226 | 283 | **1965** |

## Estimated Average Monthly Pan Evaporation (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point Pass | 325 | 287 | 213 | 140 | 92 | 71 | 70 | 85 | 119 | 175 | 246 | 307 | **2130** |
| Policemans Point | 220 | 200 | 157 | 110 | 74 | 54 | 50 | 60 | 86 | 125 | 171 | 208 | **1515** |
| Poochera | 320 | 289 | 227 | 160 | 108 | 80 | 75 | 92 | 132 | 190 | 256 | 306 | **2235** |
| Port Elliot | 220 | 199 | 155 | 110 | 78 | 62 | 60 | 69 | 90 | 125 | 169 | 208 | **1545** |
| Pt Augusta | 360 | 320 | 254 | 180 | 120 | 87 | 85 | 116 | 175 | 250 | 319 | 360 | **2626** |
| Pt Broughton | 325 | 287 | 220 | 150 | 100 | 75 | 75 | 96 | 139 | 200 | 267 | 316 | **2250** |
| Pt Germein | 350 | 313 | 246 | 175 | 120 | 92 | 90 | 113 | 160 | 225 | 293 | 342 | **2519** |
| Pt Lincoln | 240 | 217 | 168 | 115 | 75 | 54 | 50 | 61 | 87 | 130 | 182 | 226 | **1605** |
| Pt Pirie | 340 | 305 | 241 | 170 | 114 | 83 | 80 | 104 | 153 | 220 | 287 | 333 | **2430** |
| Pt Victoria | 275 | 245 | 185 | 125 | 84 | 66 | 65 | 77 | 104 | 150 | 209 | 259 | **1844** |
| Pt Vincent | 225 | 207 | 169 | 125 | 90 | 69 | 65 | 76 | 102 | 140 | 182 | 215 | **1665** |
| Pt Wakefield | 300 | 264 | 197 | 130 | 85 | 65 | 65 | 82 | 116 | 170 | 235 | 287 | **1996** |
| Quorn | 375 | 333 | 259 | 180 | 119 | 87 | 85 | 112 | 166 | 240 | 316 | 368 | **2640** |
| Redhill | 330 | 293 | 226 | 155 | 103 | 76 | 75 | 97 | 142 | 205 | 273 | 321 | **2296** |
| Renmark | 330 | 292 | 219 | 145 | 95 | 72 | 70 | 86 | 122 | 180 | 252 | 313 | **2176** |
| Riverton | 320 | 283 | 212 | 140 | 90 | 67 | 65 | 81 | 117 | 175 | 246 | 304 | **2100** |
| Robe | 210 | 187 | 139 | 90 | 57 | 42 | 40 | 48 | 69 | 105 | 153 | 196 | **1336** |
| Roseworthy AG | 320 | 285 | 212 | 140 | 93 | 72 | 70 | 81 | 108 | 160 | 231 | 297 | **2069** |
| Roxby Downs (*) | 393 | 325 | 245 | 190 | 122 | 85 | 94 | 157 | 180 | 241 | 307 | 364 | **2703** |
| Rudall | 310 | 275 | 209 | 140 | 91 | 67 | 65 | 83 | 122 | 180 | 246 | 298 | **2086** |
| Saddleworth | 320 | 283 | 212 | 140 | 90 | 67 | 65 | 81 | 117 | 175 | 246 | 304 | **2100** |
| Salisbury | 320 | 283 | 209 | 135 | 87 | 67 | 65 | 77 | 107 | 160 | 233 | 298 | **2041** |
| Sandalwood | 315 | 276 | 201 | 130 | 86 | 69 | 70 | 84 | 113 | 165 | 235 | 297 | **2041** |
| Sedan | 315 | 276 | 202 | 130 | 83 | 64 | 65 | 81 | 115 | 170 | 240 | 299 | **2040** |
| Smithfield | 320 | 283 | 209 | 135 | 87 | 67 | 65 | 77 | 107 | 160 | 233 | 298 | **2041** |
| Smokey Bay | 280 | 255 | 211 | 160 | 114 | 89 | 85 | 106 | 147 | 200 | 248 | 278 | **2173** |
| Snowtown | 325 | 287 | 217 | 145 | 94 | 71 | 70 | 89 | 130 | 190 | 259 | 313 | **2190** |
| Spalding | 330 | 292 | 222 | 150 | 97 | 71 | 70 | 92 | 136 | 200 | 269 | 320 | **2249** |
| Stansbury | 205 | 189 | 154 | 115 | 85 | 69 | 65 | 73 | 93 | 125 | 163 | 194 | **1530** |
| Stockport | 320 | 282 | 208 | 135 | 87 | 66 | 65 | 80 | 114 | 170 | 241 | 302 | **2070** |
| Stockwell | 310 | 276 | 206 | 135 | 88 | 68 | 65 | 76 | 104 | 155 | 225 | 288 | **1996** |
| Strathalbyn | 250 | 224 | 173 | 120 | 81 | 62 | 60 | 73 | 101 | 145 | 197 | 238 | **1724** |
| Streaky Bay | 280 | 256 | 207 | 150 | 103 | 76 | 70 | 86 | 123 | 175 | 230 | 270 | **2026** |
| Sutherlands | 325 | 287 | 213 | 140 | 92 | 71 | 70 | 85 | 119 | 175 | 246 | 307 | **2130** |
| Swan Reach | 315 | 276 | 202 | 130 | 83 | 64 | 65 | 81 | 115 | 170 | 240 | 299 | **2040** |
| Tailem Bend | 250 | 223 | 173 | 120 | 81 | 62 | 60 | 74 | 105 | 150 | 201 | 241 | **1740** |
| Tanunda | 310 | 276 | 206 | 135 | 86 | 63 | 60 | 72 | 102 | 155 | 226 | 288 | **1979** |
| Tarlee | 320 | 282 | 209 | 135 | 85 | 62 | 60 | 76 | 112 | 170 | 242 | 303 | **2056** |
| Terowie | 340 | 303 | 236 | 165 | 110 | 82 | 80 | 103 | 150 | 215 | 283 | 332 | **2399** |
| Tintinara | 270 | 236 | 171 | 110 | 72 | 59 | 60 | 71 | 96 | 140 | 200 | 254 | **1739** |
| Torrens Island | 310 | 274 | 202 | 130 | 82 | 61 | 60 | 74 | 106 | 160 | 230 | 291 | **1980** |
| Tumby Bay | 250 | 226 | 177 | 125 | 85 | 63 | 60 | 74 | 105 | 150 | 201 | 240 | **1756** |
| Two Wells | 310 | 273 | 201 | 130 | 84 | 66 | 65 | 78 | 108 | 160 | 229 | 291 | **1995** |
| Ungarra | 260 | 235 | 185 | 130 | 87 | 64 | 60 | 74 | 107 | 155 | 208 | 249 | **1814** |
| Uraidla | 280 | 254 | 197 | 135 | 90 | 66 | 60 | 70 | 97 | 145 | 205 | 260 | **1859** |
| Victor Harbor | 200 | 183 | 148 | 110 | 80 | 63 | 60 | 70 | 92 | 125 | 162 | 192 | **1485** |
| Virginia | 310 | 273 | 201 | 130 | 84 | 66 | 65 | 78 | 108 | 160 | 229 | 291 | **1995** |
| Wallaroo | 310 | 275 | 209 | 140 | 91 | 67 | 65 | 83 | 122 | 180 | 246 | 298 | **2086** |
| Wanbi (A) | 315 | 256 | 219 | 128 | 80 | 51 | 67 | 93 | 129 | 162 | 232 | 311 | **2043** |
| Warooka | 210 | 195 | 160 | 120 | 88 | 70 | 65 | 72 | 92 | 125 | 164 | 198 | **1559** |
| Watervale | 325 | 263 | 168 | 90 | 53 | 50 | 65 | 88 | 123 | 180 | 255 | 318 | **1978** |
| Wellington | 230 | 207 | 162 | 115 | 80 | 62 | 60 | 73 | 100 | 140 | 186 | 221 | **1636** |
| Western River | 200 | 182 | 144 | 105 | 76 | 62 | 60 | 69 | 88 | 120 | 158 | 190 | **1454** |
| Whyalla | 330 | 298 | 241 | 175 | 118 | 85 | 80 | 105 | 158 | 225 | 288 | 326 | **2429** |
| Whyte Yarcowie | 345 | 305 | 235 | 160 | 104 | 76 | 75 | 99 | 147 | 215 | 286 | 337 | **2384** |
| Willamstown | 310 | 274 | 201 | 130 | 85 | 66 | 65 | 77 | 104 | 155 | 225 | 289 | **1981** |

## Estimated Average Monthly Pan Evaporation (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Willowie | 350 | 313 | 246 | 175 | 120 | 91 | 90 | 115 | 164 | 230 | 297 | 344 | **2535** |
| Willunga | 250 | 225 | 174 | 120 | 82 | 63 | 60 | 71 | 97 | 140 | 192 | 236 | **1710** |
| Wilmington | 350 | 307 | 235 | 160 | 105 | 79 | 80 | 108 | 160 | 230 | 300 | 347 | **2461** |
| Wilpena Heat Station | 400 | 352 | 270 | 185 | 134 | 74 | 95 | 134 | 179 | 255 | 335 | 392 | **2805** |
| Wirrabra | 340 | 300 | 232 | 160 | 107 | 80 | 80 | 105 | 154 | 220 | 288 | 335 | **2401** |
| Wolseley | 270 | 239 | 173 | 110 | 71 | 56 | 55 | 62 | 83 | 125 | 188 | 248 | **1680** |
| Woomera (AMO) | 431 | 361 | 316 | 200 | 127 | 86 | 96 | 142 | 195 | 289 | 348 | 405 | **2996** |
| Worlds End Creek | 340 | 302 | 230 | 155 | 100 | 73 | 70 | 89 | 131 | 195 | 268 | 326 | **2279** |
| Yacka | 330 | 291 | 221 | 150 | 99 | 75 | 75 | 96 | 138 | 200 | 269 | 320 | **2264** |
| Yalata | 320 | 288 | 232 | 170 | 120 | 92 | 90 | 115 | 163 | 225 | 283 | 318 | **2416** |
| Yankalilla | 225 | 207 | 166 | 120 | 85 | 65 | 60 | 67 | 89 | 125 | 171 | 210 | **1590** |
| Yeelanna | 260 | 233 | 181 | 125 | 84 | 63 | 60 | 73 | 104 | 150 | 204 | 248 | **1785** |
| Yongala | 350 | 310 | 238 | 165 | 113 | 89 | 90 | 113 | 157 | 220 | 289 | 341 | **2475** |

# Appendix 10

# Climate Index for Towns in South Australia

Table 69 presents an alphabetical listing of the '*climate index*' for 220 towns in South Australia based on the average annual evaporation and rainfall. The *climate index* provides a simple method of categorising the prevailing climate of a region with respect to the potential for harvesting stormwater. Low values of climate index correspond with a high potential for stormwater to be reliably harvested from impervious surfaces within the town. As the climate index increases (region becomes more arid) the potential for harvesting reliable volumes of stormwater runoff is reduced. For towns not listed the climate index for the region can be approximated from Figure 47.

**Table 69 Climate Index for Towns – Alphabetical Listing**

| **Alphabetical Listing of Climate Index for Selected Towns** | | |
|---|---|---|
| **Town** | **Water Resources Management Region** | **Climate Index** |
| Adelaide | Adelaide and Mount Lofty Ranges | 4 |
| Alawoona | Murray - Darling Basin (SA) | 7 |
| Aldinga | Adelaide and Mount Lofty Ranges | 3 |
| American River | Kangaroo Island | 3 |
| Andamooka | Far North | 15 |
| Angaston | Adelaide and Mount Lofty Ranges | 4 |
| Appila | Mid North | 5 |
| Ardrossan | Mid North | 5 |
| Arno Bay | Eyre Peninsula | 6 |
| Auburn | Mid North | 4 |
| Balaklava | Mid North | 5 |
| Barmera | Murray - Darling Basin (SA) | 9 |
| Beachport | South East | 2 |
| Berri | Murray - Darling Basin (SA) | 8 |
| Birdwood | Adelaide and Mount Lofty Ranges | 3 |
| Black Rock | Mid North | 8 |
| Blanche Town | Murray - Darling Basin (SA) | 8 |
| Blyth | Mid North | 5 |
| Booborowie | Mid North | 5 |
| Boolero Centre | Mid North | 6 |
| Borda (Cape) | Kangaroo Island | 2 |
| Bordertown | South East | 3 |
| Bridgewater | Adelaide and Mount Lofty Ranges | 2 |
| Brinkworth | Mid North | 5 |
| Bruce | Mid North | 10 |
| Buckleboo | Far North | 8 |
| Bundaleer | Mid North | 4 |
| Bute | Mid North | 5 |

**Alphabetical Listing of Climate Index for Selected Towns**

| Town | Water Resources Management Region | Climate Index |
|---|---|---|
| Caliph | Murray - Darling Basin (SA) | 7 |
| Callington | Murray - Darling Basin (SA) | 5 |
| Ceduna | Eyre Peninsula | 7 |
| Clare | Mid North | 3 |
| Claredon | Adelaide and Mount Lofty Ranges | 2 |
| Claypans | Murray - Darling Basin (SA) | 7 |
| Cleve | Eyre Peninsula | 5 |
| Cockburn | Far North | 13 |
| Coober Pedy | Far North | 19 |
| Cook | Far North | 16 |
| Cooke Plains | Murray - Darling Basin (SA) | 5 |
| Coomandook | Murray - Darling Basin (SA) | 4 |
| Coonalpyn | South East | 4 |
| Copeville | Murray - Darling Basin (SA) | 7 |
| Corny Point | Mid North | 3 |
| Cowell | Eyre Peninsula | 7 |
| Cradock | Mid North | 9 |
| Crystal Brook | Mid North | 6 |
| Cummins | Eyre Peninsula | 4 |
| Curramulka | Mid North | 4 |
| Darke Peak | Eyre Peninsula | 6 |
| Denial Bay | Eyre Peninsula | 7 |
| Edithburgh | Mid North | 3 |
| Elliston | Eyre Peninsula | 4 |
| Ernabella | Far North | 13 |
| Eudunda | Murray - Darling Basin (SA) | 5 |
| Eurelia | Mid North | 8 |
| Farrell Flat | Mid North | 4 |
| Fowlers Bay | Eyre Peninsula | 8 |
| Frances | South East | 3 |
| Freeling Railway | Adelaide and Mount Lofty Ranges | 4 |
| Gawler Railway | Adelaide and Mount Lofty Ranges | 4 |
| Georgetown | Mid North | 5 |
| Geranium | Murray - Darling Basin (SA) | 5 |
| Gladstone | Mid North | 6 |
| Glen Osmond | Adelaide and Mount Lofty Ranges | 3 |
| Glenelg | Adelaide and Mount Lofty Ranges | 4 |
| Goolwa | Murray - Darling Basin (SA) | 3 |
| Greenock | Adelaide and Mount Lofty Ranges | 4 |
| Gulnare | Mid North | 5 |
| Hallet | Murray - Darling Basin (SA) | 5 |
| Hamely Bridge | Adelaide and Mount Lofty Ranges | 5 |
| Hammond | Mid North | 10 |
| Hawker | Mid North | 9 |
| Hoyleton | Mid North | 5 |
| Inman Valley | Adelaide and Mount Lofty Ranges | 2 |
| Iron Knob | Far North | 12 |
| Jamestown | Mid North | 5 |
| Kadina | Mid North | 5 |
| Kapunda | Adelaide and Mount Lofty Ranges | 4 |
| Karoonda | Murray - Darling Basin (SA) | 6 |
| Keith | South East | 4 |
| Kimba | Eyre Peninsula | 7 |

**Alphabetical Listing of Climate Index for Selected Towns**

| Town | Water Resources Management Region | Climate Index |
|---|---|---|
| Kingscote | Kangaroo Island | 3 |
| Kingston SE | South East | 2 |
| Koolunga | Mid North | 6 |
| Kyancutta | Eyre Peninsula | 7 |
| Kybybolite | South East | 3 |
| Lameroo | Murray - Darling Basin (SA) | 5 |
| Langhorne Creek | Murray - Darling Basin (SA) | 4 |
| Laura | Mid North | 5 |
| Leigh Creek | Far North | 14 |
| Lenswood | Adelaide and Mount Lofty Ranges | 2 |
| Lochiel | Mid North | 6 |
| Lock | Eyre Peninsula | 5 |
| Loxton | Murray - Darling Basin (SA) | 8 |
| Lucindale | South East | 2 |
| Lyndoch | Adelaide and Mount Lofty Ranges | 4 |
| Macclesfield | Murray - Darling Basin (SA) | 2 |
| Maggea | Murray - Darling Basin (SA) | 8 |
| Maitland | Mid North | 4 |
| Mallala | Adelaide and Mount Lofty Ranges | 5 |
| Mannum | Murray - Darling Basin (SA) | 7 |
| Manoora | Adelaide and Mount Lofty Ranges | 4 |
| Marrabel | Adelaide and Mount Lofty Ranges | 4 |
| Marree | Far North | 20 |
| McLaren Vale | Adelaide and Mount Lofty Ranges | 3 |
| Meadows | Murray - Darling Basin (SA) | 2 |
| Melrose | Mid North | 4 |
| Meningie | Murray - Darling Basin (SA) | 4 |
| Meribah | Murray - Darling Basin (SA) | 8 |
| Milang | Far North | 4 |
| Mindarie | Murray - Darling Basin (SA) | 7 |
| Minlaton | Mid North | 4 |
| Minnipa | Eyre Peninsula | 7 |
| Minarto | Murray - Darling Basin (SA) | 4 |
| Moonta | Mid North | 5 |
| Morgan | Murray - Darling Basin (SA) | 9 |
| Mt Barker | Murray - Darling Basin (SA) | 2 |
| Mt Bold | Adelaide and Mount Lofty Ranges | 2 |
| Mt Bryan | Murray - Darling Basin (SA) | 5 |
| Mt Burr | South East | 2 |
| Mt Compass | Murray - Darling Basin (SA) | 2 |
| Mt Cooper | Eyre Peninsula | 5 |
| Mt Crawford Forest | Adelaide and Mount Lofty Ranges | 3 |
| Mt Gambier | South East | 2 |
| Mt Pleasant | Mid North | 3 |
| Murray Bridge | Murray - Darling Basin (SA) | 5 |
| Myponga | Adelaide and Mount Lofty Ranges | 2 |
| Nackara | Murray - Darling Basin (SA) | 9 |
| Naracoorte | South East | 3 |
| Nildottie | Murray - Darling Basin (SA) | 8 |
| Nuriootpa | Adelaide and Mount Lofty Ranges | 4 |
| Oodlawirra | Mid North | 8 |
| Oodnadatta | Far North | 21 |
| Orroroo | Mid North | 7 |

| Alphabetical Listing of Climate Index for Selected Towns | | |
|---|---|---|
| **Town** | **Water Resources Management Region** | **Climate Index** |
| | | |
| Owen | Adelaide and Mount Lofty Ranges | 5 |
| Palmer | Murray - Darling Basin (SA) | 5 |
| Parafield | Adelaide and Mount Lofty Ranges | 5 |
| Paratoo | Far North | 11 |
| Parawa | Adelaide and Mount Lofty Ranges | 2 |
| Parilla | Murray - Darling Basin (SA) | 6 |
| Parndana | Kangaroo Island | 3 |
| Parrakie | Murray - Darling Basin (SA) | 5 |
| Paruna | Murray - Darling Basin (SA) | 8 |
| Paskeville | Mid North | 5 |
| Peake | Far North | 5 |
| Peebinga | Murray - Darling Basin (SA) | 7 |
| Penneshaw | Kangaroo Island | 3 |
| Penola | South East | 2 |
| Penong | Eyre Peninsula | 7 |
| Peterborough | Mid North | 7 |
| Pinnaroo | Murray - Darling Basin (SA) | 6 |
| Point Pass | Murray - Darling Basin (SA) | 5 |
| Policemans Point | South East | 3 |
| Poochera | Eyre Peninsula | 7 |
| Port Elliot | Adelaide and Mount Lofty Ranges | 3 |
| Pt Augusta | Mid North | 11 |
| Pt Broughton | Mid North | 6 |
| Pt Germein | Mid North | 8 |
| Pt Lincoln | Eyre Peninsula | 3 |
| Pt Pirie | Mid North | 7 |
| Pt Victoria | Mid North | 5 |
| Pt Vincent | Mid North | 5 |
| Pt Wakefield | Mid North | 6 |
| Quorn | Mid North | 8 |
| Redhill | Mid North | 5 |
| Renmark | Murray - Darling Basin (SA) | 8 |
| Riverton | Adelaide and Mount Lofty Ranges | 4 |
| Robe | South East | 2 |
| Roseworthy | Adelaide and Mount Lofty Ranges | 5 |
| Roxby Downs | Far North | 17 |
| Rudall | Eyre Peninsula | 6 |
| Saddleworth | Adelaide and Mount Lofty Ranges | 4 |
| Salisbury | Adelaide and Mount Lofty Ranges | 4 |
| Sandalwood | Murray - Darling Basin (SA) | 6 |
| Sedan | Murray - Darling Basin (SA) | 7 |
| Smithfield | Adelaide and Mount Lofty Ranges | 4 |
| Smokey Bay | Eyre Peninsula | 8 |
| Snowtown | Mid North | 5 |
| Spalding | Mid North | 5 |
| Stansbury | Mid North | 4 |
| Stockport | Adelaide and Mount Lofty Ranges | 5 |
| Stockwell | Adelaide and Mount Lofty Ranges | 4 |
| Strathalbyn | Murray - Darling Basin (SA) | 3 |
| Streaky Bay | Eyre Peninsula | 5 |
| Sutherlands | Murray - Darling Basin (SA) | 7 |
| Swan Reach | Murray - Darling Basin (SA) | 8 |
| Tailem Bend | Murray - Darling Basin (SA) | 5 |

**Alphabetical Listing of Climate Index for Selected Towns**

| Town | Water Resources Management Region | Climate Index |
|---|---|---|
| Tanunda | Adelaide and Mount Lofty Ranges | 4 |
| Tarlee | Adelaide and Mount Lofty Ranges | 4 |
| Terowie | Murray - Darling Basin (SA) | 7 |
| Tintinara | South East | 4 |
| Torrens Island | Adelaide and Mount Lofty Ranges | 4 |
| Tumby Bay | Eyre Peninsula | 5 |
| Two Wells | Adelaide and Mount Lofty Ranges | 5 |
| Ungarra | Eyre Peninsula | 4 |
| Uraidla | Adelaide and Mount Lofty Ranges | 2 |
| Victor Harbor | Adelaide and Mount Lofty Ranges | 3 |
| Virginia | Adelaide and Mount Lofty Ranges | 5 |
| Wallaroo | Mid North | 6 |
| Wanbi | Murray - Darling Basin (SA) | 7 |
| Warooka | Mid North | 3 |
| Watervale | Mid North | 3 |
| Wellington | Murray - Darling Basin (SA) | 4 |
| Western River | Kangaroo Island | 2 |
| Whyalla | Mid North | 9 |
| Whyte Yarcowie | Murray - Darling Basin (SA) | 7 |
| Williamstown | Adelaide and Mount Lofty Ranges | 3 |
| Willowie | Mid North | 8 |
| Willunga | Adelaide and Mount Lofty Ranges | 3 |
| Wilmington | Mid North | 6 |
| Wilpena | Far North | 7 |
| Wirrabra | Mid North | 5 |
| Wolseley | South East | 3 |
| Woomera | Far North | 16 |
| Worlds End Creek | Murray - Darling Basin (SA) | 7 |
| Yacka | Mid North | 6 |
| Yalata | Far North | 8 |
| Yankalilla | Adelaide and Mount Lofty Ranges | 3 |
| Yeelanna | Eyre Peninsula | 4 |
| Yongala | Mid North | 7 |

# Appendix 11

# Towns by Climate Index & Water Resource Management Region

Table 70 presents the '*climate index according to the water management regions*' for 220 towns in South Australia based on Figure 44 State Water Resources Management Regions (SWP 2000) and Figure 47 Climate Index for Areas of South Australia. Low values of climate index correspond with a high potential for stormwater to be reliably harvested from impervious surfaces within the town. As the climate index increases (region becomes more arid) the potential for harvesting reliable volumes of stormwater runoff is reduced. This summary shows that the potential for stormwater harvesting is significantly different between the defined water resource management regions primarily due to depending on the prevailing climate of the region.

**Table 70 Climate Index for Towns by Water Resources Management Region**

| CLIMATE INDEX | | | | | | | |
|---|---|---|---|---|---|---|---|
| **2** | **3** | **4** | **5** | **6 - 7** | **8 - 9** | **10 - 14** | **> 15** |
| **FAR NORTH** | | | | | | | |
| | | | Peake | Wilpena | Buckleboo<br>Yalata | Cockburn<br>Ernabella<br>Iron Knob<br>Leigh Creek<br>Paratoo | Andamooka<br>Coober Pedy<br>Cook<br>Marree<br>Oodnadatta<br>Roxby Downs<br>Woomera |
| **EYRE PENINSULA** | | | | | | | |
| | Pt Lincoln | Cummins<br>Elliston<br>Ungarra<br>Yeelanna | Cleve<br>Lock<br>Mt Cooper<br>Streaky Bay<br>Tumby Bay | Arno Bay<br>Ceduna<br>Cowell<br>Darke Peak<br>Denial Bay<br>Kimba<br>Kyancutta<br>Minnipa<br>Penong<br>Poochera<br>Rudall | Fowlers Bay<br>Smokey Bay | | |

| CLIMATE INDEX | | | | | | | |
|---|---|---|---|---|---|---|---|
| **2** | **3** | **4** | **5** | **6 - 7** | **8 - 9** | **10 - 14** | **> 15** |
| **MID NORTH** | | | | | | | |
| | Clare | Auburn | Appila | Boolero Centre | Black Rock | Bruce | |
| | Corny Point | Bundaleer | Ardrossan | Crystal Brook | Cradock | Hammond | |
| | Edithburgh | Curramulka | Balaklava | Gladstone | Eurelia | Pt Augusta | |
| | Mt Pleasant | Farrell Flat | Blyth | Koolunga | Hawker | | |
| | Warooka | Maitland | Booborowie | Lochiel | Oodlawirra | | |
| | Watervale | Melrose | Brinkworth | Orroroo | Pt Germein | | |
| | | Minlaton | Bute | Peterborough | Quorn | | |
| | | Stansbury | Georgetown | Pt Broughton | Whyalla | | |
| | | | Gulnare | Pt Pirie | Willowie | | |
| | | | Hoyleton | Pt Wakefield | | | |
| | | | Jamestown | Wallaroo | | | |
| | | | Kadina | Wilmington | | | |
| | | | Laura | Yacka | | | |
| | | | Moonta | Yongala | | | |
| | | | Paskeville | | | | |
| | | | Pt Victoria | | | | |
| | | | Pt Vincent | | | | |
| | | | Redhill | | | | |
| | | | Snowtown | | | | |
| | | | Spalding | | | | |
| | | | Wirrabra | | | | |
| **KANGAROO ISLAND** | | | | | | | |
| Borda (Cape) | American River | | | | | | |
| Western River | Kingscote | | | | | | |
| | Parndana | | | | | | |
| | Penneshaw | | | | | | |
| **MURRAY – DARLING BASIN (SA)** | | | | | | | |
| Macclesfield | Goolwa | Coomandook | Callington | Alawoona | Barmera | | |
| Meadows | Strathalbyn | Milang | Cooke Plains | Caliph | Berri | | |
| Mt Barker | | Meningie | Eudunda | Claypans | Blanchetown | | |
| Mt Compass | | Minarto | Geranium | Copeville | Loxton | | |
| | | Langhorne Ck | Hallet | Karoonda | Maggea | | |
| | | Wellington | Lameroo | Mannum | Meribah | | |
| | | | Mt Bryan | Mindarie | Morgan | | |
| | | | Murray Bridge | Parilla | Nackara | | |
| | | | Palmer | Peebinga | Nildottie | | |
| | | | Parrakie | Pinnaroo | Paruna | | |
| | | | Point Pass | Sandalwood | Renmark | | |
| | | | Tailem Bend | Sedan | Swan Reach | | |
| | | | | Sutherlands | | | |
| | | | | Terowie | | | |
| | | | | Wanbi | | | |
| | | | | Whyte | | | |
| | | | | Yarcowie | | | |
| | | | | Worlds End Crk | | | |

| CLIMATE INDEX | | | | | | | |
|---|---|---|---|---|---|---|---|
| **2** | **3** | **4** | **5** | **6 - 7** | **8 - 9** | **10 - 14** | **> 15** |
| **ADELAIDE & MOUNT LOFTY RANGES** | | | | | | | |
| Bridgewater | Aldinga | Adelaide | Hamely Bridge | | | | |
| Claredon | Birdwood | Angaston | Mallala | | | | |
| Inman Valley | Glen Osmond | Freeling | Owen | | | | |
| Lenswood | McLaren Vale | Gawler | Parafield | | | | |
| Mt Bold | Mt Crawford | Glenelg | Roseworthy | | | | |
| Myponga | Port Elliot | Greenock | Stockport | | | | |
| Parawa | Victor Harbor | Kapunda | Two Wells | | | | |
| Uraidla | Willamstown | Lyndoch | Virginia | | | | |
| | Willunga | Manoora | | | | | |
| | Yankalilla | Marrabel | | | | | |
| | | Nuriootpa | | | | | |
| | | Riverton | | | | | |
| | | Saddleworth | | | | | |
| | | Salisbury | | | | | |
| | | Smithfield | | | | | |
| | | Stockwell | | | | | |
| | | Tanunda | | | | | |
| | | Tarlee | | | | | |
| | | Torrens Is | | | | | |
| **SOUTH EAST** | | | | | | | |
| Beachport | Bordertown | Coonalpyn | | | | | |
| Kingston SE | Frances | Keith | | | | | |
| Lucindale | Kybybolite | Tintinara | | | | | |
| Mt Burr | Naracoorte | | | | | | |
| Mt Gambier | Policemans Pt | | | | | | |
| Penola | Wolseley | | | | | | |
| Robe | | | | | | | |

# Appendix 12
# Population Data for Towns

The population of a town along with other factors such as existing infrastructure influences the potential for effluent production and reuse. The primary source of population data is the Australian Bureau of Statistics – Report 2016.4 Census of Population and Housing. Table 71 presents the population information for the 220 towns presented in Appendices 7 to 10 where the population is greater than 200. Population information is not provided for communities with less that 200 people, however, local government can often provide this information.

**Table 71 Population, Dwelling and Growth Information for Towns**

| Place/ Town | CI | Base Load | | | | | Ultimate/Seasonal | |
|---|---|---|---|---|---|---|---|---|
| | | Permanent Population 2001 | 1991 | Growth | Dwellings Occupied | People /House | Dwellings Total | Pop Factor |
| Adelaide | 4 | 974120 | 957480 | 0% | 404059 | 2.4 | 430339 | 106% |
| Alawoona | 7 | | | | | | | |
| Aldinga | 3 | 5446 | 3541 | 5% | 2152 | 2.5 | 2690 | 124% |
| American Rvr | 3 | | | | | | | |
| Andamooka | 15 | 491 | 471 | 0% | 251 | 2.0 | 425 | 185% |
| Angaston | 4 | 1906 | 1819 | 0% | 786 | 2.4 | 837 | 106% |
| Appila | 5 | | | | | | | |
| Ardrossan | 5 | 1052 | 1008 | 0% | 492 | 2.1 | 600 | 125% |
| Arno Bay | 6 | 224 | 189 | 2% | 109 | 2.1 | 194 | 191% |
| Auburn | 4 | 323 | 331 | 0% | 147 | 2.2 | 187 | 130% |
| Balaklava | 5 | 1461 | 1439 | 0% | 631 | 2.3 | 718 | 114% |
| Barmera | 9 | 1814 | 1859 | 0% | 840 | 2.2 | 993 | 120% |
| Beachport | 2 | 403 | 443 | -1% | 186 | 2.2 | 392 | 223% |
| Berri | 8 | 4052 | 3733 | 1% | 1728 | 2.3 | 1885 | 109% |
| Birdwood | 3 | 724 | 582 | 2% | 271 | 2.7 | 286 | 105% |
| Black Rock | 8 | | | | | | | |
| Blanchetown | 8 | 211 | 215 | 0% | 108 | 2.0 | 326 | 348% |
| Blyth | 5 | 284 | 281 | 0% | 120 | 2.4 | 134 | 112% |
| Booborowie | 5 | | | | | | | |
| Booleroo Ctre | 6 | 267 | 295 | -1% | 124 | 2.2 | 140 | 114% |
| Borda (Cape) | 2 | | | | | | | |
| Bordertown | 3 | 2365 | 2235 | 1% | 965 | 2.5 | 1079 | 112% |
| Bridgewater | 2 | 13039 | 11887 | 1% | 4874 | 2.7 | 5135 | 105% |
| Brinkworth | 5 | | | | | | | |
| Bruce | 10 | | | | | | | |
| Buckleboo | 8 | | | | | | | |
| Bundaleer | 4 | | | | | | | |
| Bute | 5 | 264 | 275 | 0% | 117 | 2.3 | 134 | 115% |
| Caliph | 7 | | | | | | | |
| Callington | 5 | 336 | na | | 129 | 2.6 | 149 | 114% |
| Ceduna | 7 | 2372 | 2753 | -1% | 955 | 2.5 | 1099 | 115% |
| Clare | 3 | 2789 | 2575 | 1% | 1172 | 2.4 | 1302 | 111% |
| Clarendon | 2 | | | | | | | |

| Place/ Town | CI | Base Load | | | | | Ultimate/Seasonal | |
|---|---|---|---|---|---|---|---|---|
| | | Permanent Population | | | Dwellings Occupied | People /House | Dwellings Total | Pop Factor |
| | | 2001 | 1991 | Growth | | | | |
| Claypans | 7 | | | | | | | |
| Cleve | 5 | 656 | 738 | -1% | 292 | 2.2 | 339 | 117% |
| Cockburn | 13 | | | | | | | |
| Coober Pedy | 19 | 2170 | 2419 | -1% | 974 | 2.2 | 1287 | 135% |
| Cook | 16 | | | | | | | |
| Cooke Plains | 5 | | | | | | | |
| Coomandook | 4 | | | | | | | |
| Coonalpyn | 4 | 208 | 266 | -2% | 92 | 2.3 | 121 | 133% |
| Copeville | 7 | | | | | | | |
| Corny Point | 3 | | | | | | | |
| Cowell | 7 | 764 | 695 | 1% | 338 | 2.3 | 388 | 116% |
| Cradock | 9 | | | | | | | |
| Crystal Brook | 6 | 1157 | 1282 | -1% | 496 | 2.3 | 554 | 112% |
| Cummins | 4 | 631 | 747 | -2% | 281 | 2.2 | 320 | 115% |
| Curramulka | 4 | | | | | | | |
| Darke Peak | 6 | | | | | | | |
| Denial Bay | 7 | | | | | | | |
| Edithburgh | 3 | 408 | 453 | -1% | 197 | 2.1 | 317 | 171% |
| Elliston | 4 | 201 | 242 | -2% | 90 | 2.2 | 139 | 159% |
| Ernabella | 13 | 440 | na | na | 75 | 5.9 | 98 | 113% |
| Eudunda | 5 | 566 | 647 | -1% | 261 | 2.2 | 311 | 121% |
| Eurelia | 8 | | | | | | | |
| Farrell Flat | 4 | | | | | | | |
| Fowlers Bay | 8 | | | | | | | |
| Frances | 3 | | | | | | | |
| Freeling | 4 | 1105 | 888 | 2% | 399 | 2.8 | 428 | 106% |
| Gawler | 4 | 16573 | 13835 | 2% | 6509 | 2.5 | 6875 | 105% |
| Georgetown | 5 | | | | | | | |
| Geranium | 5 | | | | | | | |
| Gladstone | 6 | 619 | 643 | 0% | 256 | 2.4 | 300 | 117% |
| Glen Osmond | 3 | | | | | | | |
| Glenelg | 4 | | | | | | | |
| Goolwa | 3 | 4186 | 3018 | 4% | 1967 | 2.1 | 3314 | 177% |
| Greenock | 4 | 688 | 451 | 5% | 254 | 2.7 | 267 | 105% |
| Gulnare | 5 | | | | | | | |
| Hallet | 5 | | | | | | | |
| Hamely Br. | 5 | 644 | 654 | 0% | 251 | 2.6 | 276 | 109% |
| Hammond | 10 | | | | | | | |
| Hawker | 9 | 287 | 345 | -2% | 141 | 2.0 | 172 | 126% |
| Hoyleton | 5 | | | | | | | |
| Inman Valley | 2 | | | | | | | |
| Iron Knob | 12 | 176 | 293 | -4% | 89 | 2.0 | 124 | 148% |
| Jamestown | 5 | 1269 | 1359 | -1% | 559 | 2.3 | 646 | 116% |
| Kadina | 5 | 3659 | 3536 | 0% | 1522 | 2.4 | 1666 | 109% |
| Kapunda | 4 | 2264 | 1979 | 1% | 932 | 2.4 | 1013 | 109% |
| Karoonda | 6 | 286 | 326 | -1% | 142 | 2.0 | 171 | 124% |
| Keith | 4 | 1081 | 1176 | -1% | 462 | 2.3 | 509 | 110% |
| Kimba | 7 | 638 | 683 | -1% | 296 | 2.2 | 344 | 118% |
| Kingscote | 3 | 1529 | 1443 | 1% | 689 | 2.2 | 822 | 121% |
| Kingston SE | 2 | 1423 | 1425 | 0% | 625 | 2.3 | 973 | 159% |
| Koolunga | 6 | | | | | | | |
| Kyancutta | 7 | | | | | | | |
| Kybybolite | 3 | | | | | | | |
| Lameroo | 5 | 459 | 567 | -2% | 212 | 2.2 | 258 | 124% |
| Langhorne Ck | 4 | | | | | | | |
| Laura | 5 | 494 | 521 | -1% | 224 | 2.2 | 255 | 115% |

| **Place/ Town** | **CI** | **Base Load** | | | | | **Ultimate/Seasonal** | |
|---|---|---|---|---|---|---|---|---|
| | | **Permanent Population 2001** | **1991** | **Growth** | **Dwellings Occupied** | **People /House** | **Dwellings Total** | **Pop Factor** |
| Leigh Creek | 14 | 585 | 1378 | -6% | 227 | 2.6 | 450 | 191% |
| Lenswood | 2 | | | | | | | |
| Lochiel | 6 | | | | | | | |
| Lock | 5 | | | | | | | |
| Loxton | 8 | 3223 | 3322 | 0% | 1421 | 2.3 | 1522 | 108% |
| Lucindale | 2 | 277 | 249 | 1% | 114 | 2.4 | 137 | 120% |
| Lyndoch | 4 | 1251 | 957 | 3% | 472 | 2.7 | 498 | 105% |
| Macclesfield | 2 | 798 | 318 | 15% | 302 | 2.6 | 325 | 107% |
| Maggea | 8 | | | | | | | |
| Maitland | 4 | 928 | 1066 | -1% | 385 | 2.4 | 442 | 115% |
| Mallala | 5 | 663 | 588 | 1% | 248 | 2.7 | 266 | 107% |
| Mannum | 7 | 2002 | 2025 | 0% | 974 | 2.1 | 1195 | 126% |
| Manoora | 4 | | | | | | | |
| Marrabel | 4 | | | | | | | |
| Marree | 20 | | | | | | | |
| McLaren Vale | 3 | 2512 | 1469 | 7% | 1057 | 2.4 | 1118 | 106% |
| Meadows | 2 | 779 | 528 | 5% | 270 | 2.9 | 292 | 107% |
| Melrose | 4 | | | | | | | |
| Meningie | 4 | 848 | 818 | 0% | 362 | 2.3 | 428 | 119% |
| Meribah | 8 | | | | | | | |
| Milang | 4 | 443 | 352 | 3% | 212 | 2.1 | 267 | 130% |
| Mindarie | 7 | | | | | | | |
| Minlaton | 4 | 701 | 796 | -1% | 317 | 2.2 | 358 | 114% |
| Minnipa PO | 7 | | | | | | | |
| Monarto | 4 | | | | | | | |
| Moonta | 5 | 3000 | 2723 | 1% | 1382 | 2.2 | 2174 | 163% |
| Morgan | 9 | 415 | 446 | -1% | 188 | 2.2 | 229 | 124% |
| Mt Barker | 2 | 9086 | 6239 | 5% | 3557 | 2.6 | 3777 | 106% |
| Mt Bold | 2 | | | | | | | |
| Mt Bryan | 5 | | | | | | | |
| Mt Burr | 2 | 369 | 458 | -2% | 137 | 2.7 | 168 | 120% |
| Mt Compass | 2 | 496 | 310 | 6% | 171 | 2.9 | 180 | 104% |
| Mt Cooper | 5 | | | | | | | |
| Mt Crawford | 3 | | | | | | | |
| Mt Gambier | 2 | 22103 | 21153 | 0% | 9026 | 2.4 | 9746 | 108% |
| Mt Pleasant | 3 | 530 | 546 | 0% | 217 | 2.4 | 242 | 111% |
| Murray Bridge | 5 | 12783 | 12725 | 0% | 5309 | 2.4 | 5805 | 109% |
| Myponga | 2 | | | | | | | |
| Nackara | 9 | | | | | | | |
| Naracoorte | 3 | 4590 | 4711 | 0% | 1950 | 2.4 | 2154 | 111% |
| Nildottie | 8 | | | | | | | |
| Nuriootpa | 4 | 3742 | 3321 | 1% | 1597 | 2.3 | 1735 | 109% |
| Oodlawirra | 8 | | | | | | | |
| Oodnadatta | 21 | | 175 | | | | | |
| Orroroo | 7 | 472 | 574 | -2% | 214 | 2.2 | 272 | 129% |
| Owen | 5 | 218 | 237 | -1% | 104 | 2.1 | 115 | 112% |
| Palmer | 5 | | | | | | | |
| Parafield | 5 | | | | | | | |
| Paratoo | 11 | | | | | | | |
| Parawa | 2 | | | | | | | |
| Parilla | 6 | | | | | | | |
| Parndana | 3 | | | | | | | |
| Parrakie | 5 | | | | | | | |
| Paruna | 8 | | | | | | | |
| Paskeville | 5 | | | | | | | |
| Peake | 5 | | | | | | | |
| Peebinga | 7 | | | | | | | |

| Place/ Town | CI | Base Load | | | | | Ultimate/Seasonal | |
|---|---|---|---|---|---|---|---|---|
| | | Permanent Population 2001 | 1991 | Growth | Dwellings Occupied | People /House | Dwellings Total | Pop Factor |
| Penneshaw | 3 | | | | | | | |
| Penola | 2 | 1179 | 1147 | 0% | 507 | 2.3 | 590 | 117% |
| Penong | 7 | | | | | | | |
| Peterborough | 7 | 1633 | 2138 | -2% | 741 | 2.2 | 941 | 129% |
| Pinnaroo | 6 | 557 | 645 | -1% | 251 | 2.2 | 290 | 117% |
| Point Pass | 5 | | | | | | | |
| Policeman Pt | 3 | | | | | | | |
| Poochera | 7 | | | | | | | |
| Port Elliot | 3 | 1495 | 1203 | 2% | 675 | 2.2 | 1078 | 165% |
| Pt Augusta | 11 | 12516 | 14595 | -1% | 5055 | 2.5 | 5734 | 113% |
| Pt Broughton | 6 | 666 | 681 | 0% | 336 | 2.0 | 534 | 171% |
| Pt Germein | 8 | 279 | 212 | 3% | 126 | 2.2 | 168 | 136% |
| Pt Lincoln | 3 | 12278 | 11345 | 1% | 5030 | 2.4 | 5510 | 109% |
| Pt Pirie | 7 | 12959 | 14110 | -1% | 5498 | 2.4 | 6062 | 110% |
| Pt Victoria | 5 | 333 | 313 | 1% | 163 | 2.0 | 371 | 250% |
| Pt Vincent | 5 | 453 | 458 | 0% | 231 | 2.0 | 510 | 248% |
| Pt Wakefield | 6 | 492 | 512 | 0% | 220 | 2.2 | 273 | 126% |
| Quorn | 8 | 941 | 1056 | -1% | 409 | 2.3 | 509 | 126% |
| Redhill | 5 | | | | | | | |
| Renmark | 8 | 4291 | 4256 | 0% | 1915 | 2.2 | 2061 | 108% |
| Riverton | 4 | 613 | 757 | -2% | 296 | 2.1 | 332 | 114% |
| Robe | 2 | 900 | 730 | 2% | 395 | 2.3 | 857 | 223% |
| Roseworthy | 5 | 538 | na | | 180 | 3.0 | 183 | 101% |
| Roxby Downs | 17 | 3454 | 1999 | 7% | 1236 | 2.8 | 1421 | 113% |
| Rudall | 6 | | | | | | | |
| Saddleworth | 4 | 382 | 421 | -1% | 173 | 2.2 | 198 | 116% |
| Salisbury | 4 | | | | | | | |
| Sandalwood | 6 | | | | | | | |
| Sedan | 7 | | | | | | | |
| Smithfield | 4 | | | | | | | |
| Smokey Bay | 8 | | | | | | | |
| Snowtown | 5 | 358 | 428 | -2% | 167 | 2.1 | 194 | 118% |
| Spalding | 5 | 202 | 227 | -1% | 98 | 2.1 | 108 | 112% |
| Stansbury | 4 | 486 | 513 | -1% | 239 | 2.0 | 393 | 176% |
| Stockport | 5 | | | | | | | |
| Stockwell | 4 | | | | | | | |
| Strathalbyn | 3 | 3125 | 2623 | 2% | 1324 | 2.4 | 1441 | 109% |
| Streaky Bay | 5 | 1005 | 957 | 1% | 434 | 2.3 | 530 | 123% |
| Sutherlands | 7 | | | | | | | |
| Swan Reach | 8 | 262 | 230 | 1% | 123 | 2.1 | 292 | 255% |
| Tailem Bend | 5 | 1349 | 1502 | -1% | 593 | 2.3 | 667 | 113% |
| Tanunda | 4 | 3700 | 3087 | 2% | 1571 | 2.4 | 1672 | 107% |
| Tarlee | 4 | | | | | | | |
| Terowie | 7 | | | | | | | |
| Tintinara | 4 | 264 | 316 | -2% | 122 | 2.2 | 140 | 116% |
| Torrens Is. | 4 | | | | | | | |
| Tumby Bay | 5 | 1191 | 1147 | 0% | 568 | 2.1 | 688 | 124% |
| Two Wells | 5 | 634 | 519 | 2% | 236 | 2.7 | 253 | 106% |
| Ungarra | 4 | | | | | | | |
| Uraidla | 2 | 418 | 427 | 0% | 154 | 2.7 | 165 | 106% |
| Victor Harbor | 3 | 8613 | 5930 | 5% | 4077 | 2.1 | 5674 | 145% |
| Virginia | 5 | 302 | 248 | 2% | 102 | 3.0 | 107 | 104% |
| Wallaroo | 6 | 2633 | 2465 | 1% | 1208 | 2.2 | 1784 | 153% |
| Wanbi (A) | 7 | | | | | | | |
| Warooka | 3 | 216 | 236 | -1% | 94 | 2.3 | 123 | 132% |
| Watervale | 3 | | | | | | | |

| Place/ Town | CI | Base Load | | | | | Ultimate/Seasonal | |
|---|---|---|---|---|---|---|---|---|
| | | Permanent Population<br>2001 | 1991 | Growth | Dwellings Occupied | People /House | Dwellings Total | Pop Factor |
| Wellington | 4 | | | | | | | |
| Western River | 2 | | | | | | | |
| Whyalla | 9 | 20705 | 25526 | -2% | 8789 | 2.4 | 9947 | 113% |
| Whyte Yarcowie | 7 | | | | | | | |
| Williamstown | 3 | 1263 | 855 | 5% | 454 | 2.8 | 482 | 105% |
| Willowie | 8 | | | | | | | |
| Willunga | 3 | 1907 | 1164 | 6% | 691 | 2.8 | 748 | 107% |
| Wilmington | 6 | 236 | 250 | -1% | 103 | 2.3 | 119 | 116% |
| Wilpena | 7 | | | | | | | |
| Wirrabra | 5 | 234 | 292 | -2% | 111 | 2.1 | 141 | 131% |
| Wolseley | 3 | | | | | | | |
| Woomera | 16 | 544 | 1600 | -7% | 259 | 2.1 | 620 | 259% |
| Worlds End | 7 | | | | | | | |
| Yacka | 6 | | | | | | | |
| Yalata | 8 | 223 | 349 | -4% | 48 | 4.6 | 62 | 115% |
| Yankalilla | 3 | 440 | 408 | 1% | 193 | 2.3 | 221 | 115% |
| Yeelanna | 4 | | | | | | | |
| Yongala | 7 | | | | | | | |

# Appendix 13
## Evaluation of Domestic Effluent Flows

The information contained in this Appendix provides a summary of the assessment of the quantity of sewage and volumes of effluent produced adopted for this report.

The ADF adopted depends on the type of wastewater system and the availability of reticulated water supply as shown in Table 47 below.

**Table 47 Average Daily Per Capita Effluent Contribution**

| Type of Sewerage System | ADF (L/person/day) |
|---|---|
| Conventional Sewer | 200 |
| STEDS | 160 |
| Effluent (no reticulated water) | 90 |

The figures established for estimating the potential average annual yield of effluent for towns in South Australia have been based on previous work as described below.

### A13.1 SEWAGE FLOWS FROM CONVENTIONAL SEWERS

In the absence of any other information, SA Water use a figure of 200 to 230 litres per person per day of wastewater for the average annual flow when designing a conventional community sewer system with an estimated equivalent population of 10,000 (Sickerdick *pers. comm.* 2003). This flow is equivalent to 175 to 200 kL per household per year based on the average occupancy rate of 2.4 people per household for South Australia (population and occupancy rates can be found in Appendix 12). As previously discussed the 10 year average annual water consumption per property in South Australia is around 350 kL. This figure accounts for water used by all customers. In comparison, the average annual water consumption by households (served by reticulated water supply) is around 255 kL per year in South Australia (with an increasing trend in the last 5 years).

The *Water Proofing Adelaide* (2004) discussion paper reports that 60% of total water consumption is used indoors in a typical suburban household in Adelaide. Assuming that 5% of the indoor water use is for drinking and cooking (ie not discharged to sewer) then the typical sewage flow would be around 145 kL per household per year. This is equivalent to an average annual flow 165 litres per person per day based on the occupancy rate of 2.4 people per household for Adelaide (excluding contribution from industrial and commercial properties). This figure is comparable with the recorded 2003/04 sewage flow of 140 kL per year per household (or an average annual flow of 160 litres per person per day) into the New Haven Village WWTP. New Haven Village is a small housing development with a total of 63 residential allotments (or approximately 150 people) provided with conventional wastewater system and local treatment.

***The average annual sewage flow (includes wet weather flow) adopted for conventional wastewater systems adopted for this report is 200 litres per person per day.***

## A13.2 STED EFFLUENT FLOWS FROM STEDS FOR TOWNS WITH RETICULATED WATER SUPPLY

The guidelines for *Septic Tank Effluent Drainage Scheme Design Criteria* published by the Department of Human Services and the Local Government Association recommends a design flow for the system be based on the ultimate population (including any periodic influx) with an average contribution of 140 litres per person per day. Further that the design of the treatment plant for areas having more than 70 residential premises be based on average yearly flow of septic tank effluent 170 litres per person per day (includes allowance infiltration). The design criteria for waste septic tanks for a typical residential dwelling where the water supply is via a private or government reticulated system the daily inflow rate is 150 litres per person per day (SAHC 1995).

Unfortunately, the majority of STEDS serving the majority of towns in South Australia do not often monitor effluent flows and data to quantify rates of increases in effluent quantities passing through schemes over time is limited (Pugh & McIntosh 1992). However, centres like Bordertown are experiencing increases in quantity of effluent over time (Pugh & McIntosh 1992) which is associated with steady population growth of 1% per annum (over the period 1991 to 2001) as well as being a transit stop for the travelling public.

The 10 year average annual water consumption for residential customers in South Australian country towns served with reticulated water supply is around for 240 kL per year (ie 6% less than metropolitan Adelaide). This may be a reflection of the water consciousness of the rural population, higher reliance on use of rainwater and bulk bottled water (>8 litres) for drinking and cooking or a consequence of the often below average occupancy rate. Nevertheless the high correlation ($R^2 = 0.97$) between the average annual water consumption trends of metropolitan and country residential customers indicates the consumption patterns between the two groups are generally the same. Assuming the indoor water use component is between 50% and 60% of the total water use in country regions the expected sewage flow will be between 115 and 137 kL per year. Based on the typical occupancy rate of 2.2 people per household in country towns the average annual sewage flow range is 140 and 170 litres per person per day.

***The average annual effluent flow (includes wet weather flow) adopted for towns with reticulated water and community STEDS for this report is 160 litres per person per day.***

## A13.3 EFFLUENT FLOWS FOR COMMUNITIES WITHOUT RETICULATED WATER SUPPLY

Septic tanks for a typical residential dwelling where the water supply is by roof catchment storage or carted water the design criteria for daily inflow rate is 125 litres per person per day (SAHC 1995). McLaren *et. al.* (1987) determined that the total in-house water use for Adelaide was 141 litres per person per day based water consumption data. Further, that this could easily be reduced to around 90 litres per person per day by adoption of simple water conservation measures such as installing a dual flush toilet, installing a low flow shower rose, using a water efficient washing machine and being economical with water used for dishwashing.

***The average annual effluent flow (includes wet weather flow) adopted for towns without water supply will be 90 litres per person per day.***

# Appendix 14
# Historical Water Consumption Figures for Selected Towns

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The water consumption data per service and domestic water consumption for a number of the town served with reticulated water supplies are presented in Table 72 and Table 73 respectively. The water consumption data is courtesy of the South Australian Water Corporation.

**Table 72 Historical Water Consumption Per Service for Selected Towns**

| Town | Water Management Region | Climate Index | Town Consumption (1) (kL/service) | | | Compared to State (%) |
|---|---|---|---|---|---|---|
| | | | Max | Min | Ave | |
| Statewide | NA | NA | 427 | 296 | 350 | - |
| Bordertown | South East | 3 | 554 | 294 | 333 | 95% |
| Clare | Mid North | 3 | 393 | 229 | 317 | 90% |
| Cleve | Eyre Peninsula | 5 | 463 | 227 | 323 | 92% |
| Cowell | Eyre Peninsula | 7 | 477 | 230 | 341 | 97% |
| Cummins | Eyre Peninsula | 4 | 350 | 180 | 270 | 77% |
| Geranium | Murray - Darling Basin | 5 | 418 | 198 | 274 | 78% |
| Hawker | Mid North | 9 | 340 | 202 | 246 | 70% |
| Jamestown | Mid North | 5 | 362 | 206 | 311 | 89% |
| Karoonda | Murray - Darling Basin | 6 | 362 | 210 | 303 | 86% |
| Keith | South East | 4 | 456 | 262 | 291 | 83% |
| Kingscote | Kangaroo Island | 3 | 293 | 214 | 247 | 70% |
| Lameroo | Murray - Darling Basin | 5 | 411 | 213 | 282 | 81% |
| Lock | Eyre Peninsula | 5 | 392 | 209 | 311 | 89% |
| Lucindale | South East | 2 | 297 | 152 | 242 | 69% |
| Maitland | Mid North | 4 | 316 | 187 | 261 | 74% |
| Marree | Far North | 20 | 341 | 148 | 285 | 81% |
| Minnipa | Eyre Peninsula | 7 | 407 | 210 | 264 | 75% |
| Mt Pleasant (2) | Mid North | 3 | 282 | 226 | 257 | 73% |
| Oodnadatta | Far North | 21 | 681 | 423 | 545 | 156% |
| Orroroo | Mid North | 7 | 382 | 237 | 320 | 91% |
| Penneshaw | Kangaroo Island | 3 | 280 | 180 | 230 | 66% |
| Penola | South East | 2 | 231 | 146 | 170 | 49% |
| Peterborough | Mid North | 7 | 314 | 184 | 231 | 66% |
| Pinnaroo | Murray - Darling Basin | 6 | 430 | 263 | 333 | 95% |
| Port Augusta | Mid North | 11 | 606 | 358 | 434 | 124% |
| Quorn | Mid North | 8 | 306 | 211 | 268 | 76% |
| Renmark | Murray - Darling Basin | 8 | 460 | 303 | 376 | 107% |
| Snowtown | Mid North | 5 | 370 | 194 | 270 | 77% |
| Streaky Bay | Eyre Peninsula | 5 | 325 | 180 | 289 | 82% |
| Wallaroo | Mid North | 6 | 281 | 174 | 211 | 60% |
| Whyalla | Mid North | 9 | 446 | 282 | 337 | 96% |

Note 1. SA Water town water consumption figures for the period 1992/93 to 2002/03 except Mt Pleasant.

Note 2. Mt Pleasant water consumption data for the period 1998/99 to 2002/03 only.

## Table 73 Average Township Residential Water Use Per Service

| Town | Water Management Region | Climate Index | Residential Water Use (1) (kL/service) | | | Compared to State (%) |
|---|---|---|---|---|---|---|
| | | | Max | Min | Ave | |
| Statewide | NA | NA | 314 | 221 | 256 | - |
| Bordertown | South East | 3 | 421 | 237 | 295 | 115% |
| Clare | Mid North | 3 | 347 | 194 | 267 | 104% |
| Cleve | Eyre Peninsula | 5 | 397 | 219 | 292 | 114% |
| Cowell | Eyre Peninsula | 7 | 352 | 208 | 291 | 113% |
| Cummins | Eyre Peninsula | 4 | 272 | 150 | 219 | 86% |
| Geranium | Murray - Darling Basin | 5 | 448 | 224 | 290 | 113% |
| Hawker | Mid North | 9 | 304 | 172 | 208 | 81% |
| Jamestown | Mid North | 5 | 325 | 191 | 282 | 110% |
| Karoonda | Murray - Darling Basin | 6 | 345 | 195 | 273 | 107% |
| Keith | South East | 4 | 370 | 209 | 244 | 95% |
| Kingscote | Kangaroo Island | 3 | 279 | 204 | 234 | 91% |
| Lameroo | Murray - Darling Basin | 5 | 400 | 237 | 309 | 121% |
| Lock | Eyre Peninsula | 5 | 314 | 191 | 265 | 103% |
| Lucindale | South East | 2 | 244 | 145 | 208 | 81% |
| Maitland | Mid North | 4 | 295 | 186 | 237 | 92% |
| Marree | Far North | 20 | 340 | 124 | 284 | 111% |
| Minnipa | Eyre Peninsula | 7 | 325 | 182 | 219 | 85% |
| Mt Pleasant (2) | Mid North | 3 | 258 | 204 | 233 | 91% |
| New Haven (3) | Adelaide & Mt Lofty | 4 | 123 | 101 | 113 | 44% |
| Oodnadatta | Far North | 21 | 482 | 235 | 346 | 135% |
| Orroroo | Mid North | 7 | 278 | 163 | 240 | 94% |
| Penneshaw | Kangaroo Island | 3 | 239 | 156 | 196 | 76% |
| Penola | South East | 2 | 214 | 141 | 164 | 64% |
| Peterborough | Mid North | 7 | 260 | 166 | 205 | 80% |
| Pinnaroo | Murray - Darling Basin | 6 | 458 | 276 | 355 | 138% |
| Port Augusta | Mid North | 11 | 453 | 263 | 323 | 126% |
| Quorn | Mid North | 8 | 522 | 367 | 436 | 170% |
| Renmark | Murray - Darling Basin | 8 | 292 | 197 | 248 | 97% |
| Snowtown | Mid North | 5 | 443 | 291 | 356 | 139% |
| Streaky Bay | Eyre Peninsula | 5 | 273 | 189 | 230 | 90% |
| Wallaroo | Mid North | 6 | 246 | 160 | 229 | 89% |
| Whyalla | Mid North | 9 | 188 | 135 | 167 | 65% |

Note 1. Water consumption figures for residential customers the period 1992/93 to 2002/03 unless otherwise noted.
Note 2. Mt Pleasant water consumption data for the period 1998/99 to 2002/03 only.
Note 3. New Haven Village water consumption data for period 1999/00 to 2002/03 only. Excludes water used for toilet flushing and gardens as the village has dual reticulation and recycled water for these activities.

# Appendix 15

# Estimated Average Irrigation Requirements for Towns

Estimation methods for crop water requirements are used owing to the difficulty of obtaining accurate field measurements. The methods often need to be applied under climatic and agronomic conditions very different from those under which they were developed. Testing the accuracy of the methods under a new set of conditions is a time consuming and costly exercise, and yet crop water requirement data are frequently needed at short notice for project planning.

To meet this need the estimated irrigation water requirements of lawn (selected crop) for towns with different climatic conditions in South Australia is presented in Table 74 below. The estimate is expressed as 'depth of water needed to meet loss through evpotranspiration' and is based on the average climate (ie rainfall and evaporation) for the given town. The average monthly rainfall has been excluded (ie set to zero) from the calculation for towns located with a climate index greater than 10 where rainfall is highly variable.

$$\textit{Irrigation Requirement (mm)} = \max(0, ET_{crop} - \textit{Rainfall})$$

Where
$ET_{crop} = Kp \cdot K_{crop} \cdot E_{pan}$
$E_{pan}$ = *pan evaporation*
$K_{crop}$ = *crop coefficient*
$Kp$ = *crop correction factor* (derived from lysimeter studies)

The estimated irrigation requirement presented in Table 74 must be adjusted to determine the depth of water that needs to be supplied by the water harvesting and reuse scheme according to the method of irrigation application (ie flood, spray, drip or sub surface).

**Table 74 Estimated Average Monthly Irrigation Requirement for Towns**

| **Estimated Average Monthly Irrigation Requirement (mm)** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Town** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total** |
| $K_{crop}$ | 0.7 | | | | | | | | | | | | |
| Kp | 0.64 | 0.58 | 0.62 | 0.55 | 0.56 | 0.55 | 0.59 | 0.77 | 0.87 | 0.8 | 0.72 | 0.64 | |
| Adelaide | 117 | 89 | 63 | 6 | 0 | 0 | 0 | 0 | 9 | 39 | 80 | 101 | **504** |
| Alawoona | 127 | 96 | 77 | 31 | 3 | 0 | 0 | 16 | 44 | 66 | 102 | 121 | **682** |
| Aldinga | 95 | 74 | 55 | 8 | 0 | 0 | 0 | 0 | 3 | 34 | 69 | 83 | **420** |
| American River | 73 | 55 | 46 | 1 | 0 | 0 | 0 | 0 | 0 | 28 | 55 | 64 | **322** |
| Andamooka (1) | 197 | 138 | 132 | 83 | 53 | 35 | 41 | 67 | 122 | 171 | 169 | 193 | **1401** |
| Angaston | 118 | 89 | 67 | 7 | 0 | 0 | 0 | 0 | 0 | 33 | 77 | 101 | **493** |

## Estimated Average Monthly Irrigation Requirement (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Appila | 82 | 66 | 66 | 35 | 10 | 0 | 0 | 15 | 57 | 82 | 93 | 82 | **588** |
| Ardrossan | 109 | 83 | 66 | 20 | 0 | 0 | 0 | 0 | 30 | 55 | 85 | 100 | **548** |
| Arno Bay | 118 | 85 | 71 | 28 | 2 | 0 | 0 | 11 | 39 | 68 | 97 | 106 | **626** |
| Auburn | 117 | 90 | 66 | 9 | 0 | 0 | 0 | 0 | 6 | 48 | 90 | 110 | **536** |
| Balaklava | 124 | 95 | 74 | 20 | 0 | 0 | 0 | 1 | 34 | 65 | 102 | 117 | **631** |
| Barmera | 131 | 100 | 83 | 38 | 14 | 7 | 6 | 27 | 52 | 74 | 106 | 125 | **763** |
| Beachport | 71 | 52 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 34 | 56 | **244** |
| Berri | 129 | 100 | 83 | 34 | 10 | 8 | 4 | 22 | 46 | 69 | 102 | 124 | **731** |
| Birdwood | 102 | 80 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 69 | 89 | **416** |
| Blackrock | 138 | 109 | 91 | 46 | 13 | 0 | 3 | 21 | 63 | 99 | 125 | 133 | **840** |
| Blanche Town | 126 | 96 | 74 | 29 | 6 | 2 | 6 | 21 | 50 | 71 | 104 | 119 | **705** |
| Blyth | 126 | 97 | 76 | 22 | 0 | 0 | 0 | 0 | 32 | 66 | 105 | 117 | **640** |
| Booborowie | 129 | 95 | 80 | 26 | 0 | 0 | 0 | 0 | 34 | 66 | 106 | 122 | **657** |
| Booleroo Centre | 131 | 102 | 87 | 38 | 5 | 0 | 0 | 14 | 57 | 89 | 120 | 127 | **771** |
| Borda | 74 | 55 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 47 | 62 | **289** |
| Bordertown | 100 | 74 | 55 | 2 | 0 | 0 | 0 | 0 | 0 | 25 | 61 | 83 | **400** |
| Bridgewater | 92 | 70 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 53 | 76 | **335** |
| Brinkworth | 130 | 97 | 80 | 29 | 0 | 0 | 0 | 0 | 37 | 71 | 108 | 120 | **671** |
| Bruce (1) | 161 | 131 | 111 | 69 | 47 | 34 | 35 | 60 | 100 | 132 | 154 | 158 | **1192** |
| Buckleboo | 134 | 104 | 89 | 44 | 11 | 0 | 0 | 20 | 60 | 95 | 121 | 133 | **811** |
| Bundaleer | 125 | 96 | 78 | 23 | 0 | 0 | 0 | 0 | 25 | 64 | 106 | 118 | **633** |
| Bute | 122 | 92 | 75 | 24 | 0 | 0 | 0 | 0 | 38 | 70 | 105 | 117 | **642** |
| Caliph | 124 | 95 | 76 | 29 | 4 | 1 | 1 | 16 | 47 | 66 | 102 | 119 | **680** |
| Callington | 103 | 81 | 62 | 18 | 0 | 0 | 0 | 0 | 19 | 45 | 78 | 95 | **501** |
| Ceduna | 121 | 89 | 75 | 41 | 4 | 0 | 0 | 23 | 67 | 94 | 111 | 113 | **737** |
| Clare | 120 | 91 | 67 | 6 | 0 | 0 | 0 | 0 | 4 | 46 | 93 | 111 | **537** |
| Clarendon | 96 | 74 | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 60 | 80 | **370** |
| Claypans | 124 | 91 | 71 | 25 | 2 | 0 | 0 | 16 | 42 | 62 | 99 | 116 | **649** |
| Cleve | 118 | 86 | 73 | 28 | 0 | 0 | 0 | 0 | 33 | 64 | 93 | 107 | **603** |
| Cockburn (1) | 179 | 143 | 116 | 69 | 45 | 33 | 35 | 60 | 102 | 137 | 166 | 175 | **1261** |
| Coober Pedy (1) | 211 | 158 | 143 | 87 | 55 | 39 | 52 | 81 | 137 | 84 | 166 | 164 | **1375** |
| Cook (1) | 157 | 126 | 109 | 71 | 53 | 42 | 45 | 75 | 118 | 146 | 161 | 158 | **1260** |
| Cooke Plains | 99 | 74 | 56 | 16 | 0 | 0 | 0 | 0 | 21 | 44 | 74 | 87 | **473** |
| Coomandook | 106 | 78 | 58 | 16 | 0 | 0 | 0 | 0 | 18 | 40 | 73 | 92 | **480** |
| Coonalpyn | 101 | 76 | 55 | 7 | 0 | 0 | 0 | 0 | 14 | 37 | 72 | 90 | **453** |
| Copeville | 127 | 92 | 72 | 29 | 2 | 0 | 0 | 15 | 40 | 65 | 99 | 116 | **658** |
| Corny Point | 83 | 62 | 51 | 6 | 0 | 0 | 0 | 0 | 13 | 37 | 61 | 73 | **387** |
| Cowell | 120 | 90 | 75 | 31 | 9 | 1 | 6 | 22 | 49 | 73 | 101 | 113 | **690** |
| Cradock | 150 | 115 | 98 | 50 | 20 | 0 | 0 | 33 | 77 | 112 | 140 | 148 | **944** |
| Crystal Brook | 129 | 98 | 82 | 30 | 0 | 0 | 0 | 9 | 47 | 78 | 113 | 122 | **708** |
| Cummins | 106 | 79 | 66 | 22 | 0 | 0 | 0 | 0 | 18 | 51 | 81 | 93 | **516** |
| Curramulka | 97 | 75 | 59 | 14 | 0 | 0 | 0 | 0 | 15 | 40 | 73 | 86 | **460** |
| Darke Peak | 129 | 93 | 81 | 32 | 0 | 0 | 0 | 0 | 36 | 73 | 105 | 117 | **667** |
| Denial Bay | 124 | 90 | 75 | 40 | 5 | 0 | 0 | 17 | 72 | 99 | 117 | 117 | **755** |
| Edithburgh | 71 | 54 | 45 | 8 | 0 | 0 | 0 | 0 | 13 | 33 | 55 | 63 | **344** |
| Elliston | 104 | 81 | 65 | 22 | 0 | 0 | 0 | 0 | 21 | 51 | 80 | 93 | **517** |
| Ernabella (1) | 206 | 164 | 138 | 89 | 65 | 52 | 58 | 98 | 154 | 190 | 212 | 208 | **1633** |
| Eudunda | 125 | 95 | 72 | 21 | 0 | 0 | 0 | 0 | 25 | 57 | 95 | 114 | **603** |
| Eurelia | 139 | 111 | 93 | 46 | 13 | 0 | 2 | 20 | 65 | 97 | 124 | 137 | **847** |
| Farrell Flat | 121 | 94 | 74 | 19 | 0 | 0 | 0 | 0 | 20 | 57 | 99 | 113 | **597** |
| Fowlers Bay | 126 | 97 | 81 | 40 | 2 | 0 | 0 | 22 | 73 | 99 | 119 | 123 | **784** |
| Frances | 95 | 70 | 50 | 3 | 0 | 0 | 0 | 0 | 0 | 20 | 58 | 80 | **377** |
| Freeling Railway | 121 | 93 | 71 | 15 | 0 | 0 | 0 | 0 | 11 | 42 | 84 | 106 | **543** |
| Gawler Railway | 124 | 97 | 66 | 8 | 0 | 0 | 0 | 0 | 16 | 49 | 91 | 112 | **565** |
| Georgetown | 132 | 100 | 80 | 24 | 0 | 0 | 0 | 0 | 35 | 72 | 111 | 125 | **679** |
| Geranium | 107 | 78 | 61 | 18 | 0 | 0 | 0 | 0 | 20 | 45 | 78 | 94 | **502** |

### Estimated Average Monthly Irrigation Requirement (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gladstone | 130 | 102 | 84 | 32 | 0 | 0 | 0 | 4 | 43 | 79 | 112 | 124 | **711** |
| Glen Osmond | 110 | 87 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 75 | 96 | **459** |
| Glenelg | 117 | 89 | 65 | 13 | 0 | 0 | 0 | 0 | 15 | 46 | 83 | 103 | **532** |
| Goolwa | 85 | 65 | 47 | 4 | 0 | 0 | 0 | 0 | 8 | 34 | 62 | 78 | **385** |
| Greenock | 117 | 89 | 68 | 6 | 0 | 0 | 0 | 0 | 0 | 33 | 79 | 102 | **495** |
| Gulnare | 127 | 94 | 80 | 26 | 0 | 0 | 0 | 0 | 32 | 68 | 104 | 119 | **650** |
| Hallet | 132 | 99 | 80 | 28 | 0 | 0 | 0 | 0 | 32 | 72 | 109 | 123 | **674** |
| Hamely Bridge | 126 | 97 | 75 | 19 | 0 | 0 | 0 | 0 | 22 | 52 | 93 | 112 | **596** |
| Hammond (1) | 161 | 131 | 111 | 69 | 47 | 34 | 35 | 59 | 97 | 129 | 152 | 157 | **1184** |
| Hawker | 155 | 120 | 100 | 49 | 14 | 0 | 2 | 28 | 78 | 117 | 143 | 153 | **959** |
| Hoyleton | 122 | 94 | 69 | 13 | 0 | 0 | 0 | 0 | 25 | 59 | 99 | 115 | **596** |
| Inman Valley | 63 | 49 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 43 | 56 | **258** |
| Iron Knob (1) | 161 | 131 | 111 | 69 | 47 | 34 | 35 | 60 | 100 | 132 | 154 | 158 | **1192** |
| Jamestown | 131 | 102 | 82 | 30 | 0 | 0 | 0 | 0 | 37 | 72 | 157 | 121 | **731** |
| Kadina | 126 | 93 | 68 | 15 | 0 | 0 | 0 | 0 | 30 | 58 | 97 | 115 | **602** |
| Kapunda | 122 | 93 | 67 | 13 | 0 | 0 | 0 | 0 | 15 | 48 | 92 | 110 | **561** |
| Karoonda | 117 | 87 | 70 | 25 | 0 | 0 | 0 | 8 | 33 | 57 | 89 | 104 | **590** |
| Keith | 102 | 74 | 55 | 9 | 0 | 0 | 0 | 0 | 7 | 33 | 69 | 87 | **437** |
| Kimba | 136 | 100 | 87 | 40 | 6 | 0 | 0 | 14 | 55 | 89 | 120 | 131 | **778** |
| Kingscote | 79 | 60 | 46 | 4 | 0 | 0 | 0 | 0 | 7 | 31 | 58 | 70 | **355** |
| Kingston SE | 74 | 59 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 46 | 58 | **290** |
| Koolunga | 127 | 96 | 79 | 29 | 0 | 0 | 0 | 6 | 44 | 75 | 110 | 120 | **684** |
| Kyancutta | 133 | 99 | 82 | 38 | 2 | 0 | 0 | 9 | 47 | 79 | 106 | 121 | **717** |
| Kybybolite | 85 | 63 | 47 | 1 | 0 | 0 | 0 | 0 | 0 | 13 | 49 | 68 | **325** |
| Lameroo | 110 | 81 | 65 | 22 | 0 | 0 | 0 | 0 | 22 | 48 | 83 | 99 | **529** |
| Langhorne Creek | 93 | 70 | 52 | 11 | 0 | 0 | 0 | 0 | 23 | 44 | 72 | 84 | **450** |
| Laura | 131 | 101 | 83 | 29 | 0 | 0 | 0 | 2 | 38 | 75 | 113 | 126 | **698** |
| Leigh Creek (1) | 186 | 141 | 144 | 77 | 46 | 29 | 38 | 78 | 126 | 158 | 175 | 170 | **1368** |
| Lenswood (DOA) | 79 | 61 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 54 | 76 | **303** |
| Lochiel | 128 | 93 | 76 | 27 | 0 | 0 | 0 | 3 | 33 | 65 | 100 | 117 | **642** |
| Lock | 126 | 93 | 76 | 30 | 0 | 0 | 0 | 0 | 29 | 65 | 97 | 112 | **628** |
| Loxton | 130 | 97 | 79 | 39 | 10 | 1 | 4 | 19 | 44 | 70 | 104 | 121 | **718** |
| Lucindale | 85 | 67 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 52 | 67 | **328** |
| Lyndoch | 122 | 92 | 69 | 7 | 0 | 0 | 0 | 0 | 1 | 37 | 85 | 107 | **520** |
| Macclesfield | 87 | 66 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 57 | 75 | **347** |
| Maggea | 129 | 97 | 80 | 33 | 8 | 2 | 3 | 18 | 47 | 72 | 103 | 118 | **710** |
| Maitland | 113 | 82 | 63 | 6 | 0 | 0 | 0 | 0 | 19 | 49 | 85 | 102 | **520** |
| Mallala | 124 | 97 | 74 | 19 | 0 | 0 | 0 | 0 | 29 | 58 | 96 | 114 | **611** |
| Mannum | 122 | 93 | 69 | 24 | 2 | 0 | 0 | 7 | 30 | 56 | 91 | 109 | **603** |
| Manoora | 124 | 95 | 72 | 18 | 0 | 0 | 0 | 0 | 14 | 51 | 94 | 111 | **580** |
| Marrabel | 122 | 94 | 70 | 14 | 0 | 0 | 0 | 0 | 13 | 49 | 81 | 111 | **555** |
| Marree (1) | 213 | 152 | 156 | 87 | 61 | 35 | 45 | 73 | 134 | 185 | 181 | 220 | **1541** |
| McLaren Vale | 93 | 69 | 59 | 0 | 0 | 0 | 0 | 0 | 10 | 31 | 67 | 83 | **412** |
| Meadows | 82 | 61 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 51 | 69 | **306** |
| Melrose | 122 | 98 | 82 | 28 | 0 | 0 | 0 | 0 | 34 | 71 | 110 | 123 | **668** |
| Meningie | 89 | 70 | 50 | 6 | 0 | 0 | 0 | 0 | 14 | 41 | 70 | 80 | **420** |
| Meribah | 129 | 97 | 78 | 30 | 4 | 0 | 0 | 20 | 44 | 66 | 101 | 121 | **690** |
| Milang (EWS) | 81 | 52 | 50 | 7 | 0 | 0 | 0 | 0 | 28 | 45 | 76 | 87 | **427** |
| Mindarie | 129 | 95 | 77 | 31 | 3 | 0 | 0 | 11 | 40 | 63 | 101 | 118 | **668** |
| Minlaton | 98 | 74 | 57 | 10 | 0 | 0 | 0 | 0 | 14 | 39 | 70 | 87 | **450** |
| Minnipa PO (A) | 140 | 96 | 89 | 43 | 4 | 0 | 0 | 8 | 48 | 82 | 110 | 130 | **750** |
| Monarto | 125 | 92 | 70 | 14 | 0 | 0 | 0 | 0 | 6 | 48 | 95 | 112 | **560** |
| Moonta | 125 | 94 | 69 | 15 | 0 | 0 | 0 | 0 | 20 | 45 | 82 | 108 | **558** |
| Morgan | 134 | 100 | 80 | 37 | 11 | 3 | 9 | 25 | 50 | 77 | 111 | 121 | **757** |
| Mt Barker | 95 | 73 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 63 | 83 | **375** |
| Mt Bold | 91 | 66 | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 56 | 75 | **357** |
| Mt Bryan | 129 | 94 | 80 | 31 | 0 | 0 | 0 | 0 | 33 | 71 | 109 | 118 | **665** |

## Estimated Average Monthly Irrigation Requirement (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mt Burr | 73 | 48 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 55 | **238** |
| Mt Compass | 73 | 55 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 49 | 66 | **295** |
| Mt Cooper | 123 | 93 | 73 | 28 | 0 | 0 | 0 | 0 | 23 | 62 | 90 | 109 | **602** |
| Mt Crawford Forest | 115 | 81 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 76 | 99 | **450** |
| Mt Gambier (A) | 72 | 49 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 52 | **227** |
| Mt Pleasant | 109 | 82 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 76 | 98 | **452** |
| Murray Bridge | 106 | 80 | 60 | 19 | 0 | 0 | 0 | 4 | 26 | 50 | 81 | 95 | **523** |
| Myponga | 81 | 58 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 50 | 70 | **317** |
| Nackara | 139 | 107 | 88 | 49 | 17 | 2 | 6 | 30 | 73 | 105 | 131 | 137 | **884** |
| Naracoorte | 85 | 67 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 50 | 69 | **326** |
| Nildottie | 122 | 95 | 73 | 31 | 7 | 5 | 3 | 23 | 43 | 63 | 104 | 119 | **687** |
| Nuriootpa | 119 | 91 | 69 | 11 | 0 | 0 | 0 | 0 | 3 | 36 | 80 | 101 | **510** |
| Oodlawirra | 133 | 101 | 92 | 44 | 16 | 3 | 9 | 30 | 72 | 103 | 126 | 135 | **864** |
| Oodnadatta (1) | 228 | 171 | 163 | 96 | 65 | 46 | 58 | 102 | 157 | 202 | 215 | 225 | **1726** |
| Orroroo | 138 | 112 | 93 | 44 | 12 | 0 | 0 | 18 | 63 | 97 | 126 | 137 | **840** |
| Owen | 125 | 90 | 74 | 15 | 0 | 0 | 0 | 0 | 29 | 57 | 95 | 117 | **601** |
| Palmer | 115 | 83 | 67 | 19 | 0 | 0 | 0 | 0 | 12 | 45 | 84 | 101 | **527** |
| Parafield AMO | 125 | 97 | 82 | 10 | 0 | 0 | 0 | 0 | 31 | 41 | 91 | 120 | **596** |
| Paratoo (1) | 166 | 134 | 111 | 67 | 45 | 32 | 33 | 57 | 96 | 129 | 154 | 162 | **1184** |
| Parawa | 56 | 34 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 48 | **202** |
| Parilla | 115 | 84 | 69 | 24 | 0 | 0 | 0 | 4 | 30 | 55 | 88 | 107 | **576** |
| Parndana | 91 | 64 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 59 | 76 | **354** |
| Parrakie | 107 | 78 | 63 | 20 | 0 | 0 | 0 | 0 | 21 | 47 | 80 | 96 | **513** |
| Paruna | 131 | 96 | 78 | 32 | 4 | 0 | 0 | 16 | 44 | 65 | 102 | 120 | **688** |
| Paskeville | 123 | 93 | 74 | 22 | 0 | 0 | 0 | 0 | 33 | 63 | 101 | 115 | **623** |
| Peake | 105 | 76 | 60 | 18 | 0 | 0 | 0 | 0 | 21 | 44 | 79 | 92 | **497** |
| Peebinga | 119 | 96 | 75 | 24 | 1 | 1 | 0 | 15 | 38 | 58 | 90 | 119 | **636** |
| Penneshaw | 76 | 57 | 47 | 0 | 0 | 0 | 0 | 0 | 1 | 27 | 53 | 68 | **329** |
| Penola | 79 | 62 | 37 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 44 | 63 | **292** |
| Penong | 125 | 92 | 82 | 42 | 5 | 0 | 0 | 18 | 70 | 98 | 117 | 119 | **769** |
| Peterborough | 136 | 106 | 86 | 39 | 10 | 0 | 0 | 19 | 60 | 94 | 121 | 132 | **802** |
| Pinnaroo | 117 | 84 | 66 | 27 | 0 | 0 | 0 | 7 | 31 | 56 | 87 | 107 | **582** |
| Point Pass | 124 | 92 | 75 | 23 | 0 | 0 | 0 | 0 | 21 | 55 | 96 | 113 | **598** |
| Policemans Point | 72 | 61 | 44 | 0 | 0 | 0 | 0 | 0 | 7 | 29 | 59 | 66 | **339** |
| Poochera | 133 | 98 | 85 | 44 | 4 | 0 | 0 | 5 | 48 | 82 | 110 | 120 | **730** |
| Port Elliot | 78 | 60 | 45 | 0 | 0 | 0 | 0 | 0 | 2 | 27 | 56 | 70 | **338** |
| Pt Augusta (1) | 161 | 130 | 110 | 69 | 47 | 33 | 35 | 63 | 107 | 140 | 161 | 161 | **1218** |
| Pt Broughton | 130 | 98 | 79 | 28 | 0 | 0 | 0 | 14 | 49 | 80 | 114 | 125 | **715** |
| Pt Germein | 138 | 109 | 90 | 40 | 8 | 0 | 6 | 27 | 64 | 94 | 125 | 132 | **833** |
| Pt Lincoln | 95 | 73 | 54 | 7 | 0 | 0 | 0 | 0 | 4 | 38 | 70 | 83 | **424** |
| Pt Pirie | 134 | 105 | 88 | 36 | 5 | 0 | 0 | 21 | 58 | 89 | 122 | 127 | **785** |
| Pt Victoria | 110 | 81 | 64 | 15 | 0 | 0 | 0 | 0 | 26 | 51 | 83 | 98 | **530** |
| Pt Vincent | 88 | 64 | 60 | 22 | 0 | 0 | 0 | 0 | 23 | 46 | 71 | 78 | **453** |
| Pt Wakefield | 117 | 87 | 66 | 20 | 0 | 0 | 0 | 8 | 39 | 65 | 98 | 112 | **613** |
| Quorn | 149 | 114 | 98 | 48 | 12 | 0 | 0 | 19 | 70 | 105 | 137 | 145 | **899** |
| Redhill | 131 | 99 | 80 | 27 | 0 | 0 | 0 | 0 | 42 | 77 | 112 | 123 | **691** |
| Renmark | 132 | 99 | 80 | 37 | 11 | 3 | 6 | 21 | 46 | 73 | 106 | 122 | **736** |
| Riverton | 122 | 94 | 70 | 12 | 0 | 0 | 0 | 0 | 13 | 50 | 91 | 111 | **564** |
| Robe | 73 | 57 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 47 | 60 | **285** |
| Roseworthy AG | 123 | 98 | 72 | 16 | 0 | 0 | 0 | 0 | 19 | 47 | 88 | 110 | **573** |
| Roxby Downs | 176 | 132 | 106 | 73 | 48 | 33 | 39 | 85 | 110 | 135 | 155 | 163 | **1254** |
| Rudall | 126 | 92 | 76 | 28 | 0 | 0 | 0 | 3 | 38 | 71 | 100 | 113 | **645** |
| Saddleworth | 122 | 93 | 70 | 14 | 0 | 0 | 0 | 0 | 17 | 52 | 93 | 111 | **573** |
| Salisbury | 123 | 96 | 70 | 11 | 0 | 0 | 0 | 0 | 19 | 50 | 89 | 111 | **569** |
| Sandalwood | 122 | 91 | 72 | 27 | 0 | 0 | 0 | 9 | 34 | 60 | 94 | 112 | **622** |
| Sedan | 126 | 94 | 72 | 28 | 1 | 0 | 0 | 9 | 38 | 65 | 102 | 116 | **650** |

## Estimated Average Monthly Irrigation Requirement (mm)

| Town | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Smithfield | 124 | 95 | 70 | 26 | 0 | 0 | 0 | 0 | 16 | 47 | 88 | 110 | **576** |
| Smokey Bay | 117 | 89 | 79 | 44 | 19 | 0 | 0 | 20 | 64 | 92 | 108 | 111 | **741** |
| Snowtown | 127 | 97 | 77 | 25 | 0 | 0 | 0 | 0 | 37 | 69 | 107 | 120 | **658** |
| Spalding | 130 | 96 | 80 | 30 | 0 | 0 | 0 | 0 | 32 | 70 | 106 | 119 | **662** |
| Stansbury | 77 | 60 | 51 | 13 | 0 | 0 | 0 | 0 | 13 | 34 | 60 | 69 | **376** |
| Stockport | 123 | 94 | 71 | 15 | 0 | 0 | 0 | 0 | 20 | 51 | 91 | 111 | **578** |
| Stockwell | 119 | 91 | 68 | 12 | 0 | 0 | 0 | 0 | 8 | 40 | 82 | 103 | **524** |
| Strathalbyn | 91 | 69 | 51 | 6 | 0 | 0 | 0 | 0 | 9 | 36 | 70 | 83 | **415** |
| Streaky Bay | 115 | 89 | 75 | 33 | 0 | 0 | 0 | 0 | 40 | 72 | 96 | 109 | **629** |
| Sutherlands | 131 | 97 | 77 | 35 | 6 | 0 | 1 | 14 | 42 | 70 | 104 | 119 | **695** |
| Swan Reach | 125 | 92 | 71 | 31 | 4 | 0 | 2 | 17 | 42 | 68 | 103 | 116 | **670** |
| Tailem Bend | 94 | 68 | 54 | 17 | 0 | 0 | 0 | 0 | 25 | 45 | 72 | 82 | **457** |
| Tanunda | 117 | 91 | 66 | 8 | 0 | 0 | 0 | 0 | 2 | 37 | 83 | 103 | **507** |
| Tarlee | 123 | 93 | 71 | 13 | 0 | 0 | 0 | 0 | 18 | 50 | 91 | 112 | **572** |
| Terowie | 131 | 102 | 87 | 42 | 13 | 0 | 0 | 17 | 56 | 89 | 119 | 125 | **781** |
| Tintinara | 103 | 74 | 52 | 4 | 0 | 0 | 0 | 0 | 7 | 34 | 69 | 87 | **431** |
| Torrens Island | 118 | 88 | 71 | 11 | 0 | 0 | 0 | 0 | 22 | 50 | 88 | 105 | **552** |
| Tumby Bay | 101 | 75 | 63 | 23 | 0 | 0 | 0 | 0 | 26 | 54 | 79 | 89 | **509** |
| Two Wells | 120 | 93 | 69 | 15 | 0 | 0 | 0 | 0 | 28 | 54 | 91 | 108 | **578** |
| Ungarra | 105 | 75 | 65 | 23 | 0 | 0 | 0 | 0 | 18 | 53 | 82 | 91 | **513** |
| Uraidla | 90 | 69 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 71 | **324** |
| Victor Harbor | 68 | 53 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 53 | 63 | **303** |
| Virginia | 119 | 92 | 68 | 14 | 0 | 0 | 0 | 0 | 22 | 51 | 88 | 106 | **560** |
| Wallaroo | 124 | 95 | 71 | 22 | 0 | 0 | 0 | 5 | 40 | 70 | 103 | 118 | **646** |
| Wanbi (A) | 125 | 83 | 76 | 26 | 2 | 0 | 0 | 19 | 48 | 58 | 92 | 122 | **651** |
| Warooka | 80 | 62 | 54 | 12 | 0 | 0 | 0 | 0 | 10 | 34 | 61 | 72 | **385** |
| Watervale | 121 | 81 | 46 | 0 | 0 | 0 | 0 | 0 | 2 | 42 | 90 | 111 | **492** |
| Wellington | 87 | 72 | 47 | 10 | 0 | 0 | 0 | 0 | 21 | 41 | 70 | 78 | **427** |
| Western River | 73 | 54 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 48 | 65 | **302** |
| Whyalla | 129 | 96 | 89 | 48 | 18 | 8 | 11 | 32 | 70 | 99 | 122 | 126 | **848** |
| Whyte Yarcowie | 134 | 103 | 84 | 38 | 8 | 0 | 0 | 13 | 54 | 89 | 120 | 129 | **771** |
| Williamstown | 116 | 89 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 76 | 101 | **474** |
| Willowie | 139 | 106 | 91 | 47 | 14 | 0 | 5 | 28 | 67 | 99 | 126 | 133 | **855** |
| Willunga | 91 | 68 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 64 | 81 | **375** |
| Wilmington | 133 | 105 | 85 | 30 | 0 | 0 | 0 | 4 | 51 | 91 | 123 | 132 | **754** |
| Wilpena Heat Stn | 151 | 117 | 95 | 53 | 13 | 0 | 0 | 32 | 78 | 116 | 147 | 153 | **955** |
| Wirrabra | 131 | 100 | 80 | 27 | 0 | 0 | 0 | 0 | 42 | 77 | 113 | 126 | **696** |
| Wolseley | 101 | 74 | 55 | 2 | 0 | 0 | 0 | 0 | 0 | 23 | 62 | 86 | **403** |
| Woomera (1) | 193 | 147 | 137 | 77 | 50 | 33 | 40 | 77 | 119 | 162 | 175 | 181 | **1390** |
| Worlds End Creek | 136 | 102 | 86 | 42 | 7 | 0 | 0 | 11 | 44 | 80 | 114 | 126 | **748** |
| Yacka | 131 | 97 | 80 | 27 | 0 | 0 | 0 | 3 | 39 | 75 | 110 | 121 | **682** |
| Yalata | 133 | 105 | 91 | 44 | 4 | 0 | 0 | 26 | 78 | 105 | 128 | 135 | **850** |
| Yankalilla | 82 | 62 | 48 | 2 | 0 | 0 | 0 | 0 | 0 | 23 | 56 | 70 | **343** |
| Yeelanna | 106 | 79 | 66 | 23 | 0 | 0 | 0 | 0 | 20 | 53 | 82 | 93 | **522** |
| Yongala | 136 | 105 | 87 | 38 | 7 | 0 | 0 | 17 | 57 | 89 | 118 | 129 | **782** |

(1) The estimate for this location excludes average annual rainfall due to high variability

# Appendix 16
## Estimated Average Runoff for Towns and Adjacent Catchments

Estimation methods for stormwater runoff are used owing to the difficulty of obtaining accurate field measurements. The methods often need to be applied under climatic conditions very different from those under which they were developed. To meet this need Fleming (1994) determined volumetric runoff coefficients (VRC) that relate rainfall to runoff suitable for urban (town areas) and rural (adjoining) catchments for temperate climates in South Australia.

*Catchment Runoff (mm) = VRC . Rainfall (mm)*

Table 75 and Table 76 below present the estimated average monthly and average annual runoff expressed as a 'depth of water' for towns (urban) and adjoining catchments (rural) in South Australia respectively. The annual runoff expressed as a volume per hectare for the given town. Care should be exercised when interpreting the average runoff figures as the actual runoff can deviate widely from the estimated average reflecting the variability of rainfall of the region

**Table 75 Estimated Average Monthly Stormwater Runoff from Towns**

**Estimated Average Monthly Urban Runoff (mm) and Volume (kL/ha)**

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VRC (Urban) | 0.275 | 0.25 | 0.24 | 0.25 | 0.26 | 0.275 | 0.295 | 0.31 | 0.32 | 0.32 | 0.31 | 0.28 | 0.275 | |
| Adelaide | 6 | 5 | 6 | 11 | 18 | 20 | 20 | 19 | 16 | 14 | 10 | 7 | **152** | **1516** |
| Alawoona | 5 | 5 | 3 | 5 | 8 | 8 | 9 | 9 | 9 | 9 | 6 | 4 | **81** | **810** |
| Aldinga | 5 | 5 | 5 | 10 | 16 | 20 | 20 | 19 | 17 | 13 | 8 | 6 | **145** | **1448** |
| American River | 5 | 5 | 4 | 10 | 16 | 22 | 25 | 22 | 17 | 12 | 8 | 6 | **151** | **1514** |
| Andamooka | 6 | 6 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 6 | 4 | 6 | **58** | **579** |
| Angaston | 6 | 6 | 6 | 11 | 17 | 20 | 20 | 22 | 20 | 16 | 11 | 8 | **161** | **1611** |
| Appila | 5 | 5 | 5 | 7 | 10 | 12 | 12 | 13 | 13 | 12 | 9 | 7 | **110** | **1099** |
| Ardrossan | 4 | 4 | 4 | 8 | 11 | 12 | 12 | 13 | 12 | 10 | 7 | 5 | **100** | **1004** |
| Arno Bay | 3 | 5 | 4 | 7 | 9 | 10 | 11 | 11 | 11 | 10 | 7 | 5 | **93** | **929** |
| Auburn | 7 | 6 | 6 | 11 | 18 | 20 | 22 | 24 | 22 | 17 | 11 | 8 | **172** | **1723** |
| Balaklava | 5 | 5 | 4 | 9 | 11 | 12 | 13 | 14 | 13 | 12 | 7 | 6 | **110** | **1103** |
| Barmera | 5 | 5 | 3 | 5 | 6 | 6 | 7 | 6 | 7 | 9 | 7 | 4 | **68** | **676** |
| Beachport | 6 | 6 | 7 | 17 | 20 | 27 | 35 | 33 | 24 | 17 | 14 | 9 | **214** | **2142** |
| Berri | 5 | 5 | 3 | 6 | 7 | 6 | 7 | 7 | 9 | 10 | 8 | 4 | **77** | **771** |
| Birdwood | 7 | 6 | 6 | 14 | 21 | 28 | 30 | 31 | 26 | 20 | 12 | 9 | **210** | **2099** |
| Blackrock | 5 | 5 | 4 | 5 | 8 | 9 | 9 | 11 | 10 | 9 | 7 | 6 | **88** | **877** |
| Blanche Town | 5 | 5 | 4 | 6 | 7 | 7 | 7 | 8 | 7 | 9 | 6 | 5 | **74** | **741** |
| Blyth | 6 | 5 | 4 | 9 | 13 | 14 | 14 | 16 | 15 | 13 | 8 | 6 | **123** | **1232** |
| Booborowie | 5 | 6 | 4 | 8 | 12 | 12 | 16 | 17 | 15 | 14 | 9 | 6 | **124** | **1236** |

**Estimated Average Monthly Urban Runoff (mm) and Volume (kL/ha)**

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Booleroo Centre | 6 | 5 | 4 | 7 | 10 | 13 | 12 | 14 | 13 | 12 | 8 | 6 | **111** | **1110** |
| Borda | 4 | 5 | 6 | 12 | 21 | 30 | 31 | 27 | 18 | 14 | 8 | 6 | **181** | **1810** |
| Bordertown | 6 | 6 | 5 | 10 | 14 | 16 | 17 | 18 | 17 | 14 | 11 | 8 | **140** | **1403** |
| Bridgewater | 9 | 8 | 9 | 20 | 33 | 42 | 45 | 45 | 36 | 28 | 16 | 11 | **301** | **3008** |
| Brinkworth | 5 | 6 | 4 | 7 | 12 | 14 | 14 | 15 | 14 | 12 | 8 | 6 | **117** | **1170** |
| Bruce | 5 | 5 | 3 | 4 | 7 | 8 | 7 | 8 | 8 | 8 | 7 | 6 | **75** | **751** |
| Buckleboo | 6 | 5 | 3 | 5 | 8 | 9 | 11 | 11 | 11 | 9 | 8 | 5 | **90** | **903** |
| Bundaleer | 6 | 6 | 5 | 9 | 15 | 20 | 21 | 22 | 20 | 17 | 11 | 8 | **160** | **1595** |
| Bute | 5 | 5 | 4 | 8 | 12 | 15 | 14 | 15 | 13 | 12 | 7 | 5 | **114** | **1141** |
| Caliph | 6 | 5 | 4 | 6 | 8 | 7 | 8 | 9 | 8 | 10 | 7 | 5 | **84** | **835** |
| Callington | 6 | 5 | 5 | 8 | 10 | 12 | 12 | 13 | 13 | 12 | 8 | 6 | **107** | **1074** |
| Ceduna | 3 | 4 | 4 | 5 | 11 | 9 | 12 | 11 | 9 | 8 | 7 | 5 | **89** | **890** |
| Clare | 7 | 6 | 6 | 12 | 20 | 22 | 24 | 24 | 23 | 19 | 11 | 8 | **182** | **1819** |
| Clarendon | 7 | 7 | 8 | 18 | 26 | 32 | 32 | 32 | 27 | 21 | 13 | 10 | **235** | **2349** |
| Claypans | 5 | 6 | 4 | 6 | 8 | 7 | 9 | 9 | 9 | 11 | 7 | 6 | **87** | **872** |
| Cleve | 4 | 6 | 5 | 8 | 11 | 13 | 13 | 15 | 14 | 12 | 9 | 6 | **114** | **1144** |
| Cockburn | 5 | 5 | 4 | 4 | 6 | 5 | 4 | 4 | 5 | 6 | 6 | 5 | **58** | **577** |
| Coober Pedy | 5 | 6 | 3 | 2 | 4 | 4 | 2 | 3 | 3 | 5 | 4 | 4 | **44** | **439** |
| Cook | 3 | 3 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | **48** | **485** |
| Cooke Plains | 5 | 5 | 5 | 8 | 10 | 12 | 12 | 14 | 13 | 12 | 8 | 6 | **110** | **1099** |
| Coomandook | 5 | 5 | 5 | 8 | 13 | 14 | 15 | 16 | 14 | 13 | 9 | 7 | **123** | **1227** |
| Coonalpyn | 6 | 5 | 5 | 9 | 13 | 15 | 16 | 17 | 15 | 14 | 9 | 7 | **131** | **1311** |
| Copeville | 4 | 5 | 4 | 5 | 8 | 8 | 9 | 10 | 10 | 10 | 7 | 6 | **85** | **852** |
| Corny Point | 4 | 4 | 4 | 9 | 14 | 18 | 19 | 18 | 14 | 11 | 7 | 5 | **127** | **1271** |
| Cowell | 4 | 5 | 4 | 7 | 8 | 8 | 7 | 8 | 9 | 9 | 6 | 4 | **80** | **801** |
| Cradock | 6 | 6 | 4 | 5 | 7 | 9 | 10 | 8 | 8 | 7 | 6 | 5 | **80** | **804** |
| Crystal Brook | 5 | 5 | 4 | 8 | 11 | 14 | 13 | 14 | 14 | 13 | 8 | 6 | **116** | **1158** |
| Cummins | 3 | 4 | 3 | 7 | 14 | 18 | 22 | 20 | 14 | 11 | 7 | 5 | **125** | **1254** |
| Curramulka | 4 | 4 | 4 | 9 | 13 | 17 | 17 | 17 | 14 | 12 | 7 | 5 | **123** | **1233** |
| Darke Peak | 4 | 6 | 3 | 7 | 11 | 13 | 14 | 16 | 14 | 11 | 7 | 6 | **112** | **1121** |
| Denial Bay | 2 | 5 | 4 | 6 | 10 | 12 | 12 | 13 | 8 | 8 | 6 | 5 | **91** | **909** |
| Edithburgh | 4 | 4 | 4 | 9 | 13 | 16 | 17 | 16 | 13 | 11 | 7 | 5 | **119** | **1191** |
| Elliston | 3 | 4 | 4 | 7 | 14 | 21 | 21 | 19 | 12 | 10 | 6 | 4 | **124** | **1238** |
| Ernabella | 11 | 9 | 6 | 5 | 5 | 5 | 4 | 5 | 4 | 8 | 7 | 8 | **76** | **755** |
| Eudunda | 6 | 6 | 5 | 8 | 12 | 14 | 15 | 17 | 15 | 13 | 9 | 7 | **126** | **1262** |
| Eurelia | 6 | 5 | 4 | 5 | 9 | 10 | 10 | 12 | 10 | 9 | 8 | 6 | **93** | **930** |
| Farrell Flat | 6 | 5 | 4 | 9 | 14 | 16 | 17 | 19 | 17 | 14 | 8 | 7 | **137** | **1374** |
| Fowlers Bay | 2 | 3 | 3 | 6 | 11 | 14 | 13 | 11 | 7 | 7 | 5 | 3 | **85** | **850** |
| Frances | 6 | 6 | 6 | 10 | 14 | 16 | 19 | 20 | 18 | 16 | 11 | 8 | **150** | **1498** |
| Freeling Railway | 6 | 5 | 5 | 9 | 13 | 15 | 16 | 17 | 16 | 13 | 9 | 7 | **130** | **1305** |
| Gawler Railway | 5 | 4 | 6 | 11 | 15 | 18 | 17 | 18 | 16 | 14 | 9 | 6 | **138** | **1380** |
| Georgetown | 6 | 6 | 5 | 9 | 14 | 16 | 17 | 18 | 17 | 15 | 9 | 7 | **136** | **1356** |
| Geranium | 5 | 6 | 5 | 8 | 12 | 12 | 13 | 15 | 14 | 12 | 9 | 7 | **117** | **1166** |
| Gladstone | 6 | 5 | 4 | 8 | 11 | 13 | 14 | 15 | 15 | 13 | 9 | 6 | **120** | **1205** |
| Glen Osmond | 7 | 5 | 6 | 14 | 21 | 24 | 25 | 24 | 20 | 17 | 11 | 8 | **181** | **1815** |
| Glenelg | 5 | 5 | 5 | 9 | 15 | 17 | 17 | 17 | 14 | 12 | 8 | 6 | **130** | **1302** |
| Goolwa | 6 | 5 | 5 | 10 | 14 | 17 | 18 | 17 | 15 | 12 | 9 | 6 | **133** | **1329** |
| Greenock | 6 | 6 | 5 | 12 | 16 | 18 | 19 | 21 | 19 | 16 | 10 | 7 | **155** | **1547** |
| Gulnare | 6 | 6 | 4 | 8 | 14 | 16 | 17 | 18 | 17 | 14 | 10 | 7 | **135** | **1347** |
| Hallet | 5 | 5 | 4 | 8 | 12 | 15 | 16 | 17 | 17 | 14 | 9 | 6 | **129** | **1292** |
| Hamely Bridge | 6 | 5 | 4 | 9 | 12 | 14 | 14 | 16 | 14 | 13 | 8 | 7 | **122** | **1221** |
| Hammond | 5 | 5 | 4 | 5 | 7 | 8 | 8 | 9 | 8 | 8 | 6 | 5 | **77** | **767** |
| Hawker | 6 | 5 | 4 | 5 | 8 | 11 | 10 | 10 | 9 | 7 | 7 | 5 | **87** | **871** |
| Hoyleton | 6 | 5 | 5 | 9 | 13 | 15 | 16 | 17 | 16 | 13 | 9 | 6 | **129** | **1291** |
| Inman Valley | 8 | 7 | 6 | 17 | 23 | 27 | 32 | 30 | 24 | 21 | 12 | 9 | **216** | **2161** |

## Estimated Average Monthly Urban Runoff (mm) and Volume (kL/ha)

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iron Knob | 5 | 6 | 3 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 5 | 4 | **62** | **621** |
| Jamestown | 6 | 5 | 5 | 8 | 12 | 15 | 16 | 17 | 17 | 15 | 11 | 8 | **134** | **1337** |
| Kadina | 4 | 5 | 5 | 9 | 13 | 14 | 14 | 14 | 12 | 11 | 7 | 5 | **112** | **1122** |
| Kapunda | 6 | 5 | 6 | 10 | 15 | 16 | 17 | 19 | 17 | 15 | 9 | 7 | **142** | **1417** |
| Karoonda | 5 | 5 | 4 | 6 | 10 | 10 | 10 | 11 | 11 | 11 | 7 | 6 | **96** | **956** |
| Keith | 5 | 6 | 5 | 9 | 14 | 14 | 16 | 18 | 16 | 14 | 10 | 7 | **135** | **1349** |
| Kimba | 4 | 6 | 4 | 6 | 10 | 11 | 12 | 13 | 12 | 10 | 7 | 5 | **99** | **988** |
| Kingscote | 4 | 4 | 4 | 9 | 15 | 20 | 23 | 20 | 15 | 12 | 7 | 5 | **139** | **1387** |
| Kingston SE | 6 | 5 | 6 | 12 | 19 | 24 | 27 | 24 | 19 | 14 | 10 | 8 | **172** | **1724** |
| Koolunga | 5 | 5 | 4 | 7 | 11 | 13 | 13 | 14 | 13 | 12 | 8 | 6 | **112** | **1123** |
| Kyancutta | 4 | 5 | 3 | 5 | 10 | 11 | 12 | 13 | 11 | 9 | 7 | 5 | **94** | **939** |
| Kybybolite | 6 | 6 | 6 | 10 | 15 | 16 | 21 | 21 | 20 | 16 | 11 | 9 | **158** | **1575** |
| Lameroo | 6 | 6 | 5 | 7 | 11 | 11 | 12 | 13 | 14 | 12 | 8 | 6 | **112** | **1120** |
| Langhorne Creek | 5 | 5 | 5 | 8 | 11 | 12 | 13 | 13 | 12 | 12 | 8 | 6 | **112** | **1117** |
| Laura | 6 | 6 | 5 | 9 | 12 | 15 | 16 | 17 | 17 | 14 | 9 | 6 | **131** | **1314** |
| Leigh Creek (#) | 8 | 6 | 2 | 4 | 5 | 4 | 5 | 6 | 5 | 4 | 3 | 5 | **58** | **584** |
| Lenswood (DOA) | 12 | 10 | 12 | 23 | 30 | 33 | 44 | 43 | 37 | 28 | 15 | 11 | **298** | **2982** |
| Lochiel | 4 | 5 | 4 | 7 | 12 | 12 | 13 | 14 | 14 | 12 | 8 | 6 | **109** | **1094** |
| Lock | 4 | 5 | 4 | 6 | 12 | 15 | 17 | 17 | 13 | 11 | 8 | 6 | **116** | **1162** |
| Loxton | 5 | 6 | 4 | 4 | 7 | 7 | 7 | 8 | 9 | 9 | 7 | 5 | **78** | **782** |
| Lucindale | 6 | 5 | 6 | 12 | 17 | 22 | 26 | 24 | 20 | 16 | 11 | 9 | **175** | **1754** |
| Lyndoch | 5 | 5 | 5 | 11 | 16 | 21 | 22 | 23 | 20 | 17 | 10 | 7 | **163** | **1626** |
| Macclesfield | 7 | 7 | 7 | 15 | 21 | 27 | 30 | 30 | 27 | 21 | 13 | 9 | **214** | **2142** |
| Maggea | 5 | 5 | 3 | 5 | 7 | 7 | 8 | 9 | 8 | 8 | 7 | 6 | **77** | **767** |
| Maitland | 5 | 6 | 5 | 11 | 16 | 19 | 19 | 19 | 16 | 14 | 9 | 6 | **145** | **1449** |
| Mallala | 5 | 5 | 4 | 9 | 12 | 13 | 13 | 14 | 13 | 12 | 8 | 6 | **115** | **1152** |
| Mannum | 4 | 4 | 4 | 7 | 8 | 9 | 8 | 10 | 10 | 9 | 6 | 5 | **83** | **835** |
| Manoora | 5 | 5 | 5 | 9 | 15 | 16 | 17 | 20 | 18 | 15 | 9 | 7 | **140** | **1402** |
| Marrabel | 6 | 5 | 5 | 10 | 15 | 17 | 19 | 21 | 19 | 16 | 13 | 7 | **154** | **1535** |
| Marree (Est.) | 5 | 5 | 4 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 5 | **46** | **459** |
| McLaren Vale | 6 | 7 | 5 | 13 | 19 | 20 | 23 | 21 | 16 | 16 | 11 | 8 | **164** | **1637** |
| Meadows | 8 | 8 | 9 | 18 | 26 | 33 | 35 | 35 | 32 | 25 | 15 | 11 | **255** | **2546** |
| Melrose | 8 | 7 | 6 | 10 | 17 | 21 | 22 | 22 | 20 | 18 | 11 | 8 | **169** | **1689** |
| Meningie | 5 | 4 | 5 | 10 | 15 | 17 | 18 | 17 | 15 | 13 | 9 | 6 | **134** | **1339** |
| Meribah | 5 | 5 | 3 | 6 | 8 | 7 | 9 | 8 | 9 | 9 | 7 | 4 | **78** | **785** |
| Milang (EWS) | 6 | 8 | 5 | 9 | 10 | 11 | 13 | 13 | 11 | 12 | 6 | 4 | **105** | **1051** |
| Mindarie | 5 | 5 | 3 | 5 | 8 | 8 | 9 | 11 | 10 | 10 | 7 | 5 | **86** | **862** |
| Minlaton | 4 | 4 | 4 | 9 | 14 | 17 | 17 | 18 | 14 | 12 | 7 | 5 | **126** | **1260** |
| Minnipa PO (A) | 4 | 5 | 4 | 5 | 10 | 13 | 14 | 14 | 11 | 9 | 7 | 5 | **101** | **1014** |
| Monarto | 6 | 6 | 5 | 10 | 18 | 21 | 23 | 25 | 23 | 18 | 11 | 8 | **173** | **1733** |
| Moonta | 4 | 5 | 5 | 9 | 12 | 13 | 14 | 13 | 11 | 10 | 7 | 5 | **107** | **1066** |
| Morgan | 4 | 5 | 3 | 4 | 7 | 7 | 6 | 7 | 8 | 8 | 5 | 5 | **67** | **675** |
| Mt Barker | 8 | 7 | 7 | 15 | 24 | 28 | 31 | 32 | 28 | 22 | 12 | 9 | **223** | **2227** |
| Mt Bold | 7 | 8 | 6 | 16 | 24 | 25 | 31 | 29 | 23 | 21 | 13 | 10 | **211** | **2112** |
| Mt Bryan | 5 | 6 | 4 | 7 | 12 | 14 | 16 | 17 | 16 | 13 | 8 | 7 | **126** | **1262** |
| Mt Burr | 8 | 8 | 8 | 18 | 22 | 27 | 34 | 31 | 25 | 20 | 15 | 11 | **226** | **2260** |
| Mt Compass | 8 | 8 | 6 | 16 | 27 | 30 | 38 | 34 | 29 | 22 | 13 | 9 | **241** | **2410** |
| Mt Cooper | 3 | 4 | 4 | 7 | 14 | 17 | 20 | 17 | 15 | 11 | 9 | 5 | **125** | **1246** |
| Mt Crawford Forest | 7 | 8 | 7 | 15 | 25 | 26 | 33 | 32 | 27 | 22 | 11 | 8 | **220** | **2204** |
| Mt Gambier (A) | 7 | 8 | 8 | 15 | 19 | 21 | 30 | 28 | 22 | 20 | 15 | 10 | **203** | **2032** |
| Mt Pleasant | 7 | 7 | 6 | 13 | 20 | 26 | 27 | 28 | 25 | 19 | 11 | 8 | **196** | **1965** |
| Murray Bridge | 5 | 5 | 5 | 7 | 9 | 10 | 10 | 11 | 12 | 11 | 8 | 6 | **98** | **976** |
| Myponga | 7 | 7 | 6 | 15 | 25 | 31 | 34 | 30 | 26 | 20 | 12 | 8 | **218** | **2183** |
| Nackara | 6 | 6 | 5 | 4 | 7 | 8 | 8 | 8 | 8 | 8 | 7 | 6 | **80** | **798** |
| Naracoorte | 6 | 5 | 6 | 11 | 16 | 20 | 22 | 22 | 20 | 17 | 11 | 8 | **167** | **1667** |
| Nildottie | 5 | 4 | 4 | 5 | 7 | 6 | 7 | 7 | 9 | 10 | 5 | 4 | **72** | **720** |

### Estimated Average Monthly Urban Runoff (mm) and Volume (kL/ha)

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuriootpa | 6 | 5 | 5 | 10 | 15 | 18 | 19 | 20 | 18 | 15 | 10 | 8 | **149** | **1488** |
| Oodlawirra | 8 | 7 | 4 | 5 | 8 | 8 | 8 | 9 | 8 | 8 | 8 | 6 | **88** | **877** |
| Oodnadatta | 8 | 7 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | **49** | **487** |
| Orroroo | 7 | 5 | 4 | 6 | 9 | 11 | 10 | 12 | 10 | 9 | 8 | 6 | **97** | **975** |
| Owen | 6 | 7 | 4 | 10 | 12 | 12 | 15 | 15 | 14 | 13 | 9 | 6 | **123** | **1231** |
| Palmer | 5 | 6 | 5 | 8 | 12 | 12 | 14 | 16 | 15 | 12 | 8 | 7 | **121** | **1208** |
| Parafield AMO (A) | 7 | 5 | 5 | 11 | 12 | 14 | 17 | 16 | 14 | 15 | 9 | 6 | **133** | **1328** |
| Paratoo | 5 | 5 | 4 | 4 | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 6 | **64** | **644** |
| Parawa | 9 | 10 | 8 | 20 | 30 | 36 | 43 | 38 | 29 | 25 | 15 | 10 | **273** | **2731** |
| Parilla | 5 | 6 | 4 | 7 | 10 | 10 | 10 | 12 | 12 | 11 | 8 | 6 | **100** | **1001** |
| Parndana | 5 | 6 | 6 | 12 | 20 | 24 | 29 | 26 | 20 | 15 | 9 | 6 | **178** | **1779** |
| Parrakie | 5 | 6 | 4 | 7 | 11 | 11 | 12 | 14 | 13 | 12 | 8 | 6 | **109** | **1092** |
| Paruna | 4 | 5 | 3 | 5 | 8 | 8 | 9 | 9 | 9 | 10 | 6 | 5 | **79** | **795** |
| Paskeville | 4 | 5 | 4 | 8 | 12 | 14 | 14 | 15 | 12 | 11 | 7 | 5 | **112** | **1123** |
| Peake | 5 | 6 | 5 | 8 | 11 | 11 | 12 | 14 | 13 | 13 | 8 | 7 | **113** | **1134** |
| Peebinga | 7 | 5 | 3 | 7 | 8 | 7 | 9 | 9 | 10 | 11 | 9 | 4 | **89** | **892** |
| Penneshaw | 5 | 5 | 4 | 10 | 15 | 19 | 24 | 20 | 17 | 13 | 9 | 6 | **147** | **1467** |
| Penola | 7 | 6 | 7 | 12 | 18 | 23 | 26 | 27 | 22 | 19 | 13 | 10 | **189** | **1894** |
| Penong | 2 | 5 | 4 | 6 | 11 | 12 | 13 | 13 | 9 | 8 | 6 | 4 | **94** | **941** |
| Peterborough | 6 | 5 | 4 | 6 | 8 | 10 | 10 | 12 | 11 | 9 | 8 | 6 | **94** | **936** |
| Pinnaroo | 5 | 6 | 5 | 6 | 9 | 10 | 10 | 11 | 11 | 11 | 8 | 6 | **97** | **975** |
| Point Pass | 6 | 6 | 4 | 8 | 14 | 13 | 16 | 19 | 16 | 14 | 9 | 7 | **131** | **1306** |
| Policemans Point | 7 | 5 | 6 | 12 | 15 | 17 | 23 | 21 | 14 | 13 | 8 | 8 | **149** | **1489** |
| Poochera | 3 | 5 | 3 | 5 | 10 | 13 | 14 | 14 | 10 | 8 | 6 | 5 | **95** | **948** |
| Port Elliot | 6 | 5 | 5 | 11 | 15 | 18 | 19 | 19 | 17 | 14 | 9 | 6 | **144** | **1442** |
| Pt Augusta | 4 | 4 | 4 | 5 | 7 | 7 | 6 | 7 | 7 | 7 | 6 | 4 | **68** | **684** |
| Pt Broughton | 4 | 5 | 4 | 8 | 11 | 12 | 12 | 12 | 12 | 10 | 7 | 5 | **101** | **1007** |
| Pt Germein | 5 | 5 | 4 | 7 | 10 | 10 | 9 | 11 | 11 | 10 | 7 | 6 | **94** | **941** |
| Pt Lincoln | 4 | 4 | 5 | 9 | 15 | 21 | 23 | 21 | 16 | 11 | 7 | 5 | **139** | **1391** |
| Pt Pirie | 5 | 5 | 4 | 7 | 10 | 11 | 10 | 11 | 11 | 11 | 7 | 6 | **99** | **987** |
| Pt Victoria | 4 | 5 | 4 | 8 | 13 | 14 | 14 | 14 | 12 | 11 | 7 | 5 | **110** | **1099** |
| Pt Vincent | 4 | 5 | 3 | 7 | 10 | 13 | 13 | 14 | 12 | 10 | 7 | 5 | **103** | **1033** |
| Pt Wakefield | 5 | 5 | 5 | 8 | 10 | 10 | 11 | 11 | 10 | 10 | 6 | 5 | **95** | **946** |
| Quorn | 5 | 5 | 3 | 5 | 9 | 11 | 11 | 13 | 10 | 9 | 7 | 6 | **94** | **942** |
| Redhill | 5 | 5 | 4 | 8 | 13 | 15 | 15 | 16 | 14 | 12 | 8 | 6 | **121** | **1212** |
| Renmark | 4 | 5 | 4 | 5 | 7 | 7 | 7 | 8 | 9 | 9 | 7 | 5 | **75** | **754** |
| Riverton | 6 | 5 | 5 | 11 | 16 | 18 | 18 | 21 | 19 | 15 | 10 | 7 | **150** | **1502** |
| Robe | 6 | 5 | 6 | 12 | 20 | 26 | 31 | 26 | 19 | 14 | 9 | 8 | **182** | **1818** |
| Roseworthy AG | 6 | 5 | 5 | 10 | 13 | 15 | 15 | 17 | 15 | 14 | 9 | 6 | **128** | **1276** |
| Roxby Downs (*) | 4 | 5 | 4 | 2 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | **45** | **452** |
| Rudall | 4 | 5 | 4 | 7 | 10 | 10 | 13 | 13 | 12 | 10 | 7 | 6 | **100** | **997** |
| Saddleworth | 6 | 6 | 5 | 10 | 15 | 16 | 17 | 19 | 17 | 15 | 10 | 7 | **142** | **1423** |
| Salisbury | 6 | 5 | 5 | 10 | 15 | 17 | 16 | 17 | 15 | 13 | 9 | 6 | **133** | **1334** |
| Sandalwood | 5 | 5 | 4 | 6 | 9 | 10 | 10 | 11 | 11 | 10 | 7 | 6 | **94** | **945** |
| Sedan | 4 | 5 | 4 | 6 | 8 | 9 | 9 | 11 | 10 | 10 | 6 | 5 | **86** | **864** |
| Smithfield | 5 | 5 | 5 | 7 | 15 | 16 | 16 | 17 | 16 | 14 | 9 | 7 | **131** | **1313** |
| Smokey Bay | 2 | 4 | 3 | 5 | 7 | 12 | 13 | 11 | 8 | 6 | 5 | 4 | **81** | **811** |
| Snowtown | 5 | 5 | 4 | 8 | 12 | 14 | 14 | 16 | 13 | 12 | 7 | 6 | **116** | **1160** |
| Spalding | 5 | 6 | 4 | 7 | 13 | 15 | 16 | 17 | 16 | 13 | 9 | 7 | **127** | **1273** |
| Stansbury | 4 | 4 | 4 | 8 | 13 | 15 | 16 | 16 | 14 | 12 | 7 | 5 | **118** | **1182** |
| Stockport | 6 | 5 | 5 | 9 | 13 | 14 | 15 | 17 | 16 | 14 | 9 | 7 | **129** | **1289** |
| Stockwell | 6 | 5 | 5 | 10 | 14 | 17 | 18 | 20 | 18 | 15 | 10 | 7 | **144** | **1442** |
| Strathalbyn | 6 | 6 | 6 | 10 | 15 | 16 | 19 | 19 | 17 | 14 | 9 | 7 | **142** | **1418** |
| Streaky Bay | 3 | 4 | 4 | 6 | 12 | 18 | 18 | 16 | 11 | 8 | 6 | 3 | **110** | **1096** |
| Sutherlands | 4 | 5 | 4 | 5 | 8 | 8 | 8 | 10 | 10 | 9 | 6 | 5 | **82** | **818** |

### Estimated Average Monthly Urban Runoff (mm) and Volume (kL/ha)

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Swan Reach | 4 | 5 | 4 | 5 | 8 | 7 | 7 | 8 | 9 | 9 | 6 | 5 | **77** | **772** |
| Tailem Bend | 5 | 6 | 5 | 7 | 11 | 11 | 11 | 12 | 12 | 12 | 9 | 7 | **109** | **1092** |
| Tanunda | 6 | 5 | 6 | 11 | 16 | 20 | 20 | 21 | 19 | 16 | 10 | 7 | **157** | **1573** |
| Tarlee | 6 | 5 | 5 | 10 | 14 | 15 | 16 | 18 | 16 | 14 | 10 | 7 | **135** | **1345** |
| Terowie | 6 | 5 | 4 | 6 | 8 | 9 | 10 | 12 | 11 | 10 | 7 | 7 | **95** | **947** |
| Tintinara | 5 | 6 | 5 | 10 | 14 | 14 | 16 | 18 | 16 | 14 | 10 | 8 | **135** | **1351** |
| Torrens Island | 6 | 6 | 4 | 10 | 13 | 15 | 16 | 15 | 14 | 13 | 9 | 7 | **126** | **1263** |
| Tumby Bay | 3 | 4 | 3 | 6 | 10 | 12 | 14 | 14 | 12 | 10 | 7 | 5 | **101** | **1009** |
| Two Wells | 5 | 5 | 4 | 9 | 12 | 14 | 14 | 14 | 12 | 12 | 7 | 6 | **114** | **1144** |
| Ungarra | 3 | 5 | 4 | 7 | 12 | 15 | 19 | 17 | 15 | 11 | 7 | 6 | **119** | **1195** |
| Uraidla | 10 | 9 | 10 | 22 | 35 | 44 | 46 | 44 | 37 | 29 | 17 | 13 | **313** | **3131** |
| Victor Harbor | 6 | 5 | 5 | 11 | 16 | 20 | 22 | 20 | 18 | 15 | 9 | 6 | **154** | **1536** |
| Virginia | 6 | 5 | 5 | 9 | 13 | 15 | 15 | 16 | 14 | 12 | 8 | 7 | **124** | **1244** |
| Wallaroo | 4 | 4 | 5 | 8 | 12 | 13 | 12 | 12 | 11 | 10 | 7 | 4 | **103** | **1029** |
| Wanbi (A) | 4 | 5 | 5 | 6 | 8 | 7 | 10 | 10 | 10 | 11 | 8 | 5 | **86** | **864** |
| Warooka | 4 | 4 | 4 | 9 | 15 | 18 | 19 | 18 | 15 | 12 | 7 | 5 | **128** | **1279** |
| Watervale | 7 | 7 | 6 | 13 | 20 | 23 | 24 | 26 | 23 | 19 | 12 | 9 | **189** | **1887** |
| Wellington | 4 | 3 | 6 | 9 | 10 | 13 | 12 | 13 | 13 | 12 | 7 | 6 | **107** | **1070** |
| Western River | 5 | 5 | 5 | 12 | 20 | 28 | 34 | 29 | 20 | 15 | 10 | 6 | **188** | **1884** |
| Whyalla | 5 | 6 | 4 | 5 | 7 | 7 | 6 | 8 | 8 | 9 | 7 | 6 | **78** | **782** |
| Whyte Yarcowie | 6 | 5 | 4 | 6 | 9 | 10 | 11 | 12 | 12 | 10 | 7 | 6 | **98** | **985** |
| Williamstown | 6 | 6 | 6 | 14 | 21 | 28 | 27 | 28 | 23 | 19 | 11 | 8 | **196** | **1963** |
| Willowie | 5 | 5 | 4 | 5 | 9 | 10 | 9 | 11 | 11 | 10 | 7 | 6 | **91** | **907** |
| Willunga | 6 | 6 | 7 | 13 | 22 | 26 | 27 | 25 | 22 | 18 | 10 | 7 | **187** | **1872** |
| Wilmington | 7 | 5 | 4 | 8 | 13 | 15 | 16 | 17 | 15 | 12 | 9 | 6 | **126** | **1262** |
| Wilpena Heat Station | 8 | 7 | 5 | 5 | 10 | 14 | 15 | 12 | 10 | 9 | 7 | 6 | **108** | **1079** |
| Wirrabra | 6 | 6 | 5 | 9 | 13 | 16 | 17 | 18 | 17 | 15 | 10 | 7 | **138** | **1380** |
| Wolseley | 6 | 6 | 5 | 10 | 14 | 15 | 17 | 18 | 17 | 15 | 10 | 7 | **139** | **1393** |
| Woomera (AMO) | 4 | 5 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 4 | **54** | **543** |
| Worlds End Creek | 4 | 5 | 3 | 5 | 8 | 9 | 10 | 11 | 12 | 9 | 7 | 6 | **89** | **893** |
| Yacka | 5 | 5 | 4 | 8 | 12 | 13 | 14 | 15 | 14 | 12 | 8 | 6 | **116** | **1162** |
| Yalata | 3 | 3 | 2 | 5 | 11 | 15 | 12 | 11 | 7 | 7 | 5 | 2 | **84** | **836** |
| Yankalilla | 5 | 6 | 6 | 11 | 19 | 24 | 24 | 22 | 19 | 15 | 9 | 7 | **166** | **1662** |
| Yeelanna | 3 | 4 | 3 | 6 | 12 | 16 | 20 | 18 | 14 | 10 | 7 | 5 | **118** | **1181** |
| Yongala | 6 | 5 | 4 | 7 | 10 | 11 | 12 | 14 | 12 | 11 | 9 | 7 | **106** | **1062** |

## Table 76 Estimated Average Monthly Runoff from Catchments Adjoining Towns

| **Estimated Average Monthly Rural Runoff (mm) and Volume (kL/ha)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Towns** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total (mm)** | **Vol. (kL/ha)** |
| VRC (Rural) | 0.05 | 0.04 | 0.03 | 0.06 | 0.09 | 0.14 | 0.18 | 0.2 | 0.19 | 0.13 | 0.13 | 0.08 | | |
| Adelaide | 1 | 1 | 1 | 3 | 6 | 10 | 12 | 12 | 10 | 6 | 4 | 2 | **68** | **675** |
| Alawoona | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 5 | 4 | 3 | 1 | **34** | **341** |
| Aldinga | 1 | 1 | 1 | 2 | 6 | 10 | 12 | 12 | 10 | 5 | 3 | 2 | **66** | **658** |
| American River | 1 | 1 | 0 | 2 | 5 | 11 | 15 | 14 | 10 | 5 | 3 | 2 | **71** | **710** |
| Andamooka | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | **21** | **210** |
| Angaston | 1 | 1 | 1 | 3 | 6 | 10 | 12 | 14 | 12 | 7 | 4 | 2 | **73** | **727** |
| Appila | 1 | 1 | 1 | 2 | 3 | 6 | 7 | 9 | 8 | 5 | 4 | 2 | **48** | **477** |
| Ardrossan | 1 | 1 | 0 | 2 | 4 | 6 | 7 | 9 | 7 | 4 | 3 | 1 | **44** | **444** |
| Arno Bay | 1 | 1 | 0 | 2 | 3 | 5 | 7 | 7 | 7 | 4 | 3 | 2 | **41** | **406** |
| Auburn | 1 | 1 | 1 | 3 | 6 | 10 | 14 | 15 | 13 | 7 | 5 | 2 | **78** | **777** |
| Balaklava | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 9 | 8 | 5 | 3 | 2 | **48** | **480** |
| Barmera | 1 | 1 | 0 | 1 | 2 | 3 | 4 | 4 | 4 | 4 | 3 | 1 | **28** | **276** |
| Beachport | 1 | 1 | 1 | 4 | 7 | 14 | 21 | 21 | 14 | 7 | 6 | 3 | **100** | **995** |
| Berri | 1 | 1 | 0 | 1 | 2 | 3 | 5 | 5 | 5 | 4 | 3 | 1 | **32** | **319** |
| Birdwood | 1 | 1 | 1 | 3 | 7 | 14 | 18 | 20 | 16 | 8 | 5 | 2 | **97** | **972** |
| Blackrock | 1 | 1 | 0 | 1 | 3 | 5 | 5 | 7 | 6 | 4 | 3 | 2 | **38** | **378** |
| Blanche Town | 1 | 1 | 0 | 1 | 3 | 4 | 4 | 5 | 4 | 4 | 2 | 1 | **30** | **303** |
| Blyth | 1 | 1 | 1 | 2 | 5 | 7 | 9 | 10 | 9 | 5 | 3 | 2 | **54** | **544** |
| Booborowie | 1 | 1 | 0 | 2 | 4 | 6 | 10 | 11 | 9 | 6 | 4 | 2 | **55** | **555** |
| Booleroo Centre | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 9 | 8 | 5 | 4 | 2 | **49** | **485** |
| Borda | 1 | 1 | 1 | 3 | 7 | 15 | 19 | 17 | 10 | 6 | 4 | 2 | **85** | **853** |
| Bordertown | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 10 | 6 | 4 | 2 | **62** | **621** |
| Bridgewater | 2 | 1 | 1 | 5 | 12 | 21 | 28 | 29 | 21 | 11 | 7 | 3 | **140** | **1405** |
| Brinkworth | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 10 | 8 | 5 | 3 | 2 | **52** | **519** |
| Bruce | 1 | 1 | 0 | 1 | 2 | 4 | 5 | 5 | 5 | 3 | 3 | 2 | **32** | **315** |
| Buckleboo | 1 | 1 | 0 | 1 | 3 | 4 | 6 | 7 | 6 | 4 | 3 | 1 | **39** | **390** |
| Bundaleer | 1 | 1 | 1 | 2 | 5 | 10 | 13 | 14 | 12 | 7 | 4 | 2 | **73** | **727** |
| Bute | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 9 | 8 | 5 | 3 | 1 | **51** | **507** |
| Caliph | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 5 | 4 | 3 | 2 | **34** | **344** |
| Callington | 1 | 1 | 1 | 2 | 3 | 6 | 7 | 9 | 8 | 5 | 3 | 2 | **47** | **468** |
| Ceduna | 1 | 1 | 1 | 1 | 4 | 5 | 7 | 7 | 6 | 3 | 3 | 1 | **39** | **390** |
| Clare | 1 | 1 | 1 | 3 | 7 | 11 | 15 | 16 | 14 | 8 | 5 | 2 | **82** | **823** |
| Clarendon | 1 | 1 | 1 | 4 | 9 | 17 | 20 | 21 | 16 | 9 | 6 | 3 | **107** | **1070** |
| Claypans | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 6 | 6 | 4 | 3 | 2 | **36** | **363** |
| Cleve | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 | 8 | 5 | 4 | 2 | **50** | **503** |
| Cockburn | 1 | 1 | 0 | 1 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 1 | **22** | **219** |
| Coober Pedy | 1 | 1 | 0 | 0 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | **16** | **156** |
| Cook | 1 | 1 | 0 | 1 | 1 | 3 | 2 | 3 | 2 | 2 | 2 | 1 | **19** | **190** |
| Cooke Plains | 1 | 1 | 1 | 2 | 4 | 6 | 7 | 9 | 8 | 5 | 3 | 2 | **48** | **480** |
| Coomandook | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 10 | 8 | 5 | 4 | 2 | **54** | **542** |
| Coonalpyn | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 9 | 6 | 4 | 2 | **58** | **581** |
| Copeville | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 6 | 4 | 3 | 2 | **36** | **360** |
| Corny Point | 1 | 1 | 0 | 2 | 5 | 9 | 12 | 12 | 8 | 4 | 3 | 1 | **59** | **588** |
| Cowell | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 4 | 3 | 1 | **33** | **332** |
| Cradock | 1 | 1 | 0 | 1 | 2 | 5 | 6 | 5 | 5 | 3 | 3 | 2 | **34** | **338** |
| Crystal Brook | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 9 | 8 | 5 | 3 | 2 | **51** | **509** |
| Cummins | 1 | 1 | 0 | 2 | 5 | 9 | 13 | 13 | 9 | 4 | 3 | 1 | **60** | **596** |
| Curramulka | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 9 | 5 | 3 | 2 | **56** | **560** |
| Darke Peak | 1 | 1 | 0 | 2 | 4 | 7 | 9 | 10 | 8 | 4 | 3 | 2 | **51** | **507** |
| Denial Bay | 0 | 1 | 1 | 1 | 4 | 6 | 8 | 9 | 5 | 3 | 3 | 1 | **41** | **406** |

## Estimated Average Monthly Rural Runoff (mm) and Volume (kL/ha)

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Edithburgh | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 8 | 4 | 3 | 1 | **54** | **541** |
| Elliston | 1 | 1 | 0 | 2 | 5 | 11 | 13 | 12 | 7 | 4 | 3 | 1 | **59** | **585** |
| Ernabella | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | **25** | **253** |
| Eudunda | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 11 | 9 | 5 | 4 | 2 | **56** | **558** |
| Eurelia | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 8 | 6 | 4 | 3 | 2 | **40** | **398** |
| Farrell Flat | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 12 | 10 | 6 | 4 | 2 | **62** | **620** |
| Fowlers Bay | 0 | 0 | 0 | 1 | 4 | 7 | 8 | 7 | 4 | 3 | 2 | 1 | **39** | **387** |
| Frances | 1 | 1 | 1 | 2 | 5 | 8 | 11 | 13 | 11 | 7 | 5 | 2 | **67** | **668** |
| Freeling Railway | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 9 | 5 | 4 | 2 | **58** | **580** |
| Gawler Railway | 1 | 1 | 1 | 3 | 5 | 9 | 10 | 11 | 10 | 6 | 4 | 2 | **61** | **614** |
| Georgetown | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 10 | 6 | 4 | 2 | **61** | **606** |
| Geranium | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 | 8 | 5 | 4 | 2 | **51** | **510** |
| Gladstone | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 10 | 9 | 5 | 4 | 2 | **53** | **533** |
| Glen Osmond | 1 | 1 | 1 | 3 | 7 | 12 | 15 | 15 | 12 | 7 | 5 | 2 | **82** | **821** |
| Glenelg | 1 | 1 | 1 | 2 | 5 | 9 | 10 | 11 | 9 | 5 | 4 | 2 | **58** | **580** |
| Goolwa | 1 | 1 | 1 | 2 | 5 | 8 | 11 | 11 | 9 | 5 | 4 | 2 | **59** | **592** |
| Greenock | 1 | 1 | 1 | 3 | 5 | 9 | 12 | 14 | 11 | 7 | 4 | 2 | **69** | **693** |
| Gulnare | 1 | 1 | 0 | 2 | 5 | 8 | 10 | 11 | 10 | 6 | 4 | 2 | **60** | **604** |
| Hallet | 1 | 1 | 1 | 2 | 4 | 8 | 10 | 11 | 10 | 6 | 4 | 2 | **58** | **584** |
| Hamely Bridge | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 10 | 9 | 5 | 4 | 2 | **54** | **538** |
| Hammond | 1 | 1 | 0 | 1 | 2 | 4 | 5 | 6 | 5 | 3 | 2 | 2 | **32** | **324** |
| Hawker | 1 | 1 | 0 | 1 | 3 | 6 | 6 | 7 | 5 | 3 | 3 | 2 | **37** | **372** |
| Hoyleton | 1 | 1 | 1 | 2 | 5 | 7 | 10 | 11 | 9 | 5 | 4 | 2 | **57** | **574** |
| Inman Valley | 1 | 1 | 1 | 4 | 8 | 14 | 19 | 19 | 14 | 8 | 5 | 2 | **98** | **984** |
| Iron Knob | 1 | 1 | 0 | 1 | 2 | 3 | 4 | 4 | 4 | 3 | 2 | 1 | **25** | **249** |
| Jamestown | 1 | 1 | 1 | 2 | 4 | 8 | 10 | 11 | 10 | 6 | 4 | 2 | **60** | **597** |
| Kadina | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 9 | 7 | 4 | 3 | 1 | **49** | **493** |
| Kapunda | 1 | 1 | 1 | 2 | 5 | 8 | 11 | 12 | 10 | 6 | 4 | 2 | **63** | **632** |
| Karoonda | 1 | 1 | 0 | 2 | 3 | 5 | 6 | 7 | 7 | 4 | 3 | 2 | **41** | **410** |
| Keith | 1 | 1 | 1 | 2 | 5 | 7 | 10 | 11 | 10 | 6 | 4 | 2 | **60** | **597** |
| Kimba | 1 | 1 | 0 | 1 | 3 | 5 | 7 | 8 | 7 | 4 | 3 | 1 | **43** | **435** |
| Kingscote | 1 | 1 | 1 | 2 | 5 | 10 | 14 | 13 | 9 | 5 | 3 | 2 | **64** | **644** |
| Kingston SE | 1 | 1 | 1 | 3 | 7 | 12 | 16 | 15 | 11 | 6 | 4 | 2 | **79** | **792** |
| Koolunga | 1 | 1 | 0 | 2 | 4 | 7 | 8 | 9 | 8 | 5 | 3 | 2 | **49** | **495** |
| Kyancutta | 1 | 1 | 0 | 1 | 3 | 6 | 8 | 8 | 6 | 4 | 3 | 2 | **42** | **421** |
| Kybybolite | 1 | 1 | 1 | 2 | 5 | 8 | 13 | 13 | 12 | 7 | 5 | 2 | **70** | **704** |
| Lameroo | 1 | 1 | 1 | 2 | 4 | 6 | 7 | 9 | 8 | 5 | 4 | 2 | **48** | **484** |
| Langhorne Creek | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 9 | 7 | 5 | 4 | 2 | **48** | **482** |
| Laura | 1 | 1 | 1 | 2 | 4 | 8 | 10 | 11 | 10 | 6 | 4 | 2 | **59** | **585** |
| Leigh Creek (#) | 1 | 1 | 0 | 1 | 2 | 2 | 3 | 4 | 3 | 2 | 1 | 1 | **22** | **223** |
| Lenswood (DOA) | 2 | 2 | 1 | 6 | 11 | 17 | 27 | 28 | 22 | 12 | 6 | 3 | **135** | **1355** |
| Lochiel | 1 | 1 | 0 | 2 | 4 | 6 | 8 | 9 | 8 | 5 | 3 | 2 | **49** | **487** |
| Lock | 1 | 1 | 0 | 1 | 4 | 8 | 10 | 11 | 8 | 4 | 3 | 2 | **53** | **535** |
| Loxton | 1 | 1 | 0 | 1 | 2 | 4 | 5 | 5 | 5 | 4 | 3 | 1 | **33** | **325** |
| Lucindale | 1 | 1 | 1 | 3 | 6 | 11 | 16 | 16 | 12 | 7 | 4 | 3 | **80** | **800** |
| Lyndoch | 1 | 1 | 1 | 3 | 6 | 11 | 13 | 15 | 12 | 7 | 4 | 2 | **74** | **744** |
| Macclesfield | 1 | 1 | 1 | 4 | 7 | 14 | 18 | 19 | 16 | 8 | 6 | 3 | **98** | **979** |
| Maggea | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 5 | 3 | 3 | 2 | **32** | **320** |
| Maitland | 1 | 1 | 1 | 3 | 6 | 10 | 12 | 12 | 10 | 6 | 4 | 2 | **65** | **651** |
| Mallala | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 9 | 8 | 5 | 3 | 2 | **51** | **505** |
| Mannum | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 4 | 3 | 1 | **35** | **353** |
| Manoora | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 13 | 11 | 6 | 4 | 2 | **63** | **632** |
| Marrabel | 1 | 1 | 1 | 2 | 5 | 9 | 11 | 14 | 11 | 6 | 6 | 2 | **69** | **692** |
| Marree (Est.) | 1 | 1 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | **16** | **164** |
| McLaren Vale | 1 | 1 | 1 | 3 | 7 | 10 | 14 | 13 | 10 | 7 | 4 | 2 | **73** | **729** |
| Meadows | 2 | 1 | 1 | 4 | 9 | 17 | 22 | 23 | 19 | 10 | 6 | 3 | **117** | **1167** |

**Estimated Average Monthly Rural Runoff (mm) and Volume (kL/ha)**

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Melrose | 2 | 1 | 1 | 2 | 6 | 11 | 13 | 14 | 12 | 7 | 5 | 2 | **76** | **757** |
| Meningie | 1 | 1 | 1 | 2 | 5 | 9 | 11 | 11 | 9 | 5 | 4 | 2 | **60** | **599** |
| Meribah | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 5 | 5 | 4 | 3 | 1 | **33** | **329** |
| Milang (EWS) | 1 | 1 | 1 | 2 | 3 | 5 | 8 | 8 | 6 | 5 | 3 | 1 | **45** | **445** |
| Mindarie | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 7 | 6 | 4 | 3 | 2 | **37** | **369** |
| Minlaton | 1 | 1 | 1 | 2 | 5 | 9 | 11 | 11 | 8 | 5 | 3 | 1 | **57** | **574** |
| Minnipa PO (A) | 1 | 1 | 0 | 1 | 4 | 7 | 9 | 9 | 6 | 4 | 3 | 2 | **46** | **457** |
| Monarto | 1 | 1 | 1 | 2 | 6 | 11 | 14 | 16 | 13 | 7 | 4 | 2 | **80** | **797** |
| Moonta | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 8 | 7 | 4 | 3 | 1 | **47** | **467** |
| Morgan | 1 | 1 | 0 | 1 | 2 | 3 | 4 | 4 | 5 | 3 | 2 | 2 | **28** | **279** |
| Mt Barker | 1 | 1 | 1 | 4 | 8 | 14 | 19 | 20 | 16 | 9 | 5 | 3 | **102** | **1020** |
| Mt Bold | 1 | 1 | 1 | 4 | 8 | 13 | 19 | 19 | 13 | 8 | 5 | 3 | **96** | **958** |
| Mt Bryan | 1 | 1 | 0 | 2 | 4 | 7 | 10 | 11 | 10 | 5 | 4 | 2 | **57** | **568** |
| Mt Burr | 1 | 1 | 1 | 4 | 8 | 14 | 21 | 20 | 15 | 8 | 6 | 3 | **102** | **1022** |
| Mt Compass | 2 | 1 | 1 | 4 | 9 | 15 | 23 | 22 | 17 | 9 | 5 | 3 | **112** | **1116** |
| Mt Cooper | 1 | 1 | 1 | 2 | 5 | 8 | 12 | 11 | 9 | 4 | 4 | 2 | **58** | **581** |
| Mt Crawford Forest | 1 | 1 | 1 | 4 | 9 | 13 | 20 | 20 | 16 | 9 | 5 | 2 | **102** | **1015** |
| Mt Gambier (A) | 1 | 1 | 1 | 4 | 6 | 11 | 18 | 18 | 13 | 8 | 6 | 3 | **91** | **912** |
| Mt Pleasant | 1 | 1 | 1 | 3 | 7 | 13 | 17 | 18 | 15 | 8 | 5 | 2 | **90** | **904** |
| Murray Bridge | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 7 | 7 | 4 | 3 | 2 | **42** | **415** |
| Myponga | 1 | 1 | 1 | 4 | 9 | 16 | 21 | 19 | 15 | 8 | 5 | 2 | **101** | **1011** |
| Nackara | 1 | 1 | 1 | 1 | 2 | 4 | 5 | 5 | 5 | 3 | 3 | 2 | **33** | **325** |
| Naracoorte | 1 | 1 | 1 | 3 | 5 | 10 | 14 | 14 | 12 | 7 | 5 | 2 | **75** | **752** |
| Nildottie | 1 | 1 | 0 | 1 | 2 | 3 | 4 | 4 | 5 | 4 | 2 | 1 | **30** | **296** |
| Nuriootpa | 1 | 1 | 1 | 2 | 5 | 9 | 11 | 13 | 11 | 6 | 4 | 2 | **67** | **671** |
| Oodlawirra | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 5 | 3 | 3 | 2 | **35** | **353** |
| Oodnadatta | 1 | 1 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | **16** | **164** |
| Orroroo | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 8 | 6 | 4 | 3 | 2 | **42** | **416** |
| Owen | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 10 | 8 | 5 | 4 | 2 | **53** | **534** |
| Palmer | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 11 | 9 | 5 | 3 | 2 | **53** | **534** |
| Parafield AMO (A) | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 11 | 8 | 6 | 4 | 2 | **58** | **580** |
| Paratoo | 1 | 1 | 0 | 1 | 2 | 3 | 3 | 4 | 4 | 3 | 3 | 2 | **25** | **251** |
| Parawa | 2 | 2 | 1 | 5 | 10 | 18 | 26 | 25 | 17 | 10 | 6 | 3 | **125** | **1252** |
| Parilla | 1 | 1 | 0 | 2 | 3 | 5 | 6 | 8 | 7 | 5 | 3 | 2 | **43** | **429** |
| Parndana | 1 | 1 | 1 | 3 | 7 | 12 | 18 | 17 | 12 | 6 | 4 | 2 | **83** | **828** |
| Parrakie | 1 | 1 | 1 | 2 | 4 | 6 | 7 | 9 | 8 | 5 | 3 | 2 | **48** | **477** |
| Paruna | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 5 | 4 | 3 | 1 | **34** | **338** |
| Paskeville | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 10 | 7 | 5 | 3 | 1 | **50** | **501** |
| Peake | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 9 | 8 | 5 | 3 | 2 | **49** | **492** |
| Peebinga | 1 | 1 | 0 | 2 | 3 | 4 | 6 | 6 | 6 | 4 | 4 | 1 | **38** | **375** |
| Penneshaw | 1 | 1 | 1 | 2 | 5 | 10 | 14 | 13 | 10 | 5 | 4 | 2 | **68** | **678** |
| Penola | 1 | 1 | 1 | 3 | 6 | 12 | 16 | 17 | 13 | 8 | 5 | 3 | **86** | **859** |
| Penong | 0 | 1 | 0 | 1 | 4 | 6 | 8 | 9 | 6 | 3 | 3 | 1 | **42** | **423** |
| Peterborough | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 8 | 6 | 4 | 3 | 2 | **40** | **402** |
| Pinnaroo | 1 | 1 | 1 | 1 | 3 | 5 | 6 | 7 | 7 | 4 | 4 | 2 | **42** | **415** |
| Point Pass | 1 | 1 | 1 | 2 | 5 | 6 | 10 | 12 | 10 | 6 | 4 | 2 | **58** | **582** |
| Policemans Point | 1 | 1 | 1 | 3 | 5 | 8 | 14 | 14 | 9 | 5 | 4 | 2 | **67** | **666** |
| Poochera | 1 | 1 | 0 | 1 | 3 | 7 | 8 | 9 | 6 | 3 | 2 | 1 | **43** | **434** |
| Port Elliot | 1 | 1 | 1 | 3 | 5 | 9 | 12 | 12 | 10 | 6 | 4 | 2 | **65** | **646** |
| Pt Augusta | 1 | 1 | 1 | 1 | 2 | 4 | 4 | 5 | 4 | 3 | 2 | 1 | **28** | **281** |
| Pt Broughton | 1 | 1 | 0 | 2 | 4 | 6 | 7 | 8 | 7 | 4 | 3 | 1 | **44** | **439** |
| Pt Germein | 1 | 1 | 1 | 2 | 4 | 5 | 6 | 7 | 6 | 4 | 3 | 2 | **40** | **398** |
| Pt Lincoln | 1 | 1 | 1 | 2 | 5 | 11 | 14 | 13 | 9 | 5 | 3 | 1 | **65** | **652** |
| Pt Pirie | 1 | 1 | 1 | 2 | 4 | 6 | 6 | 7 | 7 | 4 | 3 | 2 | **42** | **420** |
| Pt Victoria | 1 | 1 | 0 | 2 | 4 | 7 | 9 | 9 | 7 | 4 | 3 | 1 | **49** | **490** |

## Estimated Average Monthly Rural Runoff (mm) and Volume (kL/ha)

| Towns | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) | Vol. (kL/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pt Vincent | 1 | 1 | 0 | 2 | 4 | 7 | 8 | 9 | 7 | 4 | 3 | 1 | **47** | **465** |
| Pt Wakefield | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 7 | 6 | 4 | 3 | 1 | **40** | **404** |
| Quorn | 1 | 1 | 0 | 1 | 3 | 5 | 7 | 8 | 6 | 4 | 3 | 2 | **41** | **411** |
| Redhill | 1 | 1 | 1 | 2 | 4 | 8 | 9 | 10 | 8 | 5 | 3 | 2 | **54** | **540** |
| Renmark | 1 | 1 | 0 | 1 | 2 | 4 | 4 | 5 | 5 | 4 | 3 | 1 | **31** | **313** |
| Riverton | 1 | 1 | 1 | 3 | 5 | 9 | 11 | 13 | 11 | 6 | 4 | 2 | **68** | **675** |
| Robe | 1 | 1 | 1 | 3 | 7 | 13 | 19 | 17 | 11 | 6 | 4 | 2 | **84** | **843** |
| Roseworthy AG | 1 | 1 | 1 | 2 | 4 | 8 | 9 | 11 | 9 | 6 | 4 | 2 | **57** | **566** |
| Roxby Downs (*) | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | **17** | **166** |
| Rudall | 1 | 1 | 0 | 2 | 3 | 5 | 8 | 8 | 7 | 4 | 3 | 2 | **44** | **442** |
| Saddleworth | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 12 | 10 | 6 | 4 | 2 | **63** | **634** |
| Salisbury | 1 | 1 | 1 | 2 | 5 | 9 | 10 | 11 | 9 | 5 | 4 | 2 | **59** | **591** |
| Sandalwood | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 7 | 7 | 4 | 3 | 2 | **41** | **405** |
| Sedan | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 7 | 6 | 4 | 2 | 1 | **37** | **374** |
| Smithfield | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 11 | 9 | 6 | 4 | 2 | **59** | **589** |
| Smokey Bay | 0 | 1 | 0 | 1 | 2 | 6 | 8 | 7 | 5 | 3 | 2 | 1 | **37** | **373** |
| Snowtown | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 10 | 8 | 5 | 3 | 2 | **52** | **516** |
| Spalding | 1 | 1 | 0 | 2 | 4 | 7 | 10 | 11 | 10 | 5 | 4 | 2 | **57** | **573** |
| Stansbury | 1 | 1 | 0 | 2 | 4 | 8 | 10 | 11 | 8 | 5 | 3 | 1 | **54** | **539** |
| Stockport | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 11 | 9 | 6 | 4 | 2 | **57** | **571** |
| Stockwell | 1 | 1 | 1 | 2 | 5 | 9 | 11 | 13 | 10 | 6 | 4 | 2 | **65** | **648** |
| Strathalbyn | 1 | 1 | 1 | 2 | 5 | 8 | 11 | 12 | 10 | 6 | 4 | 2 | **63** | **632** |
| Streaky Bay | 1 | 1 | 0 | 2 | 4 | 9 | 11 | 10 | 7 | 3 | 3 | 1 | **51** | **512** |
| Sutherlands | 1 | 1 | 0 | 1 | 3 | 4 | 5 | 6 | 6 | 4 | 3 | 2 | **35** | **349** |
| Swan Reach | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 5 | 5 | 4 | 2 | 1 | **32** | **322** |
| Tailem Bend | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 8 | 7 | 5 | 4 | 2 | **47** | **465** |
| Tanunda | 1 | 1 | 1 | 3 | 6 | 10 | 12 | 14 | 11 | 7 | 4 | 2 | **71** | **710** |
| Tarlee | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 12 | 10 | 6 | 4 | 2 | **60** | **596** |
| Terowie | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 8 | 7 | 4 | 3 | 2 | **41** | **408** |
| Tintinara | 1 | 1 | 1 | 2 | 5 | 7 | 10 | 11 | 10 | 6 | 4 | 2 | **60** | **597** |
| Torrens Island | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 10 | 8 | 5 | 4 | 2 | **55** | **552** |
| Tumby Bay | 1 | 1 | 0 | 2 | 3 | 6 | 9 | 9 | 7 | 4 | 3 | 2 | **46** | **459** |
| Two Wells | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 9 | 7 | 5 | 3 | 2 | **50** | **501** |
| Ungarra | 1 | 1 | 0 | 2 | 4 | 8 | 11 | 11 | 9 | 4 | 3 | 2 | **55** | **554** |
| Uraidla | 2 | 1 | 1 | 5 | 12 | 22 | 28 | 28 | 22 | 12 | 7 | 4 | **145** | **1445** |
| Victor Harbor | 1 | 1 | 1 | 3 | 6 | 10 | 13 | 13 | 11 | 6 | 4 | 2 | **70** | **695** |
| Virginia | 1 | 1 | 1 | 2 | 5 | 8 | 9 | 10 | 8 | 5 | 4 | 2 | **55** | **548** |
| Wallaroo | 1 | 1 | 1 | 2 | 4 | 7 | 8 | 8 | 6 | 4 | 3 | 1 | **45** | **449** |
| Wanbi (A) | 1 | 1 | 1 | 1 | 3 | 3 | 6 | 6 | 6 | 4 | 3 | 1 | **36** | **365** |
| Warooka | 1 | 1 | 0 | 2 | 5 | 9 | 12 | 12 | 9 | 5 | 3 | 1 | **59** | **592** |
| Watervale | 1 | 1 | 1 | 3 | 7 | 12 | 15 | 17 | 14 | 8 | 5 | 2 | **85** | **853** |
| Wellington | 1 | 0 | 1 | 2 | 3 | 7 | 7 | 8 | 8 | 5 | 3 | 2 | **47** | **468** |
| Western River | 1 | 1 | 1 | 3 | 7 | 14 | 21 | 19 | 12 | 6 | 4 | 2 | **90** | **895** |
| Whyalla | 1 | 1 | 0 | 1 | 3 | 4 | 4 | 5 | 5 | 4 | 3 | 2 | **32** | **316** |
| Whyte Yarcowie | 1 | 1 | 1 | 1 | 3 | 5 | 7 | 8 | 7 | 4 | 3 | 2 | **42** | **424** |
| Williamstown | 1 | 1 | 1 | 3 | 7 | 14 | 17 | 18 | 13 | 8 | 5 | 2 | **91** | **906** |
| Willowie | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 7 | 6 | 4 | 3 | 2 | **39** | **388** |
| Willunga | 1 | 1 | 1 | 3 | 8 | 13 | 16 | 16 | 13 | 7 | 4 | 2 | **85** | **853** |
| Wilmington | 1 | 1 | 1 | 2 | 4 | 8 | 10 | 11 | 9 | 5 | 4 | 2 | **56** | **562** |
| Wilpena Heat Station | 1 | 1 | 1 | 1 | 4 | 7 | 9 | 8 | 6 | 4 | 3 | 2 | **46** | **463** |
| Wirrabra | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 12 | 10 | 6 | 4 | 2 | **62** | **617** |
| Wolseley | 1 | 1 | 1 | 2 | 5 | 8 | 10 | 12 | 10 | 6 | 4 | 2 | **62** | **620** |
| Woomera (AMO) | 1 | 1 | 0 | 1 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 1 | **21** | **210** |
| Worlds End Creek | 1 | 1 | 0 | 1 | 3 | 5 | 6 | 7 | 7 | 4 | 3 | 2 | **39** | **391** |
| Yacka | 1 | 1 | 0 | 2 | 4 | 7 | 8 | 10 | 9 | 5 | 3 | 2 | **52** | **517** |
| Yalata | 1 | 0 | 0 | 1 | 4 | 8 | 8 | 7 | 4 | 3 | 2 | 1 | **38** | **382** |

| **Estimated Average Monthly Rural Runoff (mm) and Volume (kL/ha)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Towns** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total (mm)** | **Vol. (kL/ha)** |
| Yankalilla | 1 | 1 | 1 | 3 | 7 | 12 | 15 | 14 | 11 | 6 | 4 | 2 | **76** | **759** |
| Yeelanna | 1 | 1 | 0 | 2 | 4 | 8 | 12 | 12 | 8 | 4 | 3 | 1 | **56** | **558** |
| Yongala | 1 | 1 | 0 | 2 | 3 | 6 | 7 | 9 | 7 | 4 | 4 | 2 | **46** | **462** |

# Appendix 17

# Planning a Water Harvesting & Reuse Scheme

## A17.1 IMPORTANCE OF PLANNING

The importance of planning for a reuse water supply scheme can not be underestimated. Figure 235 shows the dependency and benefits of forward planning upon the final cost of a project. The benefits gained are seen by way of eliminating the need to make changes once the project has commenced.

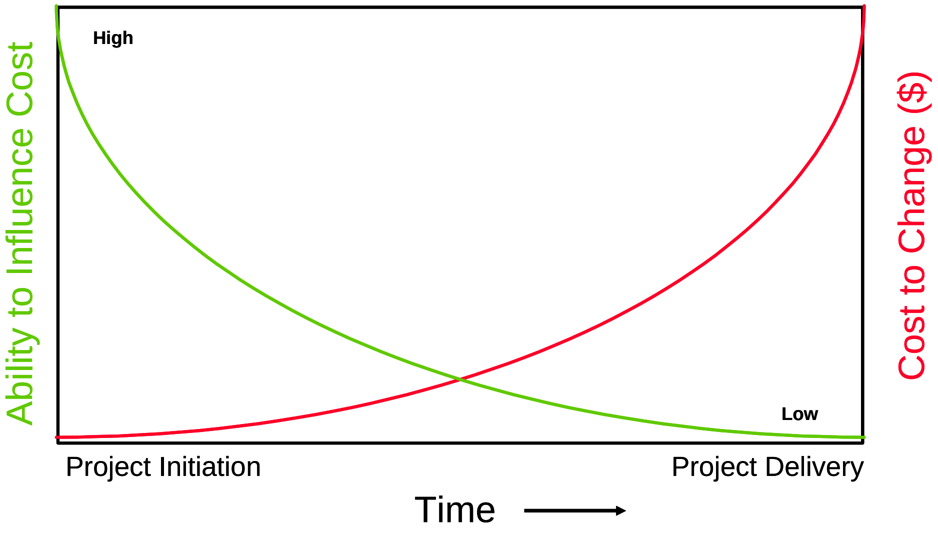

**Figure 235 Project Phases and Ability to Influence Cost**

The major capital cost savings on most projects can usually only be achieved in the early phases of the project's conception and design (Stallworthy & Kharbanda 1986, AIPM & CIDA 1995, and GSA 1996), when evaluating options and innovative process technologies. Also, the 'cost to change' any aspect of the project is lower in the early phases, but increases rapidly in the final phases (AIPM & CIDA 1995). Therefore, it follows that the costs of a water harvesting and reuse scheme can be minimised when a wide range of options are fully analysed from the outset, before any commitment to proceed is made.

Throughout each step of planning a new water harvesting or reuse scheme (or the augmentation to an existing), the community and stakeholders should be involved to provide guidance through the planning process (US EPA 1992), and steps taken to foster support and encouragement for the project.

A typical planning process suitable for a water harvesting and reuse project is outlined below in Figure 236. The process includes activities ranging from the identification of the idea, through to the operation and maintenance of the assets. For small scale water resource projects, the recommended steps for the total planning process consist of;

- define the 'ideas' to meet needs,
- form a steering committee to drive the project,
- develop options,
- evaluate and select the most appropriate option,
- prepare detailed design of the preferred option,
- construct and commission, and
- operate and maintain the scheme.

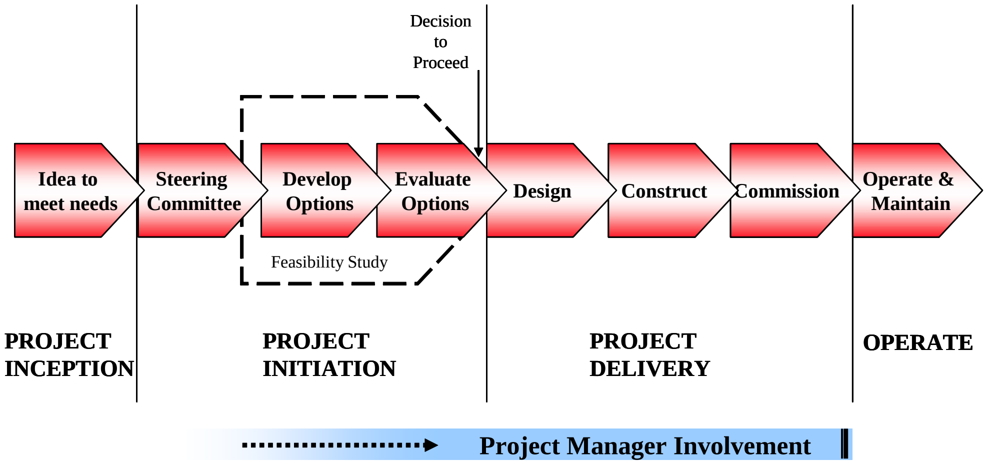

**Figure 236 System of Planning Flowchart**

Each step in the process includes a number of tasks that should be completed before proceeding to the next in the planning process. In some instances there may be a repeat of a step (ie an iterative process) when new discoveries are made and changes needed to accommodate them. With a good feasibility basis to have started with, these discoveries should only be superficial and the changes needed only minimal. Systematic planning will facilitate sound discussions about the local feasibility issues for the water reuse schemes, while taking into account the full range of issues that need to be addressed.

The planning process described above is intended to be adaptable by tailoring it to the specific needs of a project whereby ensuring that the individual needs of the community are satisfied. The effort and attention required during each phase of the project varies depending on the complexity of the project.

## A17.2 PROJECT INCEPTION

The ‘idea’ for the development of a stormwater harvesting or effluent reuse project in a rural community will always form the first step of an overall water resource management plan as depicted below in Figure 237.

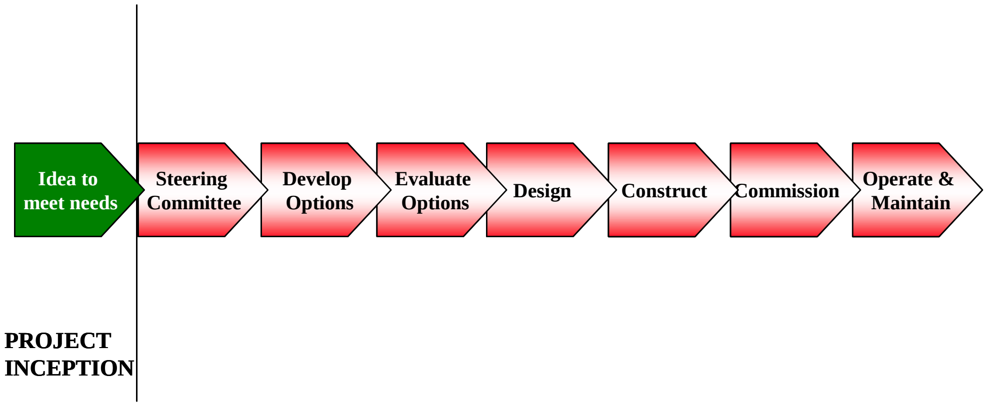

**Figure 237 Project Inception Phase**

The needs of each community will usually be unique and dependent on their local circumstances with some needs being common for all systems, these being listed below:

- save money by developing local water supply,
- pollution abatement,
- conservation of fresh water supplies by source substitution,
- compliance with discharge licences,
- enhancement of the community areas around the town,
- customer/market demand (ie. sporting facilities, irrigation),
- legislative requirements,
- environmental issues,
- assists with the communities future development,
- flood protection, and
- improves operational sustainability for the region.

In most circumstances, a specific communal/project need is identified, which becomes the driving direction for the project. For example, the Kangaroo Island Council instigated an upgrade of the septic tank effluent disposal scheme in 1994. The need for the project was clear. The STED scheme oxidation ponds disposed of treated effluent to the marine environment in breach of the Marine Environment Protection Act 1990. The licence conditions were being breached. While for the Lock Stormwater Irrigation Scheme the driving need was simply to reduce the cost to the community of maintaining a green oval through the summer period.

The ‘idea to meet needs’ has been established, but is it feasible? This is the very first question that is always asked and leads immediately to the project initiation phase of a project.

## A17.3 PROJECT INITIATION

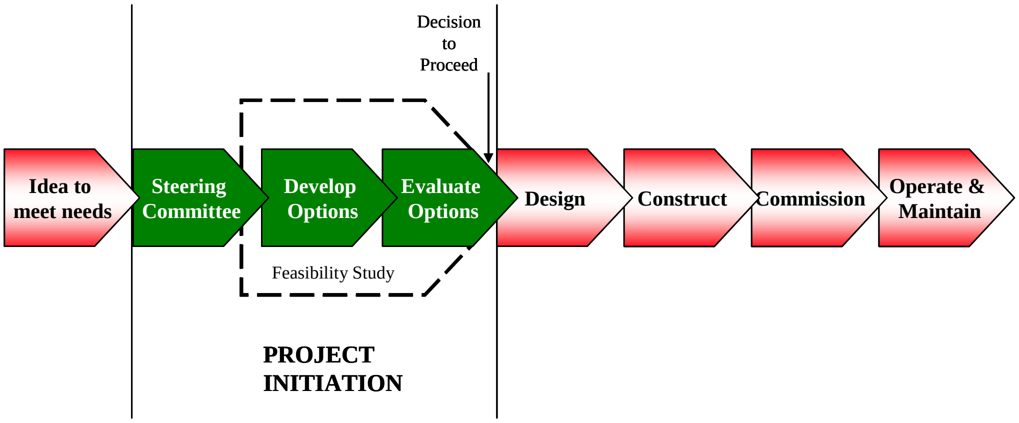

**Figure 238 Project Initiation Phase**

The key steps of the project initiation phase for planning a small reuse scheme are:

- form a steering committee;
- develop options; and
- evaluate and select the most appropriate options.

The project sponsor is generally the local council, community group(s) or supporting businesses that are driving the project. It is essential that one of these organisations or group(s) take on board the responsibility of project with strong leadership being the single most important factor when developing a successful project which is best undertaken as a key role by the Project Sponsor. The key typical tasks for implementing a successful "Project Initiation Phase" are discussed in detail in the following sub-clauses.

### A17.3.1 *Form a Steering Committee*

The group that manages and brings a project or task to completion in the proposed system of planning is called the project steering committee. One of the first steps when initiating a "Project Initiation Phase" is to form a local Steering Committee to manage the project, arrange assessment of the various options and manage project running costs and budgets (GSA 1996 and NSW DLWC 1997). This may be undertaken by the Project Sponsor or on their behalf. The Steering Committee should be led by someone acting as the project manager, even if that person does not always carry that title (Stallworthy & Kharbanda 1986).

The management of the water harvesting and reuse project by the steering committee is the key to successful project. The primary skills required by the steering committee are the ability to identify, manage and deliver the project objectives of the various stakeholders. The steering committee's key consideration and role is to effectively involve the community with the stakeholders during all phases of the project planning and implementation as will be discussed in later clause.

## Setting Up a Steering Committee

When starting up a steering committee, Campbell (1993) advises that the following agendas should be considered are:

- purpose;
- role;
- membership;
- method of selection; and
- frequency of meetings.

The purpose of the Steering Committee is to represent both the Project Sponsor and local community interests by ensuring that their interests are represented during the planning and implementation of the project.

The role of the Steering Committee is to assign project responsibilities, seek relevant approvals and control the project to completion on behalf of the Project Sponsor. It will be expected to operate with the same goals and objectives as the wider community.

The Steering Committee may include representatives from the council, groups or associations with an interest, community, government departments and/or consultants. It is recommended that the size of the group consist of at least 5 members, but limited to a maximum of 15 members. The most effective size will depend on the size and complexity of the proposed water reuse scheme.

The Project Sponsor must decide how to select suitable members for the Steering Committee. A method to accomplish this is to allow members of the community or interested groups to make an Expression of Interest. Individuals may nominate themselves or groups/organisations may nominate one of their members. It is the Project Sponsor's responsibility to consider all Expressions of Interest and ensure that members selected to be part of the Steering Committee provide a balanced representation of the community and stakeholders and also have a relevant interest in the project.

The frequency of meeting is largely dependant upon the Steering Committee and the size of the project, but anticipated to be at least quarterly. The frequency can be expected to vary as the project progresses through the various stages of planning. As an example, for the Kingscote Septic Tank Effluent (STED) reuse scheme, the Kangaroo Island Council formed the Common Effluent Drainage Scheme Working Party where its members included two councillors, chief executive officer, environmental services manager, technical services manager and the mayor.

## Terms of Reference

The key tasks that need to be addressed by the Steering Committee throughout the planning process are;

- set the needs and objectives in consultation with the project sponsor,
- develop an appropriate project organisation and strategy,
- prepare of study brief setting out the scope and activities of the feasibility study,
- engage a reputable consultant to undertake feasibility study or if resources and skill permit initiate investigation 'in-house',
- report on the range and shortlist options to the project sponsor,
- coordinate community consultation throughout the planning process,

- establish preferred procurement option(s),
- undertake and review environmental impact assessment of the preferred options,
- prepare cost estimates and manage budgets,
- appoint project manager(s) if required, and
- obtain approvals and government liaison where required.

The Steering Committee ensures that the necessary skills required for the successful project outcomes are in place to assist in undertaking the feasibility study and subsequent steps during the planning process. Where resources or skills are limited, the Steering Committee may engage Consultant(s) to assist with some of the tasks.

### Project Needs and Objectives

The Project Sponsor in consultation with the Steering Committee for each project will set needs and objectives, agreed to the scope and activities of the feasibility study, and prepare budgets to examine and report on the merits of relevant options for the project (NSW DLWC 1997). For the effective planning of a water reuse project, the objectives (deliverables) for conducting the feasibility study must be well defined by the Project Sponsor.

The most optimum water reuse projects are achieved by integrating stormwater, wastewater treatment and water supply needs into one plan (Metcalf & Eddy 1991). This integrated approach is somewhat different from what has happened in the past where the responsibility for planning activities has been undertaken by separate organisations. As a result, the feasibility study costs are generally most optimised when using the engagement of a single consultancy house (NSW DLWC 1997).

The project needs should be consistent with the project’s long range planning program adopted for the region. The area served by the project should be studied to identify conflicts or value adding with other similar projects by securing optimum development through joint use (BOR 1977). The project plan normally originates from the basis to satisfy the sponsor's specific needs. In order to gain support for the project, the sponsor may broaden the objectives to mutually satisfy the needs of other stakeholders (ie the community), and/or the purposes may multiply through project formation (joint venture with new secondary sponsors) until selections of the final magnitude and scope are reached (BOR 1977).

At the outset of the reconnaissance study, considerable basic data is usually available in the form of maps, aerial photographs, streamflow records, regional geological reports, census statistics, crop yields, market statistics, previous investigation reports etc. Data concerning the impact of the project upon the environment are not readily available and must be actively collected from appropriate sources. The investigator must evaluate the data, supplement them with rough additional data and conceive a workable basic plan that utilises the resources available to meet the needs. This plan will be refined in the feasibility study and specification stages (BOR 1977).

Governmental agencies hold a considerable amount of basic data of the form described above. The larger public libraries generally maintain files of government publications for many years. Sponsors and engineers of small projects should consult with State and Federal data collecting agencies and public libraries concerning the availability of pertinent data.

### Project Organisation and Strategy

The success of typical water reuse scheme hinges on the capability of the Steering Committee to manage the project. The effectiveness of the project organisation depends on a range of factors such as the project technology, size, remoteness, etc. The Steering Committee's task is to create a project organisation to successfully complete the project within agreed time and budget.

Strong relationships should be formed between the Project Sponsor and the Constructor. The larger projects obviously employ more people with the small projects having a range of activities undertaken by one or two individuals.

A realistic project organisation and strategy should be developed by the Steering Committee, accepted by the Project Sponsor and communicated to all involved in the implementation of the project. Such a strategy should address the following areas:-

- project management and resources;
- division and allocation of work;
- project safety requirements;
- roles of consultants and contractors;
- sponsor/project/contractor interfaces;
- type of contract; and
- commissioning responsibilities.

It is essential for the achievement of effective control on construction that a clear point of authority is established at the outset and maintained throughout the duration of the project.

A discrete project organisation should be in place before the Project Sponsor takes the decision to proceed. This results in the development of clear lines of responsibility and prevents conflict arising in dealing with contractors.

### Study Brief

The Study Brief should specify the detail of the study and include;

- description of project study area;
- alternatives to consider;
- extent of community involvement required;
- data collection;
- funding;
- public health obligations; and
- legal obligations.

## A17.3.2 *Develop Options*

This is the fact finding stage to determine the physical, economic, and legal bounds of the project. The main tasks to be undertaken in this step of the planning process are:

- identify possible sources of water;
- assess water supply and demand in and around the community;
- assess treatment and disposal needs to ensure the water is safe for its intended use;

- determine storage facilities required to balance fluctuations in demand;
- determine the associated plant required, such as a conveyance and distribution network;
- identify and assess potential environmental impacts;
- identify any public health considerations to be taken into account;
- review the legal liabilities/obligations and responsibilities of the Project Sponsor and the user(s);
- identify sources of funding which might be available;
- assess each option based on potential benefits to the community:
- find out what type of system will attract the interest and support of the community;
- prepare cost estimates; and
- secure necessary approvals and initiate government liaison.

Through all stages of planning, public involvement provides guidance to the planning process, and will increase support for the project.

### Tests of Feasibility

The objective in project planning is the determination of the projects feasibility. This involves studies which will permit a sound analysis and conclusion with respect to the specific engineering-economic-environmental considerations. These are primarily (BOR 1977):

- that the project is responsive to an urgent present or anticipated social or economic need,
- the project as planned will adequately serve the intended purpose,
- that the services proposed to be performed through the project and the benefits it will produce will justify the cost, and
- that the project will cause minimal disturbance to the ecology and environment of the area.

The study should determine that the difficulties inherent in sites which affect economy, safety of construction, and quality of operation have been satisfactorily foreseen; and that the designs are technically sound and reasonably representative of the actual structures that may be expected to be built after more detailed investigation. The soundness of the conclusions regarding these matters will depend to a considerable degree on the completeness and accuracy of the investigation.

The maximum justifiable investigation cost is, however, limited by the magnitude of the project. The project is generally unjustified if the cost of the necessary investigation would offset a large portion of the constructed projects value. A cost reduction accomplished by the elimination of a portion of the fundamental investigation is rarely a saving. It generally results in unanticipated construction or functional costs.

### Stages of Investigation

Investigation, if carried to completion, is an expensive and time consuming phases of project development. Hence, it should be planned and executed so that the probable soundness of the project will be determined as early and as inexpensively as possible.

BOR (1977) recommends to accomplish that objective the investigation is divided into as many as three stages:
- Reconnaissance Stage - primarily to support decision on whether or not to proceed with more detailed investigations on the basis of rough data and shortcut studies.
- Feasibility Stage - determines the scope, magnitude, essential plan and feature, and the approximate benefits and cost.
- Specifications Stage - supplements the feasibility stage to the degree needed for preparation of final plans and specifications after authorisation or approval has been obtained and construction is imminent.

Many of the smaller projects will not require, at the specifications stage, any information in addition to that already obtained in the feasibility study. However, larger or more complex projects may require extensive additional surveys and investigations.

### Value Engineering

The objective of value engineering is to achieve the best balance between function, reliability and cost Stallworthy and Kharbanda (1986) maintain that the basic philosophy can be summed up in the assertion; “There is a better way - find it!”. Value engineering examines a series of simple direct questions which are listed below in Table 77.

It is recommended that the Steering Committee adopt the principles of value engineering, particularly during the development and evaluation of options steps of the planning system. That is, for best results it should be applied early in the project where the ability to influence cost is greatest (refer Figure 235 page 348).

### Demand for Non-potable Water

The success of a water reuse project is largely dependent on securing markets for the new water source; therefore, in planning a stormwater or effluent reuse project, it is essential to locate potential customers or markets that are capable and willing to use the non potable water supply.

An assessment of potential customers/markets for an water reuse scheme should consist of two parts (Asano & Mills 1990 and Metcalf & Eddy 1991):
- examination of background information, including potential uses of water reuse scheme: and
- a survey of potential reclaimed water users and their needs.

The results of this appraisal form the basis for developing options as well as deciding financial feasibility of a project.

**Table 77 Value Engineering Questions (Stallworthy & Kharbanda, 1986*)***

| | **THE SEQUENCE FOR ANSWERS** | |
|---|---|---|
| **A.** | **COLLECT INFORMATION** | |
| | What is it? | • gather facts |
| | What does it do? | • determine function |
| | What is it worth? | • evaluate function |
| | What does it cost? | • evaluate cost or worth |
| **B.** | **SPECULATION** | |
| | What else will work? | • brain storming |
| | | • eliminate |
| | | • simplicity |
| **C.** | **ANALYSIS** | |
| | What does that cost? | • list pros and cons |
| | | • assign value |
| | | • select best ideas |
| **D.** | **PLANNING** | |
| | Alternative solutions | • analyse specific solutions |
| | | • assess feasibility and savings |
| **E.** | **REPORT AND IMPLEMENT** | |
| | Define | • prepare report and proposal |
| | | • discuss with management |
| | | • translate ideas into action |
| | | • schedule and funding |
| | | • monitor to completion |

*Source: Figure 4.4 page 42 of "A guide to project implementation" by Stallworthy and Kharbanda, 1986.*

### Approvals and Government Liaison

In most cases, the approval process will be time-consuming; therefore any political issues should be addressed at the outset of the development of options. Various studies have found that the time taken from the preparation of the initial brief to obtaining planning permission may take from 12 weeks to 10 years (Sidwell 1990).

Political aspects (if any) of 'high profile' projects should be addressed from the outset of the development of options and close attention paid at all stages to public and government liaison in order to secure timely approval. Water reuse schemes, in particular those involving effluent reuse, often attract public and political interest, and the Project Sponsor's image can be badly damaged by mishandling sensitive issues.

Recognition of the process of application for development as a discrete stage of the project thus requiring management is an essential pre-requisite to the successful achievement of approvals. Adequate time, funding and resources must be allowed for this task which can often be difficult for rural councils. For example, in 1997 (March - September) the Kangaroo Island Council needed to devote one person full-time for six months to undertake the negotiations and comply with the approval requirements for the Kingscote STED Scheme Upgrade.

All negotiations with outside bodies should preferably proceed via a single point of contact. This shall be one person who is seen as the promoter of the project. A comprehensive and precise documentation procedure must be instituted from the start of a project, as it is important that a well prepared and cogent case be presented for negotiation and approvals with government departments.

The effectiveness of the consultation process is dependent on the establishment of mutual trust. All applicable legislative requirements be met and the impact of the development on the community must be researched and understood before submissions for approvals are sought. Issues that will be contentious should be identified and concern for these issues demonstrated in the documents.

As the project develops, the relationships that need to be established with others is important. The requirements vary, but local, regional and even national authorities are involved when approval is sought for a project to proceed. Planning permission and an 'environmental impact assessment' may be required. There are a number of other statutory requirements and limitations which will have to be borne in mind and dealt with at the appropriate time (licenses etc). The list is long, but all these matters should be reviewed before the project is implemented, since one refusal could stop the project going ahead. This consultation process will not stop when approvals are granted, and the goodwill established should be fostered to help during the project delivery phase.

### Technical Risk

The risks involved with using new or unfamiliar technology must be recognised and brought to the attention of the Project Sponsor. In cases where new boundaries of technology are being approached the likely problems must be identified. The advice of relevant outside consultants may also be used as necessary.

The risk of time and cost over-run generally will be reduced when either the Project Sponsor or the Constructor has recently constructed (or is at an advanced stage of constructing) a similar project. However, allowances should be made for problems which may arise when:

- the new project is to be built at a significantly different location involving different environmental or operating practices;
- a lapse of several years from the time of construction of the original project has rendered some of its components unobtainable or obsolete.

## Cost Estimates

Reliable cost estimates are essential as an underestimate may lead to a non-viable project while an over estimate could result in rejection of a viable project. Local factors (eg shortage/surplus of particular skills, transport costs to remote areas) can have a significant effect on the final project cost and should be taken into account in the estimate. There is often scope for capital cost savings by challenging the need for all significant items of equipment. This can be instrumental in bringing a small project to fruition. The role of the Steering Committee is critical in ensuring acceptance by all involved of the reduction in facilities to be provided.

Risks arise from investments incorporating new technology or large, complex, highly integrated schemes. While actions can be taken to minimise such risks, it is important that appropriate allowance is made for them in terms of cost and timing. Risk appraisal techniques are available to assist in dealing with major uncertainties in cost estimating. Risk management is addressed by Australian Standard AS 4360 Risk Management. In addition to capital costs talk about future operation and maintenance and administration costs.

Project costs may be seriously underestimated unless full account is taken of the stated health, safety and environment requirement of local, state and national authorities and of the full practical implications for the consequent redesign of licensor’s packages. Allowance should be made for any likely tightening of such requirements. A reliable assessment of cost must be available before the Project Sponsor takes the decision to proceed particularly if commercial negotiations such as product pricing are critical to the overall economics of the water reuse scheme.

Rough overall estimates of project feature costs are commonly made during the reconnaissance stage for the purpose of comparing alternative sites and for determining the size and scope of the development. More detailed estimates involving quantities and unit costs are necessary for inclusion in feasibility reports supporting authorisation or approval for construction, after plan formulation studies have established the optimum scale for economic soundness of the development (BOR 1977). Estimates should include, in addition to the construction costs of the dam and appurtenant structures, the probably cost of lands, water rights (if existing rights must be purchased or leased), right of way, and clearing the reservoir areas; costs of relocating public services; engineering and administrative costs. Estimates are also needed for annual costs for financing and for operation, maintenance, and replacement. The feasibility estimate may not be in full detail but in overall amount it should represent a ceiling within which the project features can be built, barring significant advances in unit prices. The final estimate will be based on subsequent detailed studies made in conjunction with the preparation of specifications and should be in sufficient detail to serve as a guide in securing bids and awarding a contract for construction (BOR 1977).

### Planning Report

A reconnaissance report is generally prepared by the investigating engineer to make a record of the data available, to present a preliminary concept of the project plan with a rough economic and financial analysis, and to draw conclusions as to whether the project, based on the data at hand merits further study (BOR 1977). If the recommendation is favourable, the report should outline the feasibility grade investigation to be made, the estimated costs and time required, and the requirements for personnel, equipment etc (BOR 1977).

The project feasibility report is generally prepared on completion of the feasibility investigations as a basis for advertising the sponsor or owner or others who must approve or authorise the project of its merits. The report describes the project plans, features, costs, benefits, relationships to existing and future developments, problems and financing (BOR 1977). It should present definite recommendations, and should be adequately supported by the investigations, as documented in the report or its appendixes, in such a form that the work may be readily reviewed by the proper authorities (BOR 1977).

## A17.3.3 *Evaluate Options*

This step involves quantifying and costing the difference the water reuse project will make to a community by analysing the benefits of each of the options which were short listed in the develop options stage.

The key tasks in this step are:
- economic analyses of options;
- financial analyses of options;
- commitment to proceed.

Currently, monetary factors tend to be the overriding concern in determining whether the Project Sponsor is willing to commit to implementing a water reuse project, even though technical, environmental, and social factors are just as important in project planning process. Environmental considerations and public policy issues may be of greater importance than mere cost effectiveness as a measure of the feasibility of a project (Asano and Mills 1990).

Evaluation of options, based on established water resources economics, fall into two categories: economic analysis and financial analysis.

### Economic Analysis

The economic analysis is focused on the value of the resources invested in a project to construct and operate it, measured in monetary terms.

The basic result of the economic analysis should answer the question "Should a reuse project be constructed?"

## Financial Analysis

Equally important, however, is the answer to the question, "Can a reuse project be constructed?" Both orientations are therefore necessary but only water reuse projects that are viable in the economic context are given further consideration for a financial analysis.

The financial analysis is focused on the perceived costs and benefits of a project from the viewpoints of Project Sponsor, participants and others affected by the project. These perceived costs and benefits may not reflect the actual value of resources invested because of subsidies or money transfers (Asano and Mills 1990)

Whereas economic analysis evaluate projects in the context of impacts on society, financial analysis focus on the local ability to raise money from project revenues, government grants, and loans to pay for the project.

If the economics of the project are critically dependent on one specific Agreement, this Agreement should be agreed at least in principle before requesting project approval and should identify the risk involved if the contract does not materialise. Similarly, the Project Sponsor must be wary of entering into projects on the basis of attractive terms entered into under favourable market circumstances and later having to bow to pressure to renegotiate under depressed market conditions.

While it can be possible to obtain security from a monopoly buyer of recycled water this is almost inevitably paid for by having to accept lower prices and possibly a controlled level of production. Investment decisions may be easier in such circumstances and the projected revenue from the project should be known with a higher degree of certainty. In such situations protracted negotiations may be necessary.

## Project Manager

If a Project Manager is to be appointed it is desirable that the appointment be made before the decision to proceed is taken.

Appointing a Project Manager from the local community or council staff can contribute to the overall success of the project. The project will benefit from the Project Manager’s knowledge of local matters and good communications with the local groups during construction.

Rural communities often lack the technical resources and experience to support their interest in implementing an water reuse project effectively. It may be important in such circumstances that full and timely advice and support is sought from an appropriate Consultant.

The Project Managers task is completed when the project has been commissioned and handed over to the Project Sponsor for operation and maintenance.

The less experience the Steering Committee has of project management, the more need it has of external expertise and it is here the consultant can both guide and help (Stallworthy & Kharbanda 1986).

### A17.3.4 *Decision to Proceed*

This is the decision taken by the Project Sponsor based on the recommendation of the Steering Committee. The Project Sponsor has several options at this stage as follows:-

- dismiss the project
- suspend the project until constraints identified are removed
- grant commitment to proceed. This is the point of 'no return' – after this a project can be stopped at a price.

#### Project Definition

This step documents the preferred option to bring the project (including cost and time schedule) to a point where the detail design can commence.

Many projects have experienced delays and overspending due to inadequate definition of requirements and deficiencies in basic engineering design work prior to the decision to proceed. This has been the most significant contribution to poor project performance over the years.

The Project Sponsor's needs should be laid down in a formal Statement of Requirements and agreed by all concerned.

If a precise, unambiguous definition of requirements is not available the following risks must be recognised and reflected in the calculation of economics and in the sensitivity analysis:

- unrealistic forecasts of project costs and completion date, with consequent incorrect economic forecasts;
- inadequate project manning levels, resulting in inefficiency and delay;
- inadequate information for contract tendering and consequent exposure to construction delays and claims;
- the greater likelihood of changes being required during the detailed design phase (or worse still, during construction) leading to delays and increased costs (refer Fig 3.1).

The Steering Committee should ensure that a Statement of Requirements (SOR) is produced promptly once the preferred option has been selected. This should be a full and complete record of the Project Sponsor's needs as any subsequent amendments or additions could lead to confusion and delay. It should have sufficient engineering detail to allow the preparation of a preliminary cost estimate to justify the approval of funds for the project delivery phase.

The Project Sponsor must ensure that an operating and maintenance philosophy is produced at the same time as the detailed statement of requirements, to ensure self-consistency and that any tendency for the operator to introduce unnecessary equipment, purely for convenience, is resisted.

## A17.4 PROJECT DELIVERY

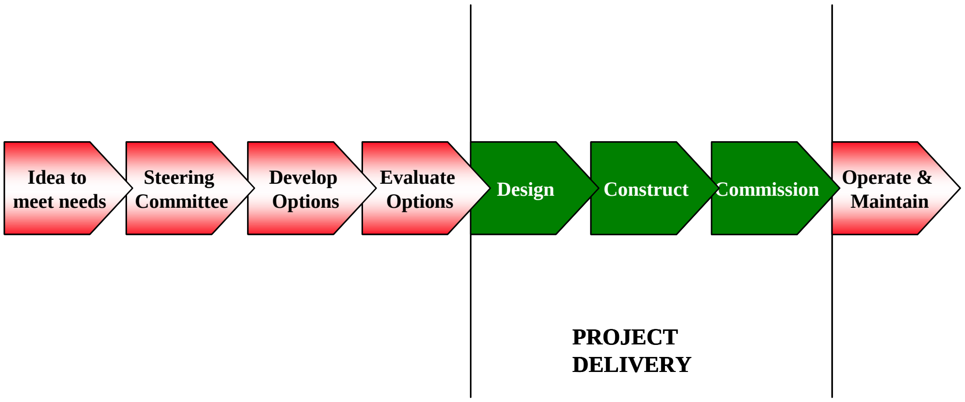

**Figure 239 Project Delivery Phase**

The key elements in the project delivery phase of planning and implementing a small scale project are:

- call for Expressions of Interest;
- assess and select several tenderers;
- invite tenders, provide performance based design and construct tender documents to the selected tenderers - may include operation and maintenance for up to two years;
- evaluate tenders;
- engage and manage contractor;
- inspect works;
- oversee commissioning program;
- undertake operator training and prepare O&M manuals; and
- post commissioning project evaluation

This may be undertaken by the Steering Committee or by an external consultant acting as the Project Manager on behalf of the Project Sponsor

## CONTRACT OPTIONS

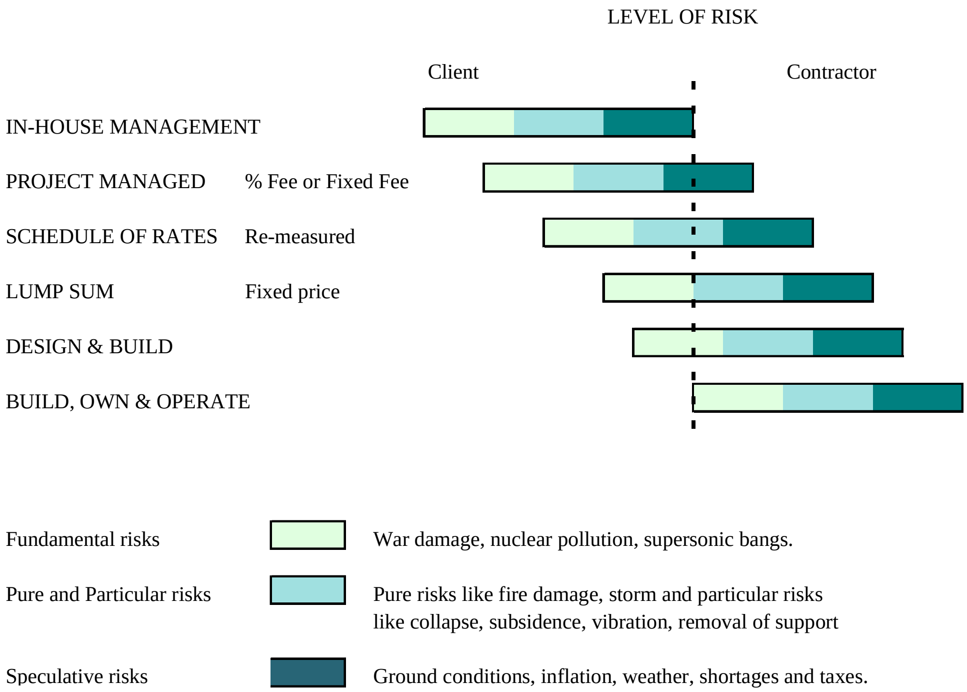

**Figure 240 Contract Options and Level of Risk**

. There are several contract options which may be considered as shown below.

### A17.4.1 *Design*

Inspection and approval of design drawings should not be sacrificed for speed even if this results in delayed approval. A little extra effort at the design stage always saves time and additional cost later in the project. Close attention should especially be paid to detailed design layout when space considerations are seen to be critical.

The operator should be given a full opportunity to comment on the project, preferably through having a representative on the team during the design phase. This should help to minimise the maintenance problems which may arise after commissioning.

#### Project Specification

The project specification is the document that defines the 'work' that the Constructor will be required to do, in cooperation with the Project Sponsor and any other third party involved (ie consultant).

Early provision of operating and maintenance documentation should be specified at the tender stage and enforced as a contractual requirement. Commissioning and subsequent operation can be handicapped by inadequate information regarding unfamiliar equipment.

## Tendering

Contractors must be given adequate time to prepare their bids, say two to eight weeks, to allow the Contractor time fully assess all of the specified requirements. In addition, an allowance must be made for the often considerable time required for critical examination of all bids received which may take anywhere from three to twelve weeks depending on the complexity of the project.

The Steering Committee need to know the length of time it will take to go through the approval process and specify a time that the tenders remain valid for. It is just as important to specify the defects liability period and warranties at the time of tender.

If tender prices vary markedly, then a check should be made to ensure that all contractors have fully understood the intent and/or scope of the contract. The use of a formal post tender meeting should be considered.

## Contractor Selection Process

Contractors should be assessed in detail with emphasis on recent construction performance.

In the case of the new Renmark WWTP which incorporates effluent reuse the choice of contractor (Hickingbotham) with recent experience in the use of the technology and of construction in South Australia was of considerable benefit (George Tenter pers. comm).

If contractor screening is inadequate the potential for cost overrun and frustration is increased. For example, this could be the case if selection was based on good performance some years previously since when the contractor's organisation and staff had changed significantly.

Price should be only one of several criteria used in selecting the successful contractor. Typically emphasis should also be placed on:-

- financial stability;
- experience of similar projects;
- experience of similar technology;
- appreciation of knowledge of local conditions;
- the size of the project in relation to the contractor's manpower capability;
- existing workload;
- quality of personnel nominated to carry out the project;
- planning and control procedures
- timeliness to complete project; and
- ability to provide owner with ongoing support post commissioning.

The natural pressure to accept the lowest bid must be resisted if the contractor shows serious weaknesses in any of these areas. The ability of the contractor to provide ongoing support services is of special importance when the plant is being built in the country or at a location where appropriately trained operating personnel are not available. Some contractors are also able to offer training facilities.

### A17.4.2 *Construct*

Communication channels and reporting relationships must be clearly defined and formally agreed by all involved from the outset. Failure to do so could lead to frustration and conflict which could adversely affect the outcome. Commissioning is important as it is at this stage that you can rectify faults (if any), repairs breakdowns and evaluate your system. This may take some time

### A17.4.3 *Commission*

Commissioning is an important step in the process which requires careful planning. Stallworthy & Kharbanda (1986) warn that the start up of a wastewater treatment plant takes time, often longer than expected and recommend allowing from two to six months for this task. Thoroughly prepared operating and maintenance manuals and procedures must be available well before commissioning. Staff must be trained.

#### Post Project Appraisal

A post completion review should be undertaken as soon as construction of the project is completed. It provides an ideal opportunity to identify any details in planning which need to be amended or updated to improve the process for other projects currently in the planning or design phase (if any). This review should include a statement of performance achieved in comparison with planned performance in terms of cost, time, quality and safety. Suggested improvements with respect to future projects should be provided. It should also provide an appraisal of the effectiveness of the method of contracting and the contractor's performance.

## A17.5 OPERATING & MAINTENANCE

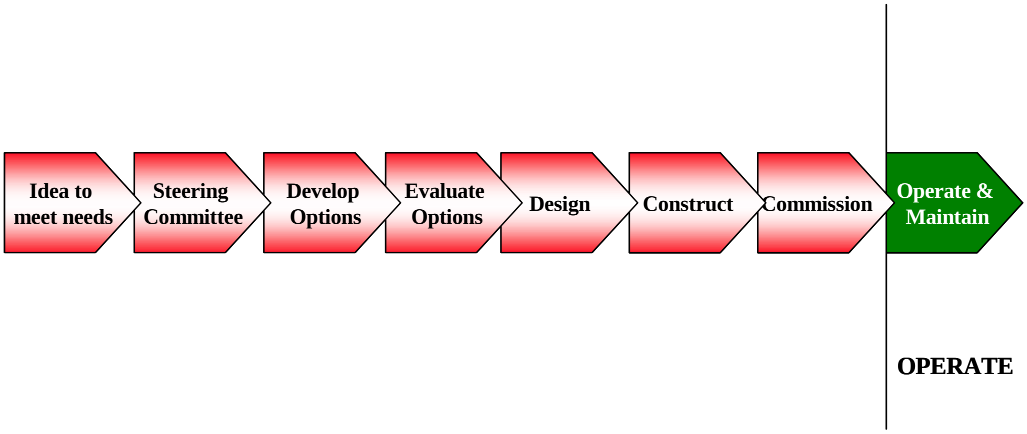

**Figure 241 Operational Phase**

The key elements of the operation and maintenance (O&M) stage of a water harvesting and reuse scheme include;

- operation of the system to consistently meet performance requirements,
- maintenance of the equipment to ensure proper operation and service, and
- access to appropriately trained operating personnel.

Proper operation and good maintenance is essential in ensuring the continued viability and safety of a water harvesting and reuse scheme. It not only provides protection for the owner (public liability) but the general public as well. Furthermore, the cost of proper operations and maintenance is small compared with costs of the consequences of a system failure which could include major repairs, possible loss of life, property damage and litigation. However, installation of lower cost technologies often involves a trade off between initial capital costs and ongoing maintenance (O&M) costs. It is important that the project sponsor, usually the local council, is committed to a comprehensive and ongoing O&M program to avoid operational problems which can arise from lower cost options which are not properly monitored and maintained.

### Monitoring and Reporting

The parameters monitored and testing frequencies are determined to ensure process control and compliance with licence conditions. The health and environmental regulators will generally require reporting of reclaimed water quality data on a regular basis. Also any changes or abnormalities in treatment plant performance resulting in changes in reclaimed water quality would generally be reported to the regulator. Sampling frequency may be reduced based on a satisfactory historical record and subject to approval by the health regulator. For small and/or remote rural communities where it is not feasible to apply normal microbiological monitoring the recommended frequencies may be reduced. In such cases greater reliance may be placed on surrogate parameters such as lagoon detention time or disinfection residuals (NHMRC, ANZECC & ARMCANZ 1996).

### Operation and Maintenance Manuals

An operational and maintenance (O&M) manual for the water harvesting and reuse scheme should be prepared to collect in one document operating procedures and maintenance instructions. The purpose of the O&M manual is to provide guidance for proper operation of the water harvesting and reuse scheme regardless of the passing of time and changes in operating personnel. Operating procedures should be developed for the safe operation under adverse conditions (worst case scenarios) as well as normal conditions. These enable responsible persons unfamiliar with the water harvesting and reuse scheme to operate the system during an emergency situation or at such other times as may be necessary.

ANCOLD (1994) recommend that the structure of an O&M manual be divided into the following areas,

- General Information - background, administration, responsibilities and supporting documentation
- Operating Procedures - detailed information required by an operator to ensure proper and safe operation of the systems and associated equipment
- Maintenance Instructions - for performing periodic maintenance so that new personnel can understand the task and experienced personnel can verify that tasks have been completed the work properly.
- Operations Log - standardised forms for the collection and reporting of all types of data

Further, that the O&M manual should be reviewed and if necessary updated at 5 yearly intervals or when changes or other circumstances dictate (ANCOLD 1994).

### Operations Log

A log of O&M activities should be provided at the facilities and entries should be periodically verified by supervisors to ensure compliance with authorised procedures and instructions set out in the manual (ANCOLD 1994)

Brief instructions and standardised forms for the collection and reporting of all types of dam and reservoir data should be included. For example, routine data may be required at a dam on the following:
- storage water level,
- storage inflow,
- spillway overflow,
- irrigation demand,
- water supply draw off,
- weather, and
- water quality.

Each water harvesting and reuse scheme should have an operations log whether or not it has full or part time attendants or is normally unattended. This log should be maintained by operations personnel (preferably in a bound book) and should contain a chronological record of all important events at the facility for future reference. This log could be helpful in providing clues to the cause of equipment failure and the development of unusual conditions.

Reclaimed water systems require a high standard of operation, control, and monitoring to protect public health. The supply authority will be required to demonstrate it is implementing an appropriate quality management program, seek continuously to improve the quality of its reclaimed water system, and incorporate new developments (NSW RWCC 1993)

The authority shall designate a 'Reclaimed Water Supervisor' with appropriate professional qualifications to be responsible for the monitoring of reclaimed water quality for compliance with requirements of the regulatory authorities, operation of the authority's distribution system, and for surveillance of onsite systems (NSW RWCC 1993)

The RWS shall develop and maintain an effective quality management system, including documented standard procedure, training schemes and manuals, and a written log. The log will contain details of standard operating procedures, all audit checks, and include system failures and violations and details of corrective action taken both at the time and to prevent reoccurrences (NSW RWCC 1993)

### Conditions of Supply

The authority shall adopt appropriate regulations to control the use of reclaimed water and shall give effect to these in a set of conditions of supply to users (NSW RWCC 1993)

The conditions of supply should include provision for (NSW RWCC 1993):

- the responsibility of the user for the operation and surveillance of onsite domestic potable and reclaimed water systems to avoid cross connections,
- the right by the authority to enter upon the user's premises during reasonable hours for the purpose of inspecting the reclaimed water facilities and their operations and testing for cross connections, and
- work on the system to be only undertaken by the authority or approved licensed plumbers.

### Community Information

Acceptance and understanding of water harvesting and reuse scheme by users is vital to the ongoing success of a scheme. When the scheme is about to be commissioned, the Supply Authority should provide individual users with education about the system operation and instructions on the proper use of the system. Users should be made clearly aware of their responsibilities under the conditions of supply. Users should be made aware of the measures required to minimise potential adverse impacts on soil and vegetation and minimise runoff (NSW RWCC 1993)

Prior to initiation of a reclaimed water scheme, a community consultation process should be undertaken (NSW RWCC 1993)

# Appendix 18
# Involving the Community

## A18.1 INTRODUCTION

South Australian rural communities are generally self-reliant because of their remoteness. Further, most people concern themselves with how things will impact on the success and future of their community. This community spirit can be harnessed and used to stimulate interest in the development their alternative water resources. Nevertheless, encouraging community participation and involvement is not always an easy task when introducing new ideas because most people are wary of change, particularly if they perceive a specific change to be detrimental to their interests, or controlled by others. However, a broad cross section of the community is usually willing to share ideas when a community involvement process has been designed to include them and is directed by trusted local leaders (Nugent *et. al*. 1997).

The process should be introduced in the earliest stages of the system of planning described in Appendix 17 to allow ample time for the dissemination of information and acceptance of new ideas among the community. Active participation from the beginning is likely to create a cooperative rather than competing or conflicting relationship (Dugdale 1989 & US EPA 1992) between the project sponsor, the steering committee and the community. The process may accelerate the implementation of a project by uncovering any opposition early enough to adequately address concerns raised (US EPA 1992).

This information contained in this Appendix is intended to highlight the importance of involving the community in the planning and establishment of a water reuse project and also provides a brief overview to the vast range of participation techniques available. The emphasis is with developing a unique community involvement process to cultivate community support especially in the context of small and/or rural communities.

### A18.1.1 *Community Acceptance and Support*

Water harvesting and reuse projects enjoy greatest public acceptance where water resource issues and pollution abatement issues have been combined. This is because ‘the Community’ tends to support environmentally beneficial projects, such as water conservation, water quality protection of water resources and public health protection.

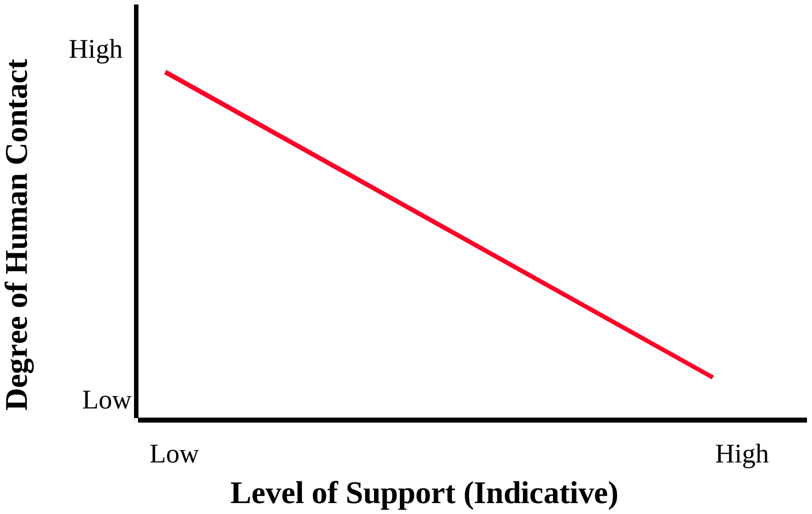

**Figure 242 Level of Support (Indicative) for Water Reuse Projects**

The main objective of community involvement is to influence 'public opinion' in order to increase the level of acceptance and support for the proposed project. Black (1993) defined 'public opinion'; the predominant attitude of a community; the collective will of the people; or the summation of public expression regarding a specific issue. Extensive studies have been carried out to determine the general public's knowledge and attitude towards treating effluent to drinking water standards. The main obstacle limiting direct potable reuse has been community acceptance (Polin 1977, WPCF 1989 and Law 1999) and will continue to be for some time yet.

Burvold (1988) developed two significant hypotheses which provide guidelines for assessing public acceptance of an effluent reuse project:

- In general reuse surveys, the degree of human contact was the more important determinant of public opinion on effluent reuse; and
- For specific reuse applications, where water reuse was an imminent possibility (i.e. construction to provide reclaimed water service was being considered) the more important determinants of public opinion became:
  - the ability of the project to conserve water;
  - environmental enhancement achieved by the project;
  - protection of public health;
  - the cost of treatment required; and
  - the cost of distribution.

Cargill (1997) reports that Sydney Water acknowledges the general public's attitude toward treating effluent for the potable water supply. Sydney Water has initiated a long term community involvement process concentrating on education which includes constructing a demonstration Water Factory.

Less published information is available on community support for stormwater harvesting, storage and use but it is reasonable to adopt the same principles when planning a stormwater or combined effluent and stormwater scheme.

If a water harvesting and reuse project is being planned a survey of public opinion within the community should be undertaken to help make the project a success. The project sponsor and the steering committee need to be aware of the level of support within the community, particularly, as the community must pay for the project as well as accept the end use of the water to be reused. Acceptance of the selected option, which may incorporate lower standards associated with lower capital costs, will be more likely if the community has been briefed on the progress and likely outcomes through the life of the project.

Unless the community has ownership of the outcome of the feasibility study and the recommended option, it will be difficult to maximise the potential benefits of lower cost options. This may well be the difference between the water harvesting and reuse scheme being affordable and not affordable.

Several government agencies have the responsibility of regulating the goals of liquid waste management. The South Australian Government recognised over 30 years ago that stringent regulation by applying generic standards and practices developed for larger sewerage systems can impede the adoption of appropriate, cost effective solutions to the liquid waste management problems of small communities. Where affordability is the major factor in deciding whether or not improvements are made, to address existing public health/environmental deficiencies, it is vital for small communities that relevant agencies specify public health and environmental requirements that are appropriate to the specific needs of that community.

In some circumstances, the community involvement process may be more important than the final detail of selected water reuse scheme because people want to be informed and have an opportunity to complain (Sarkissian et. al.1986). This is particularly relevant in small rural communities.

Sarkissian et. al.(1986) point out that any participation at local level can elicit informed and useful responses on questions of local detail, on things that may not seem important to designers (who are therefore unlikely to think of them) but may be very important in the lives of those suggesting them. The success of a water harvesting and reuse project depends on support from the local community. Experience indicates that a small number of motivated individuals can often be responsible for developing the required commitment (US EPA 1992).

Individuals who have taken part in the planning process will be effective proponents of the selected option and become direct broadcasters of the water harvesting and reuse scheme. Having educated themselves on the issues involved they will understand how the various interests have been accommodated. Their understanding of the process will be communicated to the larger interest groups - neighbourhood residents, clubs, and municipal agencies - of which they are a part (US EPA 1992). Indeed, the potential water reuse customer enthusiastic about the prospect of receiving the service can be one of the most effective means of generating support (US EPA 1992) for a water harvesting and reuse project.

To maintain the strong support and cohesion the local community must manage the project. However, sometimes it can be an advantage to engage a person outside of the community to facilitate public meetings because such a person has to ask a lot of questions to understand that particular community.

### A18.1.2 *What is Community Involvement?*

Community involvement is not *'a means of getting the public onside'* (Sewell *et. al* 1985) but is;

- a way of tapping into the rich reservoir of ideas from individuals,
- a sounding board for proposals,
- access to local knowledge of issues which may affect a proposal,
- an avenue to educate the community, and
- raise awareness of alternative water resources.

It is a vital component of the planning process, particularly in small or rural communities, to generate support and cooperation. In practice it involves:

- researching public opinion, attitudes and expectations;
- establishing and maintaining two-way communication based on truth and full information;
- preventing conflicts and misunderstandings;
- promoting mutual respect and social responsibility; and
- harmonizing private and public interest.

Black's (1993) 'iceberg syndrome' analogy, presented in Figure 243 illustrates the hidden aspects of developing a Community Involvement Program. It emphasises the contrast between the general perception of community involvement and the complex reality.

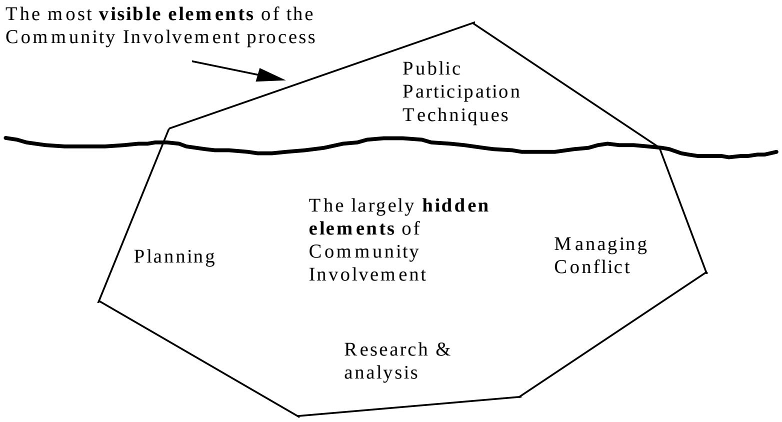

**Figure 243 Community Involvement & the Iceberg Syndrome**

An effective Community Involvement Program (CIP) requires a considerable amount of work behind the scenes which is often overlooked during the development of a water harvesting and reuse project. Involving the community will take time, cost money (Sarkissian et. al. 1986), and raise expectations (Praxis 1988), however, in small or rural communities, it need not be overly time consuming or expensive. Nevertheless, to successfully promote a project sufficient budget and resources must be allocated to the task.

### A18.1.3 *'The Community'*

'The Community' is any person or group of people that have a distinct interest or stake in an issue (Praxis 1988). The project sponsor will have a range of individuals and groups with which it may wish to communicate (Black 1993) depending on the size and complexity of the proposed water reuse project. These may include any combination of the following stakeholders:

- potential customers/users of the water reuse supply,
- major water users,
- residents affected by the proposal,
- the wider community,
- local interest groups,
- service clubs (ie. Rotary Club, Lions and others),
- resource management agencies,
- local business and industrial groups,
- state and local government,
- environmental and other pressure groups,
- the media, trade and professional associations, and
- academic and research institutions.

Each member that forms part of 'The Community' has the right to express views on all issues, and it is important that none are excluded from the process. Rowe & Abdel-Magid (1995) have noted that the interest and pressure groups have demonstrated most interest in the water resource issues. This is partly because they have established mechanisms through which their views can be heard. Reaching the 'unorganised' public is more difficult (Davis, 1996) and may require use of public meetings, letter drops, talk-back radio programs to solicit opinions.

The Steering Committee need to recognise that each individual group within the community has different interests at stake. Furthermore, that the composition of 'The Community' will change for each major issue, and will often grow larger as a decision gets closer and its consequences are better understood. Therefore, it is necessary to determine which groups of 'The Community' are most relevant at any particular project phase and tailor the participation techniques selected in the Community Involvement Program to match this.

## A18.2 WHEN TO INVOLVE THE COMMUNITY

Community involvement is appropriate when the issue is of significance to the community or the issue is about development or growth of the town. Throughout South Australia, water has always been linked with the most important political, economic, and community issues. Change and development of new ideas or innovative technologies frequently involves conflict within the community. The conflict may not be open hostility but a simple misunderstanding of stakeholder's different needs. Dugdale (1996) suggest that even if the conflict is not resolved, the clarification of issues provide a better chance for understanding; at the very least the parties will understand the different perspectives and be more ready to accept the final decision.

It is a continuous, two-way communication process whereby individuals, families, and other community members are involved throughout the project as illustrated in Figure 244. A focussed Community Involvement Program can provide guidance throughout the four phases in the system of planning an alternative water supply scheme. For example, Councils making application for funding assistance to install a STED scheme are required to support the application with information demonstrating the need for a scheme. The application will be given a relative priority for funding assistance based upon the level of need demonstrated. Information from 80% of the premises to be served is considered a fair and representative view.

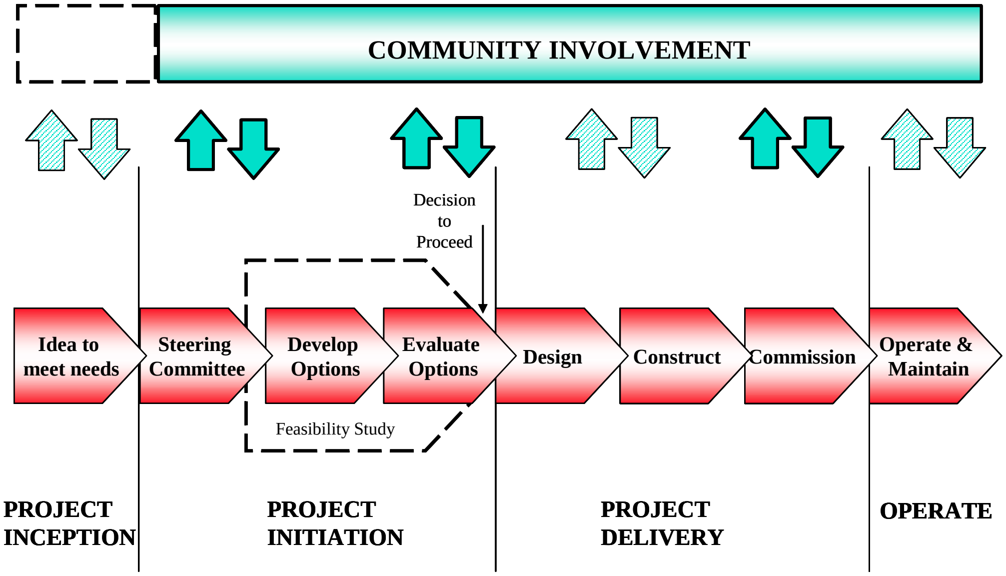

**Figure 244 Community Involvement and the System of Planning**

The Steering Committee is responsible for developing the Community Involvement Program as an integral part of planning process. The process will only be effective if the Project Sponsor appreciates the importance of "implementing planned programs of action which will serve both the organisations and the public interest" (Black 1993). If adequately resourced, this activity can make its maximum contribution to efficiency and profitability of the alternative water supply scheme.

### A18.2.1 *Degree of Community Involvement*

The degree of involvement invited by the Steering Committee will depend on the primary objective of the Community Involvement Program. In general, the more comprehensive the program, the greater must be the Project Sponsor's commitment to support the process and to use the results which are generated by it (Praxis 1988). Less than total commitment to proceed with the process will induce disaster (AWRC 1992) and could result in decreased interest and support for the proposed alternative water supply scheme.

Table 78 shows the level of commitment to the community involvement process and the corresponding message this gives to the public.

**Table 78 Degree of Community Involvement and Level of Commitment**

| Degree of Involvement | Message to the Public |
|---|---|
| Public Information Release | You want them to know about it. |
| Public Education Program | You want them to understand and support your project. |
| Opinion Sampling | You care about what people think. |
| Checking Plans for Acceptance | You are willing to alter plans and operations to accommodate their views. |
| Extended Advisory Involvement | You expect to implement most of their advice. |
| Joint Planning and Decision Making | You are fully committed to using the results in all but the most extenuating circumstances. |

*Adapted from Table 2 page 12 of Volume 3 Part 1 of 'Public Involvement - Planning and Implementing Public Involvement Programs by Praxis 1988.*

If a project truly has minimal impact on the general public the Steering Committee may choose to limit the program. The more complex the participation techniques chosen the more costly the overall program becomes. It is sometimes beneficial to engage a consultant to design the best approach to match the objectives. The consultant can also be used to implement the Community Involvement Program on behalf of the Project Sponsor.

## A18.3 THE BENEFITS AND PROBLEMS OF INVOLVING 'THE COMMUNITY'

The decision to involve the community, is made essentially on the basis of a balance of the positive benefits and the problems (Sarkissian et. al.1986). Regular dialogue with 'The Community' throughout the planning process builds an essential level of knowledge and understanding within the community which in turn means 'The Community' is in a better position to be able to contribute. Although there can be no guarantees, if a consultative planning approach is adopted, particularly in small or rural communities, the chance of substantial delays can be reduced (Gesalman 1994). Unfortunately, a Project Sponsor will typically focus on only one or two of the many participation techniques available, and choose the quickest and least expensive ones. As expected the value of the resulting input from the community is usually a direct reflection of the Project Sponsor's commitment to the process.

### A18.3.1 *Benefits*

Involving residents and business people can aid in gaining essential concessions such as access, land use, funding or accepting temporary inconvenience. Experience has shown that given the opportunity, members of a small or rural community are prepared to actively contribute to alternative water supply schemes and environmental enhancement of their local water ways and town.

Benefits which may result from involving the community during the planning (Sarkissian et. al. 1986 & Dugdale 1989) of an alternative water supply scheme can include:

- clarifying the major issues of concern to the community,
- improving sensitivity of the alternative water supply project to the needs of the wider community,
- reducing misapprehension and fears,
- increasing the level of understanding in the community through availability of accurate information,
- balancing differing viewpoints,
- opportunities for the resolution of any conflicts which may exist,
- stimulating community volunteers and organising working bees,
- gaining support from local businesses which may be in the form of finance, direct purchase of materials and equipment, or use of plant and machinery,
- selection of low operation and maintenance cost alternatives, and
- successful pursuit of funding assistance.

### A18.3.2 *Problems*

Some problems that may be encountered in the community involvement process (Rowe & Abdel-Magid 1995) can include the following:

- lack of experience by the community members,
- confusion of issues by the community,
- lack of knowledge as to the program's objectives, layout, and method of implementation,
- erroneous information (rumours and hearsay),
- inadequate community motivation and lack of interest,
- budgetary problems, particular to fund community involvement activities,
- project delays due to social and political issues,
- the tendency of community members to lose interest and thus affect the continuity of the process of community involvement throughout the different project phases, and
- uncertainty of the results of the program.

Sarkissian (1986) reported that community involvement in planning in Australia is beset by problems despite organisations trying and spending money. The reasons for this, can be summarised as follows (Sarkissian et. al. 1986):

- participation in the local planning process usually occurs too late, generally well after the directions are set,
- there is very little real community involvement or informed public discussion on the biggest issues,

- state and local governments are able to avoid community involvement, if they wish, by making decisions secretly or without sufficient time for public discussion, and
- ‘The Community' is not generally well resourced in time, expertise or money to make its voice heard effectively.

Not everyone chooses to, become involved in policy making (Davis 1996). A common criticism of community involvement programs is that they often involve only a relatively small cross section of the community and are therefore not representative of community attitudes. For example, in the Mt Lofty Ranges Review only about 1% of the region’s population actively participated in workshops. People who disagree with the outcomes of a community involvement program will often cite the low level of direct input as a justification for not accepting policies (Dugdale & West 1991).

## A18.4 PREPARING A COMMUNITY INVOLVEMENT PROGRAM

There is no precise formula for selecting an effective Community Involvement Program because each community will have its own particular needs. The selection of the most appropriate approach is a matter of judgement, however, the decision should be made easier by the knowledge the Steering Committee has of local community attitudes. The range of participation techniques to choose from is vast and a single technique is rarely used alone but in conjunction with a carefully chosen selection of those available.

Dugdale & West (1991) outline some fundamental community involvement principles, which if applied sensitively can significantly increase the likelihood of success. The basic principles are:

- begin participation at the earliest opportunity,
- network the community to identify and involve key people,
- achieve broad representation of those who will be affected,
- make relevant information easily available,
- use interactive consultation techniques,
- conflict resolution should be a feature of the process,
- use staff who have good communication skills,
- provide feedback on issues and outcomes, and
- evaluate effectiveness of the whole program.

The purpose of these principles is to involve groups and individuals who are interested or are likely to be affected and provide a flexible process which maximises community input to the decision making process.

The assumptions underlying the development of an effective Community Involvement Program are:

- the recognition that all parties in the process have an important contribution to make,
- the need for access to a common information base,
- the need for consultation on the process itself,
- the need for a clear statement of issues and objectives, and

- the view that consensus building is possible, but it requires flexibility, compromise, and sufficient time and resources.

The plan should incorporate details regarding financial support needed and the expected expenditures for the Community Involvement Program. Many agendas announce public participation at the beginning of the project, but few decide on a budget for its implementation. Establishing a realistic budget at the beginning will ensure that participation is sufficiently resourced and not tagged on as an after thought.

Support is required to cover the entire consultation process:
- establishing objectives,
- identifying the significant groups in 'The Community',
- providing information to the community,
- selecting appropriate consultation methods,
- undertaking consultation,
- using consultation outcomes, and
- evaluating approaches and processes used.

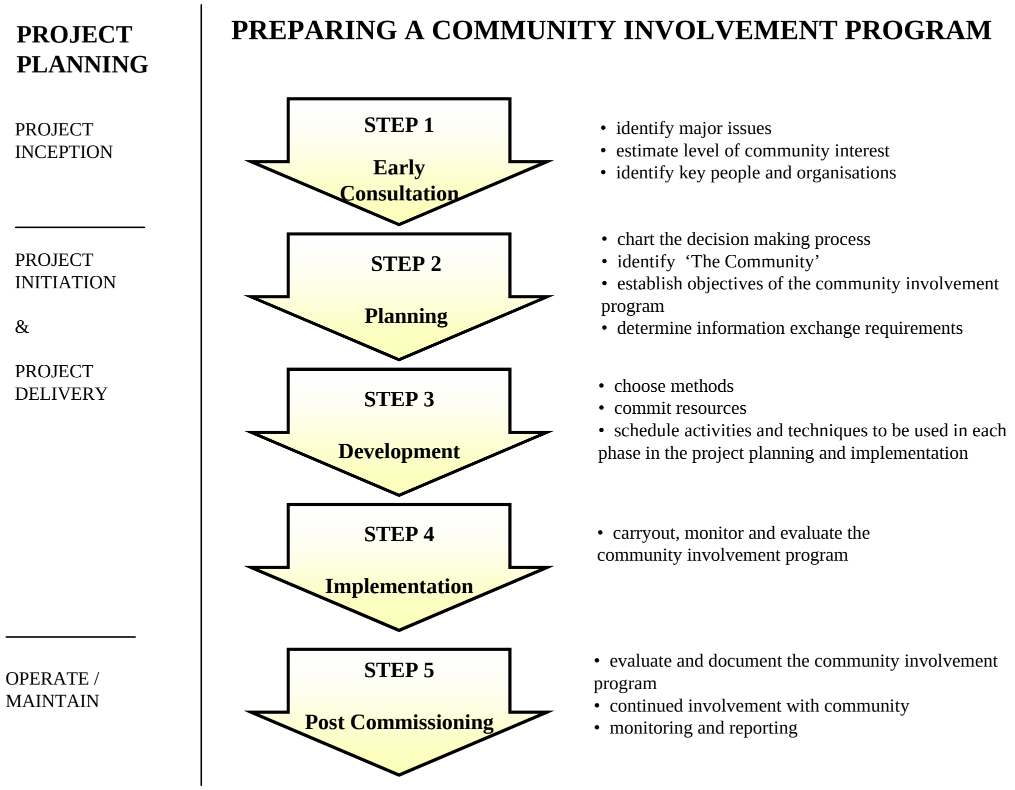

**Figure 245 Steps to Prepare a Community Involvement Program**

Each step is explained in more detail in the following sections. Each community involvement program should be appropriate for the site and based on the results of community interviews on how best to involve the community and past experiences.

### A18.4.1 *Step 1 - Early Consultation*

Early consultation with members of the public who are interested in, or will be directly affected by, the proposed alternative water supply project is an excellent investment. If the first stage is 'reconnaissance' both the planning and decision making processes can benefit by:

- early identification of the major issues of concern;
- estimating the level of community interest; and
- identification of the key people and organisations.

During this stage it is possible to explore the issues that may be raised by the implementation of the project. This early discussion allows time to sort out those issues that are likely to cause real concern in the community from those which are hypothetical. Even if all the information has not been assembled or analysed for the alternative water supply project, it is preferable to touch base with the various groups in the community now rather than wait. It is important to broadcast the schedule for obtaining the preliminary information and the timing and method of the feasibility studies. Do not assume that the issues that have been identified will remain the same or that new issues will not arise during the planning and consultation process as the options develop.

#### Profiling the Community (For external consultants)

By learning more about the nature of the community, it is possible to refine each subsequent stage of the process to be more responsive to the community's customs and requirements (Dugdale & West 1991). This may include visiting the communities, touring the sites of the proposed projects, and collecting planning and other documents, including local histories. From these sources a demographic profile and an economic profile of each county within the study area can be prepared. This is necessary to establish baseline data. Such profiles can be helpful for a deeper understanding of the people with whom the Project Sponsor and the Steering Committee would be working in the community involvement activities. Cortese & Firth (1997) cite that such preparation dispels the typical and often correct attitude of the local community that 'out-of-town consultants know nothing about us'.

#### Interview Key Informants (Networking) & Identify Stakeholders

During the initial visit to the community meetings or interviews with a range of 'key informants' should be arranged. In general, these are local officials, informal community leaders, representatives of relevant organisations or associations, and people who may be directly affected by the proposal (ie. land owners). These people can begin to identify and describe local issues and concerns related to the project. Cortese & Firth (1997) say that by taking the time to talk to the 'key informants' it is possible to learn of groups, organisations, businesses, and agencies in the local community that would not have been discovered or expected to have an interest in a proposed project. Another goal of the key informant interviews is to identify all those with an interest in the establishment of an local water supply system project (Nugent, Wellman & Gregory 1997).

### A18.4.2 *Step 2 - Planning the Process*

A formulated program should be presented to the community in an easy to understand format. The program should include the ideas of the community and its leaders.

#### The Decision Making Process

To make good decisions it is necessary to assemble as much information as possible on the factors that will influence the decisions. A knowledge of local attitudes and knowledge will help the Steering Committee make this decision with more confidence. That's why Step 1 is useful. Management of a community involvement program, requires a clear understanding of the objectives of both the program and the alternative water supply project. It is important to be realistic in the assessment of the situation and not underestimate what is required in terms of resources to complete a particular course of action selected for the community involvement program.

#### Defining Objectives

The objective of the CIP must be in line with and reinforce the objectives of the proposed alternative water supply scheme. They should be made clear at the outset. Also wherever possible they should be stated in terms of numbers, dates or dollars.

Rowe & Abdel-Magid (1995) suggest that the objectives of a community involvement community may include:

- information and community education;
- identification of problems, needs and important values;
- idea generation and problem solving;
- reaction and feedback on proposals;
- evaluation of alternatives; and
- conflict resolution and consensus.

The objectives should be written down, reviewed and modified regularly as the project progresses. It is important that the objectives are not 'set-in-concrete', as they are a guideline. Once the objective has been established it is time to develop an appropriate community involvement program.

### A18.4.3 *Step 3 - Development*

The steering committee should be responsible for arranging the development of an appropriate community involvement program. There is no single strategy that is sufficient in all cases. Each situation will require a unique set of participation techniques according to the financial and managerial resources available of the local community. Programs often include continuing activities, such as newsletters, public workshops and briefings, a telephone information line, and reading rooms.

In addition, the cost of each of the public participation techniques chosen should be determined. In this way it is possible to determine the effectiveness of the CIP and each of the various strategies selected.

There is a need to establish a flow of information to and from the potential reuse customer. For implementation purposes, the designer requires information on the system(s) to receive the reclaimed water and to ensure compatibility. The potential customer on the other hand will wish to have a clear understanding of the proposed alternative water supply project and provide input regarding their needs and concerns.

In order to avoid difficulty associated with public acceptance, it is of paramount importance that the expected benefits of the proposed alternative water supply projects be established. For example, if the project is intended to extend water resources, the preliminary studies should address how much water will be made available and compare the cost of reclamation to that of developing additional potable water sources. If the cost of reclamation is not competitive with potable water in cost, there must be overriding non-economic issues that equalise the value of the two alternative sources. Where reclamation occurs for environmental reasons, such as the reduction or elimination of a surface water discharge, the selected reuse alternative must be competitive with other disposal options.

Once firmly established with supporting evidence as necessary the benefits will become the planks of a community involvement program and it is possible to state 'why' the program is necessary and desirable. Without such validation, alternative water supply projects will be unable to withstand public inspection and the likelihood of project failure is increased.

The community is most interested in four aspects of the project:
- facility siting,
- environmental controls,
- end-use of the alternative water supply, and
- end benefit of the project.

These concerns are the same regardless of the community for which the facilities are proposed (Bontrager & Frieling 1990).

The following is a summary of the most significant issues, questions, and concerns typically raised during the public input process (Bontrager & Frieling 1990):
- people near the proposed site,
  - potential odours
  - decrease in property value
  - health risks
- general apprehension about locating reclamation facilities in a residential area,
- concerned, regardless of the depth of the studies undertaken, that not all viable alternatives have been explored,
- there is generally a consensus among the public that reclaimed water itself does not constitute a significant health risk, and
- the public generally support the end benefit of the reuse project, usually some community facility such as a park, lake, or greenbelt.

## Table 79 List of Community Involvement Techniques

| | Public Information | Information Feedback | Consultation | Extended Involvement | Joint Planning |
|---|---|---|---|---|---|
| Advertising | ✓ | | | | |
| Brochures | ✓ | | | | |
| Citizen Training Programs | ✓ | | | | |
| Contests/Events | ✓ | | | | |
| Direct Mail | ✓ | | | | |
| Exhibits/Displays | ✓ | | | | |
| News Conferences | ✓ | | | | |
| Newsletters | ✓ | | | | |
| Newspaper Inserts | ✓ | | | | |
| News Releases | ✓ | | | | |
| Position Papers | ✓ | | | | |
| Political Review | ✓ | | | | |
| Publications/Reports | ✓ | | | | |
| Public Announcements | ✓ | | | | |
| Community or Social Profiles | | ✓ | | | |
| Web Participation | | ✓ | ✓ | | |
| Focus Groups | | ✓ | ✓ | | |
| Interviews | | ✓ | ✓ | | |
| Policy Profiling | | ✓ | | | |
| Polls | | ✓ | | | |
| Questionnaires | | ✓ | | | |
| Surveys | | ✓ | | | |
| Written Submissions | | ✓ | | | |
| Brainstorming | | | ✓ | | |
| Coffee Corners | | | ✓ | | |
| Conferences | | ✓ | ✓ | | |
| Delphi | | ✓ | ✓ | | |
| Dialogues | | | ✓ | | |
| Field Offices | ✓ | ✓ | ✓ | | |
| Nominal Group Process | | ✓ | ✓ | | |
| Open Houses | ✓ | ✓ | ✓ | | |
| Panels | ✓ | ✓ | ✓ | | |
| Participatory Television | | ✓ | ✓ | | |
| Phone Lines | ✓ | ✓ | ✓ | | |
| Public Meetings | ✓ | ✓ | ✓ | | |
| Simulation Games | | ✓ | ✓ | ✓ | |
| Technical Assistance | ✓ | ✓ | ✓ | ✓ | |
| Trade-off Games | | ✓ | ✓ | ✓ | ✓ |
| Workshops | | | ✓ | ✓ | ✓ |
| Advisory Committees | | | ✓ | ✓ | |
| Task Forces | | | ✓ | ✓ | |
| Arbitration | | | | ✓ | ✓ |
| Collaborative Problem Solving | | | | ✓ | ✓ |
| Conciliation | | | | ✓ | ✓ |
| Mediation | | | | ✓ | ✓ |
| Negotiations | | | | ✓ | ✓ |

*Source: Table 2 page 59 of Volume 3 Part 2 of 'Public Involvement - Planning and Implementing Public Involvement Programs' by Praxis 1988*

### A18.4.4 *Step 4 - Implementation*

The steering committee is responsible for implementing the selected community involvement program. Before construction begins, a brochure may be prepared and distributed within the community which describes the project, explains why the project is necessary, and what the community can expect over the next 3 years. The questions which might be addressed at this stage are:

- What local sources of water might be suitable for use?
- What are the potential local markets for the alternative water supply?
- What public health considerations are associated with its use, and how can these be addressed?
- What are the potential environmental impacts of using the alternative water supply?
- how would the use of the alternative supply 'fit in' with present uses of other water resources in the area?
- what local, state or federal agencies must review and approve implementation of a alternative water supply project?
- what are the legal liabilities of a supplier or user of reclaimed water?
- what sources of funding might be available to support the alternative water supply project?
- what type of alternative water supply scheme would attract the interest or support from within the community?

At the appropriate stage, the agreed program will be implemented. It then becomes essential to decide what should be communicated, to whom and by what methods. In general, there are two reasons for communicating with ‘The Community’ - for information and for persuasion. The two reasons are not mutually exclusive and it can be expected that inclusion of sufficient accurate information will fulfil the persuasive requirement (Black 1993). When a Community Involvement Program has been agreed to by the Project Sponsor, the plan will usually include a number of different methods of communicating the message to priority groups in ‘The Community’.

#### Feedback

Feedback to the public as to how their comments were used (in a timely manner) in revising plans is important part of the process to maintain openness and foster trust. Cortese & Firth (1997) recommend that the results are analysed and short reports sent to participants within three weeks of the meetings, to thank them for their contributions and invite further comments or questions. The reports show the participants how their contributions have been interpreted. Feedback to participants, during the early in the stages of the planning process, can be helpful when often over a year later, copies of the final option are sent to the communities, and members of the community are asked to attend public meetings. Community involvement in a water harvesting and reuse scheme does not stop once the project has been commissioned. The plan must include and evaluation of the project during and after its completion. It is important that past successes be promoted to assist communities to implement similar or improved programs (McLaren et. al. 1987). Dugdale (1993) supports the view that unless initiatives are documented and evaluated there can be no reliable way of verifying and measuring success, and avoiding previous mistakes.

# Appendix 19

# Draft Guidelines for Country Townships

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## A19.1 INTRODUCTION

This appendix contains a complete copy of the *DRAFT Guidelines for the Assessment of Water Management Opportunities for Country Towns* submitted in July 1999 for the Customer Service Senior Management Improvement Program.

| | |
|---|---|
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Disclaimer:

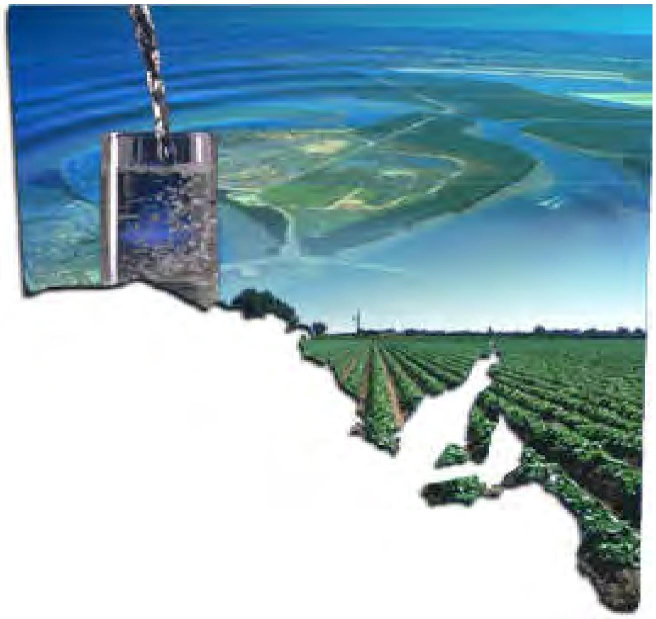
This is a South Australian Water Corporation internal document. Until the Government has approved the contents it has no official status. In particular it must not be assumed that any recommendations contained herein or any proposals for future action are part of any Government approved policy.

Nevertheless, the Hoffrichter *et al.* (1999) guidelines indicate that individuals within SA Water are seeking to find solutions to water supply issues by cooperation with local communities in accordance with widely recognised 'best practice' principles. The guidelines also recognise that community involvement and local expertise are important to delivery of sustainable water services that support growth in small towns. The research undertaken by Hoffrichter *et al.* (1999) indicated that there is generally a strong community interest in issues and that communities would be actively involved in any consultation on water supply issues provided '*social justice*' issues (equity) are adequately addressed and maintained. This could possibly be interpreted as concern over further withdrawal of services to rural areas and not being required to pay more for water. Regrettably, the proposed assessment guidelines have not been applied to any community to date (Swift *pers. comm*. 2005)

**SA Water**

SOUTH AUSTRALIAN
WATER CORPORATION

# *Assessment of Water Management Opportunities for Country Townships*



# DRAFT
# Guidelines

## GROWING BUSINESS WITH COUNTRY COMMUNITIES

**July 1999**

DRAFT

# GUIDELINES
# FOR THE
# ASSESSMENT OF
# WATER MANAGEMENT
# OPPORTUNITIES
# FOR COUNTRY TOWNSHIPS

| | |
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**South Australian Water Corporation**

# TABLE OF CONTENTS

*[Original page numbering has been removed]*

## 1 EXECUTIVE SUMMARY

There are many country town communities where the water distribution infrastructure is struggling to meet demand, particularly during peak periods. Councils and Development Boards have advocated that the lack of adequate water supply in their communities is one of the prime reasons for not being able to pursue development in their areas. These guidelines establish a framework for SA Water to assist country town communities assess water management opportunities within their area.

A model has been devised which encompasses all of the issues to be considered in the application of the Guidelines. There are four principal elements to the model, namely:-

| | |
|---|---|
| • **Demand** | The past, present and future water requirements of the community |
| • **Supply** | The current and potential sources of water available to the community |
| • **Supplier** | Providing water to meet customer requirements in a cost effective manner |
| • **Customer** | The water needs and expectations of the community and their willingness to pay. |

A four-stage consultation process is recommended which allows for establishing the scope of the investigation, deciding on the options to be considered, reviewing the evaluation of options and considering the final direction to be taken. Decision making points occur throughout the process after the following key activities:-

- ➢ Scoping the issues
- ➢ Reviewing the options selected
- ➢ Reviewing the evaluation of the options
- ➢ Preparing the final report.

## 2 BACKGROUND

There are many country town communities where SA Water’s infrastructure is struggling to meet demand particularly during peak periods. Some of the reasons for this include:-

- The original infrastructure was designed for a different type of development than it is currently supporting
- The infrastructure is old and in places contributes to poor water quality, flows and pressures
- The population of communities can increase dramatically during summer holiday periods, creating very high demands for relatively short periods of time
- The cost of upgrading or augmenting supplies is high and disproportionate to the size of communities.

Councils and Development Boards have advocated that the lack of adequate water supply in their communities is one of the prime reasons for not being able to pursue development in their areas.

SA Water’s stance has been:-

- Augmentation of supplies needs to be commercially viable. In most cases the cost is high and the return does not warrant the expenditure.
- The ‘developer’ benefits and should contribute to augmentation works. In a large water supply system, it is often difficult to determine how far back into the system augmentation needs to start and where the developer's responsibility begins.
- A policy of ‘no expansion’ in some country communities due to limited supplies.

During the 1980’s, SA Water was a key participant in the Country Water Supply Improvement Program. The program enabled access to funds (on an equal share basis) from Commonwealth, State and Local Governments to provide improvement in water supplies in selected communities. The program is no longer operating.

SA Water has the opportunity to establish a fresh approach by working cooperatively with selected country town communities to facilitate commercially, environmentally and socially responsible initiatives that support growth for SA Water’s business and for country communities.

## 3 GUIDELINES OVERVIEW

These guidelines establish a framework for SA Water to assist country town communities assess water management opportunities within their area. They emphasise a cooperative and consultative approach between SA Water and communities and encourage the formation of alliances benefiting both parties. They also establish a mechanism to examine social, environmental and economic factors associated with providing country water supplies.

Key principles behind the guidelines include:

- Supporting community growth
- Generating commercial return for SA Water
- Maximising the availability of water
- Facilitating efficient use of water
- Managing customer satisfaction

The guidelines are part of a continuing SA Water service improvement initiative to work with customers, establish alliances and networks and seek opportunities that benefit involved parties. Initial discussions with communities have clearly indicated this approach is both welcomed and desired. Outcomes will include the development of goodwill and the improvement SA Water's image.

Not all situations will justify applying this structured approach as significant time and resources are required. Therefore, in reaching an early decision on whether to apply the guidelines, questions such as the following, need to be addressed:

- Does a commercial opportunity exist?
- Is there any potential competition?
- Will a case for Community Service Obligation funding be assisted?
- Can SA Water's action support development in the area?
- Is there community and/or political pressure?
- Are conventional solutions uneconomical?

Having decided to apply the guidelines it is essential to involve the community in the process of decision making. Water supply is an issue of prime significance to them and is critical in future planning for their community.

A four stage consultation process is outlined which allows for involvement in establishing the scope of the investigation, deciding on the options to be considered, reviewing the evaluation of options and considering the final direction to be taken. This process is designed to develop mutual understanding of the issues and influencing factors, address community expectations openly and provide a mechanism for rigorous evaluation which is aligned to current environmental, social and economic objectives. The aim is to find solutions that support the growth of both SA Water and country communities.

## 4 GUIDELINES MODEL

A model has been devised which encompasses all of the issues to be considered in the application of these Guidelines (refer Figure 246).

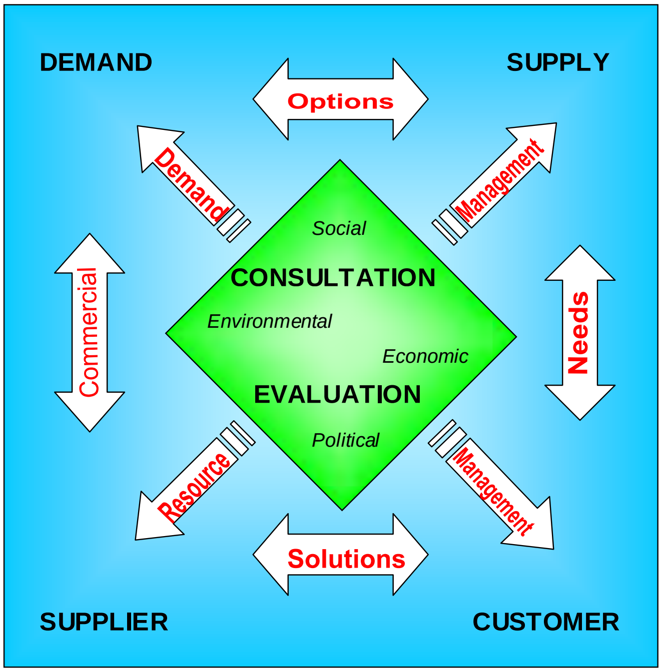

**Figure 246 Model to Grow Business with Country Towns (Hoffrichter *et al.* 1999)**

There are four principal elements to the model, namely:-

| | |
|---|---|
| **Demand** | The past, present and future water requirements of the community |
| **Supply** | The current and potential sources of water available to the community |
| **Supplier** | Providing water to meet customer requirements in a cost effective manner |
| **Customer** | Customers' water needs and expectations of the community, and their willingness to pay. |

Each of these elements is linked by a series of inter-relationships which must be considered if an acceptable outcome is to be achieved. The central focus of the model is to provide the means of addressing these links by using *Consultation* and *Evaluation*. Only through consideration of each of the elements and links will there be successful outcomes in *Growing Business with Country Communities*.

The relationships between the elements are explained in further detail below.

## 4.1 GUIDELINE 'TRIGGERS'

Firstly, it is important to understand that the '*trigger*' or entry point into the model can be from any one of the four key elements or from the central focus. Examples of the different '*triggers*' include:

### Demand Trigger

- An inability to supply water of sufficient quantity or appropriate quality
- A short term seasonal demand from an influx of tourists / recreationists
- Potential development or industry growth constrained by water limitations

### Supply Trigger

- Inadequate infrastructure due to aged systems, high maintenance costs or under-sized pipework
- The identification of alternative water sources of suitable quality which could commercially supplement demand requirements
- Conventional system upgrades / replacements are uneconomic and alternatives need to be found

### Supplier Trigger

- The identification of a commercial opportunity to increase profit through system growth, eg by demand management with little investment in infrastructure
- Competitors facilitating improved water supply options through water re-use, water harvesting or treatment technology
- Competitors focussing on low cost opportunities to generate market penetration

### Customer Trigger

- Developers are unable to expand or enhance growth in areas due to actual or perceived water supply limitations
- The community is dis-satisfied with water restrictions, poor pressure or poor quality.

### Consultation Trigger

- Campaigns driven by political or local community agendas seeking assistance for new or improved service
- Environmental issues arising from the use of water
- Where proposed infrastructure investment will require community understanding and acceptance in selecting a cost effective solution

## 4.2 RELATIONSHIPS BETWEEN ELEMENTS

Whilst each of the elements needs to be considered in detail, it is their relationship with each other that is used to determine the best outcome.

**Demand : Supply = <u>Options</u>**

The link between Demand and Supply is about a matching process used to develop options

- for the supply to meet the demand,
- for the demand to be managed within the limits of the available supply constraints, or
- a combination of the above.

**Demand : Supplier = <u>Commercial</u>**

The link between Demand and Supplier is to achieve a commercially viable way to meet and / or manage the demand

- with its own funds and business activities,
- with the support of external funds,
- as a joint venture or other partner / alliance arrangement, or
- by selling water at a point and enabling the private sector / local community to invest in the required infrastructure.

**Customer : Supply = <u>Needs</u>**

The link between Customer and Supply is about matching the needs and expectations of the community to realistic supply options.

**Customer : Supplier = <u>Solutions</u>**

The link between Customer and Supplier is the bridge across which solutions are devised. This is the relationship between a customer / community having a real need and a supplier seeking to assess feasible options to satisfy that need whilst ensuring the solution is commercially sound and within the bounds of the community's acceptance of the solution and willingness to pay.

**Customer : Demand = <u>Demand Management</u>**

The link between Customer and Demand is critical in assessing the extent to which demand management initiatives can be brought into the solution. It may be possible to significantly influence the demand to allow the current or future water needs to be met without investment in infrastructure.

**Supplier : Supply = <u>Resource Management</u>**

The link between Supplier and Supply is critical in assessing the extent to which the supplier can capitalise on the available water resources.

### CONSULTATION and EVALUATION

The central focus of the model is Consultation and Evaluation which binds the entire model. Considering any element without transition through the central hub is likely to produce an inadequate outcome.

The model also shows several other issues in the central hub, namely Social, Environmental, Economic and Political. Each of these, whilst not justifying the status of a key element, can have significant implications throughout any consultation and evaluation process. It is therefore important that these issues be identified early in any proposal under consideration and that they be routinely monitored until a final decision is adopted.

## 5 CONSULTATION

### 5.1 Communication Strategy

To grow business with country communities, it is essential that communication with the community is an integral part of developing and implementing any proposal, and that the communication be planned. The reasons for this include:

- Water related issues are a high priority within these communities
- Early and progressive communication encourages choice / participation and ownership in the decision making process
- Communication enables the level of knowledge and awareness within the community to increase, particularly regarding future planning
- Informed debate can occur about potential opportunities, constraints and realities.

To be successful, the communication process should:

- Be included in the initial planning as a specific component, with timing and resource provisions
- Begin early in the overall process
- Identify early the key interest / influencing people and / or groups
- Consider stages that target the general community, specific segments, community representatives, key interest / influencing groups and the local media
- Be continuous and two-way; plan ‘with’ rather than ‘for’
- Be known to the community in terms of what they can expect from the communication process
- Use local media to build a bank of positive information about the process / proposal
- Ensure clarity and consistency of information.

The importance of communication regarding a proposal also applies within SA Water. This is particularly true for key areas which could contribute to the solution or be impacted upon by the process, including the relevant Region, Commercial Development, Operations Planning, Land Development Services, Water and Wastewater Networks and Finance.

### 5.2 Consultation Strategy

A program of consultation is **essential**. All of the above points regarding communication are equally relevant to consultation. Planned consultation **must** be built into the process from the inception. There are four basic stages to be considered in the consultation program:

#### 5.2.1 Scoping the Issues

The extent of the issue and the boundaries of the review are established by:

- Clarifying the water issues (quantity, quality, continuity, seasonal)
- Understanding the current system (limitations, local knowledge)
- Identifying previous research, investigations and findings
- Confirming development and growth opportunities, and local / regional planning strategies
- Determining basic data including community profile, seasonal patterns, population / business trends
- Understanding potential implications for the community and/or local authorities regarding
    - implementation and acceptance of demand management practices
    - differing standards of supply
    - pricing and willingness to pay
- Clarifying community expectations and perceptions regarding the water issue
- Reaching agreement on the scope of issues.

#### 5.2.2 Review of Options

The review of options is supported by:

- Checking options against issues and expectations raised during the scoping stage
- Identifying potential benefits (growth, development, security of supply, environmental, social)
- Identifying potential costs / risks (magnitude of costs, water resource sustainability)
- Assessing priority order of benefits against costs / risks
- Reviewing implications to customers / systems in other areas

- Agreeing on whether to proceed or not, and if so, on which options need further evaluation.

### 5.2.3 Evaluation of Options

Evaluating the options and selecting a preferred option are undertaken by:

- Examining the implications of each option
- Checking options against issues and expectations raised during scoping and review
- Reviewing benefits and costs / risks for each option
- Reviewing proposed recommendations
- Identifying need for further consultation and comment
- Agreeing on revisions to proposal
- Selecting a preferred option.

### 5.2.4 Final Report Presentation

The final report represents the outcome of the investigation into water supply opportunities for a particular country community. In presenting a preferred option, it will clearly indicate:-

- That the proposed solution is commercially viable and meets the needs of the community
- The likely benefits, costs and risks
- The preferred timeframes for implementation
- Any alliances / partnerships that are part of the proposal (particularly in the area of financing the project)

The report is presented to the relevant Regional Manager for implementation in line with SA Water's '*Capital Expenditure Policies and Procedures*'.

# 6 IMPLEMENTATION STRATEGY

## 6.1 SELECTION OF OPTIONS

The selection of options for further evaluation should come from an initial examination of the water demands of the community and the total water resources available to it. It is important to look at these areas in the context of community expectations. For this reason the essential first step is initial consultation with the community to facilitate a mutual understanding of all the water supply and other related issues.

In order to make informed decisions, the benefits, disadvantages and the approximate cost of possible options need to be considered. This information must be easy to understand and must facilitate the comparison of options. Where relevant, the implications to the community should also be readily apparent. It is important that SA Water and the community come to agreement on any options that merit further evaluation and that a ‘sign off’ occurs before progressing to the next step. This will help focus the attention on specific areas without committing the parties to a particular solution.

The suggested approach is shown in Figure 247.

In addition to the high priority placed on community consultation, a large degree of technical investigation is required so that only the most viable schemes receive attention. For this reason, the coordination of the investigation and consultation should be under the oversight of a person who is able to present the practical issues of options before the community in a concise and clear manner.

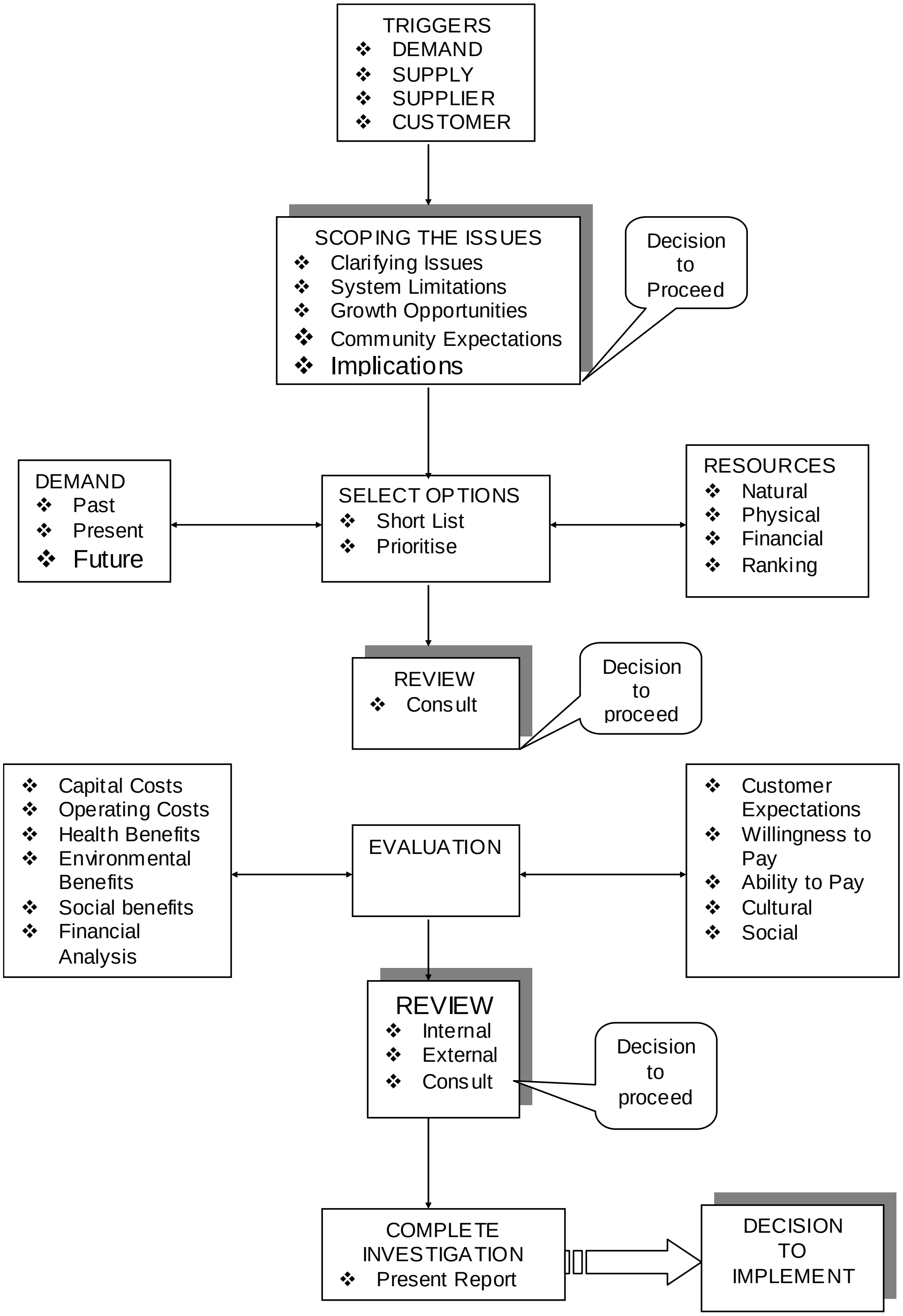

**Figure 247 Decision Making Model (Hoffrichter *et al.* 1999)**

### 6.1.1 Water Demands

The examination of a community's water demands requires a look at its past, present and future water requirements. A study of the '*past*' will provide an insight into areas such as:

- Seasonal trends
- Average and peak consumption
- Population growth rates
- Requirements of different community sectors

In addition to the above, the experience and knowledge of operators and representatives of the community will assist in providing an understanding of the current system's ability to meet the water demands that the community has experienced in the past.

A greater understanding of the '*present*' situation can be gained by including some of the following (as appropriate) in the investigations.

- Usage patterns of various segments of the community including – industrial, residential, recreational, institutional.
- A survey of how water is used (particularly in the home eg gardens, cooking, drinking, laundry, bathroom)
- An estimate of the leakage rate within the system ( eg comparison of meter data if available)
- An estimate of leakage rates on the consumers side ( eg overnight testing of a sample of the community)
- Comparison of community water usage against similar communities in the area

The forecast of the 'future' requirements of a community is critical in the selection of possible options. However, care must be exercised in assessing future demand/growth as unrealistically high estimates may jeopardise the whole process of review. It is important to use up-to-date information in any forecasting of future water demands. Suggested areas of investigation include:

- Recent approaches from developers
- New development opportunities that are on the community agenda
- The growth of tourism in the area
- Projected population growth from the Australian Bureau of Statistics for the community (if available) or the region
- The opportunity for further subdivision in the community
- Changing trends in land use eg vineyards or olives versus broadacre farming.

Information gathered from the above areas of study, whilst providing essential data for decision making in the future, will assist in educating the community on how it uses one of its most valuable resources.

## 6.1.2 Resources

There are three main resources that need to be examined – natural, physical and financial. Each can have significant bearing on whether a particular option is feasible.

### 6.1.2.1 Natural Resources

This includes all the potential available sources of water in the general vicinity of the community such as groundwater, runoff, stormwater, effluent, rainwater, streams and reticulated. As a starting point these should be given a preliminary ranking in terms of their quality, quantity, reliability, practical availability and proximity.

The estimation of potential quantity requires specific expertise. A document such as the “Use of Effluent and Urban Stormwater in South Australia 1998 – Total Water Cycle Management” published by the Department for Environment, Heritage and Aboriginal Affairs is a useful resource in this field.

In addition to water resources a preliminary examination of the soil and native vegetation in the area should be undertaken. This will provide a valuable insight into whether reuse is likely to be sustainable, the most appropriate watering methods for the soil type and the varieties of low water demand plants that may be suitable to the area. This information will be of assistance in the formation of particular strategies focused on demand management, eg water conservation programs.

### 6.1.2.2 Physical Resources

Physical resources cover a variety of areas including water supply infrastructure, private facilities (eg rainwater tanks and bores), the availability of operational and maintenance personnel and information gathered from prior studies or investigations.

A review of the existing infrastructure needs to be known in terms of the following:

- The extent of SA Water, local government and private systems
- The asset condition and remaining operational life
- The system capacity (eg via a network analysis)
- Areas of poor pressure or flow
- Consumption patterns which may point to periods of spare capacity
- Existing storage capacity and tank balancing periods

This information will provide an existing evaluation baseline as to which options will need to be built upon. The existing infrastructure is likely to be an integral part of any solution and therefore, a good understanding of its limitations is necessary.

In many situations, substantial work has already been devoted to examining a range of potential augmentation works. Review of this information (if available) should be carried out as it often provides valuable data on previous forecasts for growth, total system capacity and costs. This is not to promote ‘infrastructure upgrade or augmentation’ over other solutions, rather as a point of comparison.

Private facilities should not be overlooked. The prevalence of rainwater tanks, bores for stock water, and private storages such as dams and tanks can have a significant impact on the ability of a community to endure peak demand periods. These supplementary storages can even out the demand and increase the overall system capacity. This is also an area that Councils can influence through their planning powers.

The extent of water saving devices such as low flow shower roses can also have an impact on peak flow. Any survey conducted on community water usage habits (as suggested above) should include a section on such devices. This may provide an indication of the potential benefit of water conservation in the community.

People resources are often not considered adequately in the ongoing operation and maintenance of schemes. The complexity, ease of maintenance and reliability of schemes are issues that may influence the required availability of people and skills. It is necessary to take a long term view to safeguard the investment in any chosen solution. The other significant resource is the community itself. An understanding of attitudes and preparedness to alter habits may be a key requirement in successfully implementing strategies.

#### 6.1.2.3 Financial Resources

Funding may well be a deciding factor in considering various options. An early understanding of the degree of cost sharing between SA Water and the community needs to be established. In this regard, SA Water has a responsibility to clearly indicate the parameters within which it operates, including accountability to its Board and the Government for capital investment, and its need to make commercial decisions and judgements on the acceptable level of business risk.

Not withstanding this, all areas of potential funding assistance besides SA Water should be addressed including:-

- Local Government
- Community assistance
- Developers
- Commonwealth initiatives
- State Government

This may lead to SA Water and other parties working together through an alliance, joint venture or cooperative relationship. The assessment of financial resources also requires consideration of:

- Each party’s willingness to invest resources in finding solutions
- The impact on existing customers in areas not directly benefiting from a specific solution
- Pricing
- Competitors and their ability to penetrate into the market
- Taking a direct role in the solution or facilitating private sector / local communities to find the solution

- The strategic alignment of the issue with capital, operating, maintenance and business capabilities
- The community's willingness to accept differing standards and willingness to pay
- The options for water management education programs, and
- The specific needs of developers, industry, business, tourism / recreation and other growth generators.

This is essential to avoid the supplier overpromising on the water yield without adequate consideration of the technical, financial, environmental, quality and sustainability aspects. This is even more important in a competitive market where other suppliers, with potentially very different financial structures and commercial motives, may be looking to generate markets and returns from the same water resources and technologies.

### 6.1.3 Ranking

Having considered the natural, physical and financial resources available, an initial ranking should be carried out. Emphasis should be placed on those sources contributing significantly in the areas of quantity and quality. No more than three options should be presented for further evaluation and it is essential that these be agreed with the community before proceeding further. To assist with that decision the order of cost, the degree of match with community expectations and SA Water commercial requirements, and the benefits and disadvantages should be detailed against each option.

## 6.2 EVALUATION OF OPTIONS

The essential questions to be answered by the evaluation process are "Which option is the right one?" and "Is the investment of resources (time and money) justified ?" In addressing these questions there are many issues to consider from the point of view of the supplier and the consumer. All options should be compared against the '*do nothing*' option. This provides a common baseline from which to assess the overall benefits and disadvantages of each. It is necessary to develop a list of variables which builds on the preliminary selection of options and on which comparisons can be based. A suggested list for consideration includes:

- The specific need it addresses (eg domestic, development, recreational, industry)
- Standard of supply (quality and quantity)
- Ability to meet secondary requirements (eg fire fighting).
- Security and reliability
- Whether it is sustainable
- Environmental impacts
- Costs ( capital, recurrent, present value estimates)
- Costs in terms of $/property
- Operational and maintenance issues
- How well it fits with community requirements and expectations
- Implications for the community
- Commercial potential ( including the level of business risk)

The level of assessment should equate to the ‘Preliminary Level’ defined in the SA Water ‘*Capital Approval – User Guide*’. This approach will ensure that each option is fully defined and takes account of many of the issues indicated above. The findings of the evaluation should form the basis of a draft report to be reviewed in consultation with the community. The report needs to be clear and easy to understand with costings and analyses confined to the appendices. A summary matrix should be included to provide a simple method of comparison.

The draft report for consultation should not state a recommended option. Its purpose is to provide a fair comparison based on information that will assist decision-making. Following the review of the draft, a final report is prepared taking into account comments from the community. Once completed, this final report is submitted for endorsement and implementation.

## 6.3 DECISION MAKING

Decision making throughout the process is essentially focussed at the following four key points, refer Figure 247.

After **Scoping the Issues**. At this stage the issues have been clarified, the system limitations and community expectations have been broadly assessed, and the growth opportunities and implications have been identified. Based on the reasonableness of this information, a decision can be made about whether to invest more time and resources in proceeding or not.

After **Reviewing the Options Selected**. At this stage the demand and the resources (natural, physical and financial) have been assessed and a number of options generated which match the demand against the resources. Based on the reasonableness of the options that have been short-listed, a decision can be made about whether to proceed to evaluate the selected options.

After **Reviewing the Evaluation of the Options**. At this stage an assessment has been made of the commercial, environmental and social benefits / costs against the community’s expectations and the customers’ willingness and ability to pay. Based on the reasonableness of the options after the evaluation, a decision can be made about whether to proceed to complete the investigation.

After **Preparation of a Final Report**. At this stage, consultation around a draft report has taken place and a final report has been prepared. The final decision involves the acceptance of the recommendation(s) and determining to proceed to implement.

This decision making approach directly reflects the relationships as shown in the Model for these Guidelines, refer Figure 246, ie

> **Options** have been considered and a **Solution** proposed which is **Commercially** viable and which satisfies the community’s real **Needs**.

The Solution must support the growth of both SA Water and the Country Community.

# 7 ORGANISATIONAL ISSUES

## 7.1 Regional Managers

In terms of the application of these Guidelines, Regional Managers are responsible for:

- the provision of a water supply service to the SA Water reticulated communities in their area
- addressing community needs for a reliable, adequate supply covering quantity, quality and continuity issues
- initiating, or responding to requests from communities for, water management reviews
- engaging the Manager Commercial Development in the initial planning of actions
- budgeting for investigations and funding the approved option, possibly in partnership with other alliance parties,
- implementing the approved option, possibly in partnership with other alliance parties.

## 7.2 Client Coordinator

In applying these Guidelines, the Regional Manager should engage the services of the Manager Commercial Development to act as Client Coordinator to:

- provide the Regional Manager with specialist advice and support in addressing the issue
- act, if requested, as the Regional Manager's representative in coordinating and negotiating the solution
- participate or provide guidance in community consultation initiatives
- mentor a Community Advocate.

## 7.3 Community Advocate

In each instance of applying these Guidelines, it is recommended that a Community Advocate be designated. This person will provide a direct link with the community on behalf of the Regional Manager. It is suggested that the Community Advocate be mentored by the Manager Commercial Development, who may personally take on the role for projects of major significance.

The Community Advocate will

- act as the main point of contact for the community on communication and consultation matters
- ensure all relevant areas of the Corporation are informed and involved
- provide overall coordination and monitoring of progress throughout the process
- ensure the community's views are comprehensively and effectively included in the review
- display excellent communication and project management skills, and have a sound background in water supply services and water management.

## 8 ACKNOWLEDGEMENTS

The author's acknowledge the representatives of the:-

- District Council of Franklin Harbour
- Yorke Peninsula Water Resources Council
- Department of Environment Heritage and Aboriginal Affairs and
- Peter Lokan, SA Water General Manager Retail ,the project sponsor
- Jo Stewart-Rattray, Project Manager, ElectraNet SA, the project mentor
- All of the SA Water personnel who provided valuable assistance and advice during the preparation of this document.

## 9 RECOMMENDED REFERENCES

The following are recommended as further references in applying the Guidelines.

*Guidelines for Low Cost Water Supplies for Small Communities* – Australian Water Resources Council, Water Management Series No 17, Department of Primary Industries and Energy.

*Integrated Water Management for Selected Rural Towns and Communities of South Australia* – Volume 1 and 2, B van der Wel and G McIntosh, Department for Environment, Heritage and Aboriginal Affairs.

*Handbook for Affordable Water Supply and Sewerage for Small Communities* – Urban Water Research Association and the Agriculture and Resource Management Council of Australia and New Zealand.

*Community Communication Programs – A Seven Step Guide* – Major Urban Water Authorities of Australia.

*Proposal for a Water Conservation Program for Streaky Bay, South Australia* – Engineering and Water Supply Department, 83/2.

*Water Conservation for Communities in Arid Areas of Australia* - Engineering and Water Supply Department, 1987.

This is the end of the Hoffrichter *et al.* (1999) *Draft Guidelines for the Assessment of Water Management Options for Country Townships.*