



Issues encountered in advancing Australia’s water recycling schemes

There is a pressing need to implement sustainable projects that adequately contribute to Australia’s diminishing water supply while protecting public health and the environment. Recent drought conditions have focussed attention on this issue and raised our awareness that present demands on Australian water utilities are heavy and set to intensify. Indeed, water and wastewater sectors are amongst the fastest growing utility sectors. As part of integrated water cycle management in urban and rural contexts, realising the potential of water recycling projects is one of the greatest challenges of the 21st century. Internationally, non-potable reuse is widely practiced but to what extent will these schemes be implemented in Australia?

Dr Sophia Dimitriadis
Science, Technology, Environment and Resources Section

Contents

Glossary	4
List of acronyms	8
Executive summary	9
Introduction	10
Pressures on Australia’s water resources.	11
Figure 1: CSIRO Climate Change Projections—Australian Annual Rainfall (mm)..	12
What is recycled water?.	13
Water recycling in OECD countries	13
Commonwealth and State regulatory environment and legislation	13
Legislation	13
National Water Initiative	14
Guidelines	14
National and international legal issues	15
National enforcement	15

International treaty obligations.	15
Water recycling methodology	16
Figure 2: The use and reuse of water through the water cycle.	16
Non-potable use	17
Evaluating water recycling.	17
Benefits	17
Disadvantages of water recycling.	18
Recycling water today – need for accurate statistics.	18
Table 1: Estimates of water reuse by State and Territory from water utility sewage treatment plants in Australia 2001-2002 in gigalitres (GL).	19
Advances and developments	19
Pimpama Coomera	19
Rouse Hill	20
Sydney Olympic Park	20
Mawson Lakes	20
Process chains.	20
Integrated water cycle management	20
Variability of system solutions.	20
Monitoring of standards	21
Scale of recycling systems.	21
Economics of water recycling	22
Transportation	22
Greywater	22
Centralised versus decentralised schemes	22
Consumer reaction	23
Economies of scale	23
Technical issues—scales of operation	23
Public participation	23
Public consultation	24
Controversy	24
Health considerations	25
Prudent consideration of concerns	26
Perceptions.	26
Energy intensity and greenhouse emissions.	27
Energy efficiency	27

Greenhouse emissions	27
Externalities	27
Business case evaluation: the Triple Bottom Line	28
Funding programs and financial assistance	29
Incentives, funding and grants	29
Incentives.	29
Grants	30
Funding for research and practical implementation	30
Loans.	31
Pricing of recycled water	31
Table 2: Comparison of the costs of some recycled water schemes with the price charged and prices of drinking water.	32
Project implementation	33
Social.	33
Environmental	33
Human health.	33
Economic.	34
Practical implementation and engineering.	34
Legal	34
Conclusions	35
Endnotes.	36

Glossary

Abstraction charge	An imposed fee, expense or cost for removal of water. It can be a nominal licence fee linked to permits or a metered charge.
Aquaculture	The process of raising and harvesting fresh and saltwater plants and animals.
Aquifer	Natural underground storage that yields water to wells or springs.
Asset management	A process that enables a utility to determine how to minimise the total cost of owning and operating infrastructure assets while continuously delivering appropriate service levels to customers.
Biofilm	Forms when bacteria attach to surfaces exposed to water, and begin to excrete a slimy, glue-like substance. It is common in water pipes.
Black water	The heavy and solid part of wastewater that contains animal or food wastes.
Carbon sequestration	The long-term storage of carbon underground or in oceans so that the build-up of carbon dioxide (the principal greenhouse gas) in the atmosphere slows. Sequestration may include other sinks.
Contaminants	Unwanted and potentially detrimental organic, inorganic and biological substances.
Desalination	One of the processes used in the production of recycled water that removes salts and most other impurities by distillation or electro-chemical and/or physical means. See definition of salinity or sodicity.
Direct reuse	The use of recycled water straight from a wastewater treatment plant.
Dual reticulation	Two separate pipelines that supply a building, one is a lilac-coloured pipe that delivers recycled water while the other pipe is reserved for drinking water.
Dual-pipe scheme	An urban water recycling scheme where recycled water is provided to households for certain uses via a reticulation system that is separate from the drinking water supply. These are sometimes referred to as 'third-pipe schemes'.

Effluent water	Water that flows out of treatment plants.
Emissions	By-products of energy production and wastewater treatment or other activities that are released into the environment (air, water etc). For example, substances such as carbon dioxide, methane, sulphur compounds and so on, that need to be taken into account when comparing recycling treatment processes.
Endocrine disrupting compounds	Chemicals that can interfere with normal hormone function in humans and animals by influencing metabolism, growth and reproduction.
Environmental flows	Water of sufficient quantity and quality that is required to maintain and sustain aquatic and terrestrial environments and the services they provide.
Externalities	Costs not routinely recorded in financial balance sheets. For example, costs associated with turning wetlands into urban development or releasing effluent into oceans. Some Organisation for Economic Cooperation and Development (OECD) countries are working towards 'internalising' all marginal costs including environmental costs in decisions that affect water use. Whilst progress has been made in Australia, full implementation remains some way off.
Gigalitre (GL)	1 GL = 1000 megalitres or 1 billion litres.
Greenhouse gases	Although greenhouse gases are a natural part of the atmosphere, human activity is increasing them mostly through increases in carbon dioxide, methane and nitrous oxide. Emissions from water recycling are usually presented as carbon dioxide equivalent units (CO ₂ -e) calculated using Australian Greenhouse Office methodologies.
Greywater	Wastewater from households or small commercial establishments like water from washing clothes that does NOT include the most polluted water (black water) from sources like toilets.
Groundwater recharge	Water from precipitation that flows on ground surfaces as runoff or percolates into soils, eventually replenishing natural underground water supplies (aquifers).
Indirect reuse	Use of reclaimed water after it has passed through water bodies like storages or wetlands following treatment.

Influent water	Inflowing water that feeds treatment operations.
Kilolitre (kL)	A metric unit of volume or capacity equal to 1000 litres.
Megalitre (ML)	1 000 000 litres, 1000 kL, or the volume of an Olympic swimming pool.
Non-potable water	Water that is not suitable for drinking.
Potable water	Water that is drinkable and considered safe for human consumption.
Parts per million (ppm)	A unit of concentration often used when measuring levels of pollutants in water. One ppm is 1 part in 1 000 000. The common unit of milligram/litre is equal to ppm.
Preventative risk management	The systematic evaluation of processes to identify hazards, assess risks and implement strategies to manage these risks.
Purple-pipe schemes	Internationally, lilac-coloured pipes are dedicated for recycled water transport to ensure that recycled water mains are NOT confused with potable water mains for delivering drinking water. All recycled buried pipes in Australia must be clearly labelled and state: 'non-potable or reclaimed water—Do Not Drink'.
Recharge	Replacement of water once drawn or pumped from a source like an aquifer.
Recycled water	Wastewater suitable for beneficial use as a result of appropriate treatment. Desalination is frequently one of the treatment processes. Synonymous with 'reused water'.
Reticulation	Water that travels through a network of pipes, pumping stations and treatment plants to make up the water supply system.
Reverse osmosis (RO)	Used to purify water and remove salts and other impurities. It is amongst the finest forms of filtration known. The process involves forcing water through a membrane to allow the removal of particles as small as ions. The biggest hurdle is pre-treatment for removal of suspended solids and turbidity to a level suitable for trouble-free RO.

Salinity or sodicity	Soil and water environments are vulnerable to soluble salts, of which sodium chloride is the most common. Salinity refers to the total concentration of all salts in the water or soil. Soil sodicity represents the relative amounts of sodium ions compared to others like calcium, magnesium and potassium. See definition of desalination.
Sewer mining	The extraction of water from sewers or wastewater systems that is treated and used elsewhere with the return of solids to the sewerage system.
Stormwater	Rainwater that is collected on roofs, driveways and roads. This water is carried away in a system of stormwater drains that is separate from sewers.
Third-pipe	There are at least two separate systems which carry water away—the sewerage and stormwater systems. Another system delivers drinking water. A third system that may be added is a pipe delivering recycled water. Some suggest we should refer to recycled water as the fourth system—the other three pipes carrying potable water, sewage and stormwater, respectively.
Total dissolved salts (TDS)	Salt level estimated from conductivity values, measured as milligrams per litre.
Trickle-fed	A very thin, slow flow of water that does not require pumping.
Wastewater	Water carrying contaminants. Note that wastewater to one user may be a desirable supply or resource to the same or another user at a different location for a different purpose.
Water hardness	Hardness is caused by calcium and magnesium salts. Hard water requires more soap and synthetic detergents for washing and contributes to scaling in boilers and industrial equipment. Inland water supplies are usually very hard and require considerably more chemical additives during treatment.
Water mining	Extraction of water from sewerage systems for recycling.
Water recycling	An umbrella term for the process of treating wastewater for beneficial use, storing and distributing recycled water, and the actual use of recycled water.
Water reuse	See recycled water.

List of acronyms

ACT	Australian Capital Territory
ACTEW	Australian Capital Territory Electricity and Water Corporation Limited
AHMC	Australian Health Ministers Council
ATSE	Australian Academy of Technological Sciences and Engineering
COAG	Council of Australian Governments
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EDC	Endocrine disrupting chemicals
EPA	Environmental Protection Agency
EPHC	Environment Protection and Heritage Council
GDP	Gross Domestic Product
GHG	Greenhouse gases
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NSW	New South Wales
NWI – IGA	National Water Initiative – Intergovernmental Agreement
OECD	Organisation for Economic Cooperation and Development
PMSEIC	Prime Minister's Science Engineering and Innovation Council
QLD	Queensland
SA	South Australia
TBL	Triple Bottom Line
UK	United Kingdom
USA	United States of America
WSAA	Water Services Association of Australia

Executive summary

Globally, the water and wastewater industries are growing fast. Water recycling is one of the measures being used increasingly to reduce the demand for potable water. One of the ways this is being achieved is by using recycled water as a substitute. Realising potential benefits of water recycling and water conservation are identified as two of the greatest challenges of our time.

In the Australian context, demands on water utilities and supplies are expected to intensify. Each year, on average, every Australian uses more than one million litres of freshwater. Concurrent with this growth in water use, is the trend towards water recycling since non-potable water reuse is now an increasingly accepted practice. It is now recognised that recycled water is a valuable resource that could be harnessed by implementing sustainable projects. Such initiatives could free up potable water supplies and recharge systems while improving the protection of public health and the environment.

Water recycling mimics the natural water cycle by using water over and over again. Recycling schemes however, differ from their natural counterpart by requiring careful consideration of technical, health and social factors when planning, developing, regulating and operating the plants. Sustainable recycling operations may be secured through informed industry, sound integrated management and treatment processes with suitably stringent standards and practices. These are achieved through scientifically-based quality assurance and the use of best practices that incorporate environmental standards to ensure the maintenance of consumer confidence.

Successful Australian water recycling ventures invariably demonstrate the need for appropriate and adequate stakeholder engagement and public consultation. Additional considerations include adequate infrastructure, research and development, as well as fair water price setting and incentives for the development of markets for Australian water recycling services and technology. The implementation of water recycling schemes is necessarily site-specific. There is no single solution or technology that can be applied. Further, financial incentives may be required to drive and boost investment in some water recycling ventures.

This paper *does not focus on the vast array of available technologies*. Instead it broadly examines the factors relating to the implementation of schemes such as scale, financial and business-case evaluation, legislative and liability issues. Further, it does *not* aim to discuss the economics of water in detail since pricing is a vexed question. The issues surrounding the public perception of associated risks are also by nature complex and controversial, and there are many different and sometimes irreconcilable views. These are clearly important but they are beyond the scope of this paper. This paper instead seeks to provide a commentary on some challenges, opportunities and benefits of water recycling schemes.

Introduction

The inter-annual variability of river flows and runoff in Australia is about twice that of most other countries. As a result of this variability and other pressures, the use of water resources in many parts of Australia is approaching the limits of sustainability. With world freshwater demand doubling every 20 years, the significance of a reliable source of clean water to future prosperity is a key concern in all nations.¹ Average annual expenditure on capital works and renewals for urban water supply and sewage treatment is a significant part of Australian economic expenditure.²

While Australia's water supply and sewage treatment infrastructure is well established, these systems are necessarily expanding to meet the demands of industrialisation and urbanisation. In terms of construction activity, in 2003–04 A\$911 million was spent on water storage and supply and A\$1323 million on sewerage and drainage.³

Further to the present range of water conservation measures, one avenue for augmentation of traditional water supplies is offered by water reclamation of wastewater and stormwater in the form of water recycling ventures. As a nation, we currently recycle somewhere between 9 to 14 per cent of our water from effluent or urban stormwater and this could be significantly expanded.⁴

The main barriers to reuse of water in Australia are issues of public confidence, health, the environment, reliable treatment, storage, economics, the lack of relevant regulation, poor integration in water resource management, and the lack of awareness.⁵

While urban water supplies may only comprise around 30 per cent of total Australian water use, according to the Commonwealth Scientific and Industrial Research Organisation (CSIRO), they have significant impacts on the catchments in which they are situated. These may occur through the diversion of water resources to supply cities, the flow of stormwater and the discharge of wastewater to recipient land or water bodies. In addition to rising public demand in the cities, there is increasing pressure caused by salinity problems and droughts in rural areas. These issues are leading to an expansion of water recycling schemes as the water utilities tend to move from an emphasis on the supply of water towards a greater focus on resource usage.

The range of water qualities (recycled, potable, distilled etc) that can be purchased by consumers has expanded in concert with increasing efforts made towards controlling pollution. In this context, government water authorities are the main purchasers and users of water goods and services while private industry is perhaps the most effective developer and marketer of water recycling technologies that serve these needs. Specifically, it has been found that:

application of end-of-pipe measures depends at least partially on regulatory pressure, whereas cleaner production may be motivated—among other factors—by market forces.⁶

As outlined below, there are some outstanding challenges for Australia to tackle. Although no definitive solution can be provided in this paper, these have been identified as:

- improving the integration of environmental costs into water charges
- correctly pricing water in a way that allocates resources efficiently
- operating water services cost-effectively
- ensuring that water of a suitable standard is available to all, and
- water sharing for consumptive uses and environmental flows.

Pressures on Australia's water resources

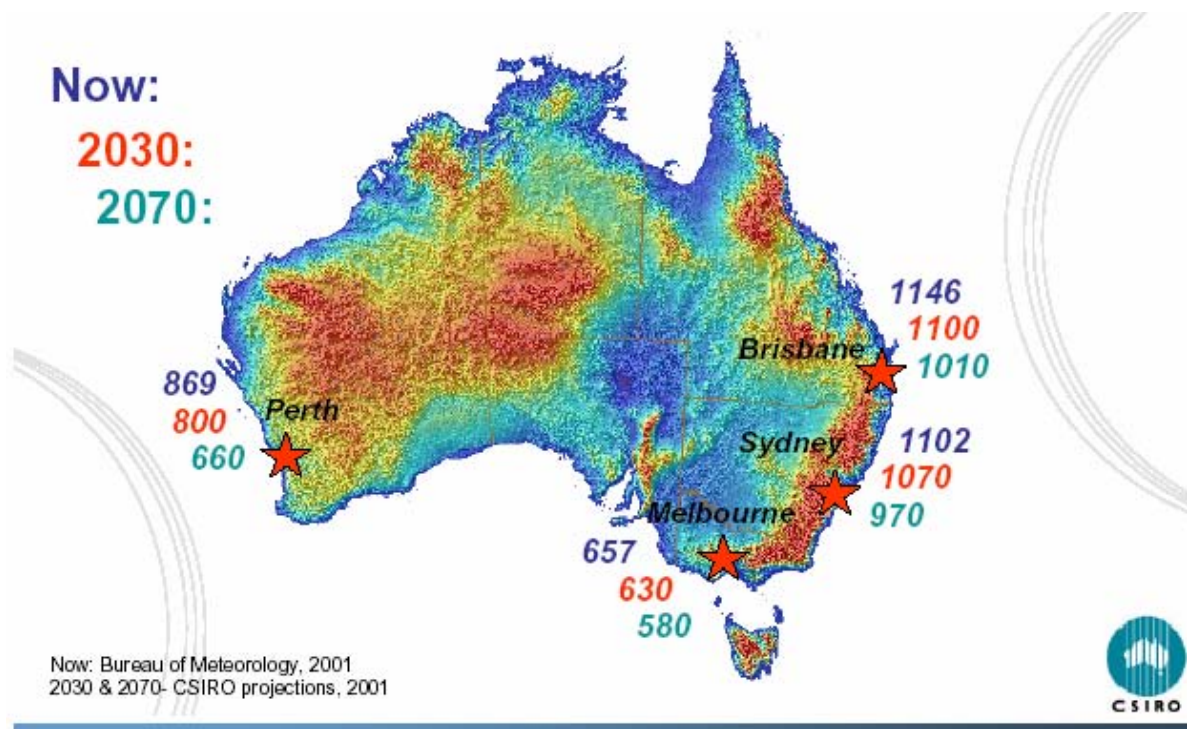
Pressure on the availability of Australian freshwater resources is increasing principally due to emerging climate change and population growth.

With regard to climate change, the predictions by CSIRO are compelling. For example the average number of days above 35 °C annually in Brisbane is predicted to increase by 20 days by 2070. An increase in annual national average temperatures of between 1.0 °C and 6.0 °C by 2070 is also anticipated.⁷ In terms of rainfall, the annual average is predicted to drop from 1140 mm to 1010 mm (see Figure 1).⁸ The decline in rainfall is projected to be far greater in Perth with a reduction from an annual average of 869 mm at present to 660 mm by 2070.⁹

South-western Western Australia is generally expected to undergo a large decrease in winter and spring rainfall while Tasmania is anticipated to have wetter winters. South-eastern Australia is predicted to have drier winters and springs whereas rainfall in North-eastern Australia may become more variable.¹⁰ Researchers from CSIRO predict such changes in rainfall and temperature will have significant impacts on urban water demand that will vary between cities.¹¹ Importantly, any reduction in runoff into streams and dams may sometimes be equivalent to twice the observed reduction in rainfall.¹²

Figure 1: CSIRO Climate Change Projections—Australian Annual Rainfall (mm).

This figure shows levels of rainfall in millimetres for the present (Now) in dark blue and projections for 2030 in red, and 2070 in light blue.



Source: C. Howe, 'Climate change scenarios—Implications for the Australian Water Industry', OzWater 2005, Bureau of Meteorology www.bom.gov.au/climate/averages; 2030 & 2070: CSIRO's assessment of nine climate models driven by a range of projected increases in greenhouse gases www.dar.csiro.au/publications/projections2001.pdf. Reproduced with the permission of C. Howe, CSIRO.

Australia is a country of 20 million people, and the Water Services Association of Australia projects a 32 per cent population increase in urban areas by 2030.¹³ As a result of this population growth a serious shortage of catchment capacity is developing in coastal cities like Brisbane and Perth.¹⁴ Carol Howe, from the CSIRO, estimates that even if Australia were to cut per capita water use by 7 per cent and one-quarter of new suburbs were to use recycled water for outdoor activities and toilet flushing, the country would still face a shortfall in supply of 800 gegalitres (GL) by 2030.¹⁵

To meet this increase in demand for water, a balanced range of water sources that reach beyond traditional catchment storage projects is necessary. For instance, the CSIRO Marine and Atmospheric Research Division cautions that Australia has the largest per capita water storage capacity in the world and yet:

you could get to where you are building ever bigger storages but you don't have the water to fill them.¹⁶

Thus in addition to storages, projects will likely include a portfolio of facilities, delivery and processing systems, as well as management techniques like water transfers, water conservation measures, desalination and water recycling initiatives.

What is recycled water?

'Recycled water' is the output or product from wastewater, stormwater or effluent that is usually treated to some extent, and redirected back into a water use scheme. Examples include recirculation systems for washing and cooling.¹⁷ Aside from use within single institutions, recycling can also occur between organisations such as when urban wastewater is reused for irrigation purposes. The fraction of recycled water that is not consumed usually flows back to river catchments, wetlands, aquifers and lakes as 'environmental water'. This is ideally of a suitable quality and quantity to maintain healthy aquatic environments and scenic values.¹⁸

Water recycling in OECD countries

In the Organisation for Economic Cooperation and Development (OECD) countries, total industry and energy-related use of water has fallen by 12 per cent in the past two decades, in part due to water recycling.¹⁹ Some OECD countries have even experienced declines in average water use at the household level. These responses most likely reflect the wider adoption of volume-based water charges. Other successes in water conservation have occurred due to the application of integrated water management (see section below).

Many OECD countries have recently undertaken extensive reviews of their water laws and policies. Most are well into the process of reforming the institutions that deliver these policy goals. In general, water management trends have been shifting away from national approaches to 'place-based' approaches. Such decentralised approaches put more emphasis on the biological quality of receiving waters, as well as setting objectives for their use at particular locations.

Decentralised approaches are compared with centralised schemes later in the paper.

Commonwealth and State regulatory environment and legislation

Legislation

A primary advantage of reliance on fewer pieces of legislation within jurisdictions is certainty in decision-making.²⁰ The interpretation of different pieces of legislation can otherwise be problematic due to inconsistencies between imposed conditions.²¹ Another issue is that regulations can lack transparency and may not adequately recognise the cost of externalities as required under the COAG water reform principles.²² At the national level,

increased demand on water supplies has prompted the Council of Australian Governments (COAG) to update its water reform agenda.²³

A range of documentation has evolved for governing effluent discharge licensing in addition to the development of various guidelines for recycled water.²⁴ While most Australian states currently have guidelines relating to recycling of sewage effluent for irrigation purposes, there are some remaining gaps and discrepancies in their criteria for urban uses and water types.

National Water Initiative

A National Water Initiative - Intergovernmental Agreement (NWI - IGA) was signed on 25 June 2004. The National Water Commission (NWC) may address some of the aforementioned issues relating to decision-making and discrepancies. The aims of the NWC may also be directed towards addressing improvements in water use efficiency. These include increasing the recycling of wastewater. Another component includes encouraging water conservation in cities through better use of stormwater and recycled water.²⁵

Guidelines

Recent reviews by the Australian Academy of Technological Sciences and Engineering (ATSE) and others have identified differences between national, State, and Territory guidelines that include reclaimed water sources, recycling options, nominated quality criteria, monitoring frequencies, sampling and testing methods, as well as accreditation.²⁶ Most of these guidelines and policies are in the process of being reviewed. For example, NSW is currently strengthening its greywater policy applying to water from showers/washing machines for diversion to garden irrigation.²⁷

To deal with this issue, the Environment Protection and Heritage Council (EPHC) and the Natural Resource Management Ministerial Council (NRMMC) have formed a Joint Steering Committee to oversee the development of National Water Recycling Guidelines for Australia. These guidelines are directed towards providing a unified framework for safe and environmentally sustainable recycling of wastewaters across Australia.

After its recent meeting in April 2005 the NRMMC issued a statement saying:

This will be a major milestone in the development of this important document that is designed to facilitate safe and effective water recycling for rural and urban areas as part of the National Water Initiative.²⁸

The membership of the Steering Committee is drawn from a number of government agencies, the National Health and Medical Research Council (NHMRC), the Australian Health Ministers Council (AHMC) and the Water Services Association of Australia (WSAA). This work will take account of a report by the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) on urban water reuse and recycling.²⁹

The first stage of guideline development will address the recycling of sewage effluent and greywater from large-scale centralised treatment facilities for non-potable use. In addition, this stage will address on-site greywater treatment at residential and office developments for use in residential applications.

It is expected that the draft guidelines will be released for public consultation in October 2005 following their development by three working parties responsible for addressing different aspects.³⁰ At a later date, a second stage of guideline development will be undertaken for aquifer storage of stormwater and treated greywater for use at large scales.

One view under consideration is that wastewater should not be classified as a waste under relevant regulations if there is potentially a beneficial use for it. The challenge is to ensure that the meaning of 'environmental values' is defined widely enough to ensure that environmental risk and health impacts are sufficiently incorporated.³¹

Inherent in any consideration of the regulations relating to recycled water is that requirements should be scientifically sound and adequately identify concerns associated with the broad array of proposed uses for recycled water.³² Here, the ability to which the ever increasing knowledge base of science can specify critical values or indicators for standards together with the definition of key terms and concepts is vital.³³ Scientific definitions especially with regard to sentinel systems, biological indicators and the specification of hazard thresholds will need to be employed adequately and in an operational form.³⁴ It is also foreseen that these will need to be updated by means of rolling revisions as the underpinning research progresses and detection techniques are improved.

National and international legal issues

National enforcement

Responsible treatment of recycled water will necessarily involve adequate penalties and enforcement in Australia. At the state level, changes have recently been proposed by NSW that toughen liability laws and reinforce the *Protection of the Environment Operations Act 1997* (NSW).³⁵ The existing maximum penalties for environmental negligence is set to double to \$2 million for companies and \$250 000 with 7 years imprisonment for individuals.³⁶ For example, the first company director to be imprisoned for an environmental offence in NSW in 1997 was convicted of wilfully discharging sewage from the septic tanks of a holiday caravan village into wetlands and the Karuah River near Port Stephens (with likely impacts on oyster farm leases).³⁷ Enforcement requires separate consideration from the penalties imposed, and is complicated by the difficulties of proving links with pollution, health outcomes and tracing sources.

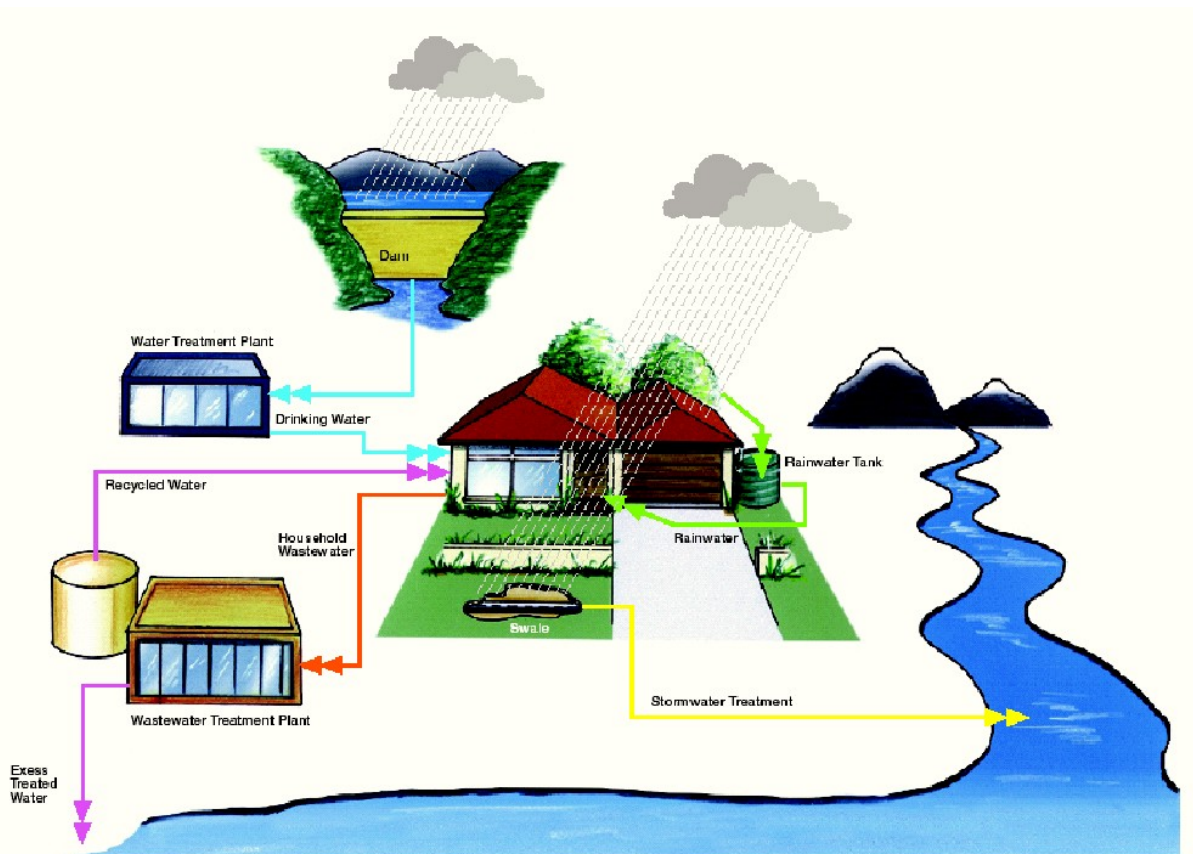
International treaty obligations

Aside from domestic liability issues, there are international treaty obligations. For example, article 3(1) of the Ramsar Convention on Wetlands obliges signatories to formulate and implement their planning so as to promote the conservation of the wetlands included in the

list of wetlands, and as far as possible, the wise use of wetlands in their territory. Actions that may have a significant impact on the ecological character of a Ramsar wetland require the Commonwealth environment Minister's approval under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). This could potentially include discharge of inadequately treated recycled water into Ramsar Wetlands or associated river systems.

Water recycling methodology

Figure 2: The use and reuse of water through the water cycle.



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

Reproduced with permission from: ASTE. Source: J. Radcliffe, 'Water recycling in Australia' for Australian Academy of Technological Sciences and Engineering, 2004. Available at: <http://www.atse.org.au/index.php?sectionid=597>

Non-potable use

The most common recycled water uses are non-potable (not for drinking) and include:

- Landscape irrigation of golf courses, parks, sports fields
- Industrial uses such as cooling, laundries, car washing facilities
- Agricultural uses such as irrigation of produce, pastures for animal feed, and nurseries
- Emergency use in dust suppression and fire-fighting
- Use in office buildings for toilet flushing
- Aquaculture (the cultivation of aquatic organisms like fish), and
- Groundwater recharge.

Non-potable recycled wastewater is primarily used as a substitute for potable water in non-drinking applications and therefore has potentially an important role in helping meet future demand levels for water in Australian cities. Currently, 97 per cent of urban runoff and 86 per cent of effluent wastes are untapped and flow directly into rivers and coastal areas.³⁸

At present, only 9 to 14 per cent of all wastewater produced is recycled, even though recycled water could potentially supply about 50 per cent of the water needs of urban users and a significant proportion of the water needs for irrigation in Australia.³⁹ This share of wastewater is however set to increase significantly with State and Commonwealth legislation and standards encouraging a maximum reuse of 20 per cent of all wastewater produced by 2012 (e.g. Western Australian State water strategy).⁴⁰ For example, in recent years, Western Water of Victoria has recycled over 80 per cent of all wastewater.⁴¹

Evaluating water recycling

Compared with the traditional storage-based approach, water recycling is one of the most effective ways of improving efficiencies in cities where water resources are constrained.⁴² In the past, wastewater and stormwater were seen as nuisances to be disposed of rather than resources to be captured and processed effectively for reapplication. Furthermore, demands were seen simply as a matter of quantity rather than viewing demands as multi-faceted in a context where choice of infrastructure is closely matched to end-use.⁴³

It is now more widely recognised that the benefits of water recycling include:

Benefits

- Substitution of potable water with recycled water for non-potable applications where water quality is less important and non-potable water would be adequate

- Improvement of water quality due to more comprehensive and rigorous monitoring systems or in contexts where recycled water has a better quality than existing raw water supplies
- Boosting the reliability of current water supplies for drought periods. For example, Shoalhaven (NSW) dairy farms reused urban wastewater to survive a drought⁴⁴
- Meeting environmental requirements by improving wastewater treatment plants and reducing the quantity and quality of effluent discharged to coastal waters.⁴⁵ For example, the Australian Government Clean Seas Program aims to reduce pollution of coastal, marine and estuarine environments by wastewater discharges through increased reuse.⁴⁶ The marine disposal of water is increasingly less acceptable because of concerns associated with contamination of bathing waters and aquatic ecosystems, community concerns, and limits on land waste disposal options in coastal areas⁴⁷
- Provision of new supplies for environmental enhancement and aquifer recharge. For example, the Burdekin Delta is Australia's oldest artificial recharge scheme operating in an irrigation district. Stringent water quality objectives set for receiving waters are designed to address concerns about the fate of solutes including salts that leave irrigated land as surface runoff or deep drainage⁴⁸
- Displacement of reliance on potable water for primary production (e.g. food crops, pasture, nursery production, and horticulture) by irrigation with recycled water.⁴⁹ For example, the Western Australian Environmental Protection Authority chief, Dr Wally Cox has stated that development of new water sources for Perth could be delayed by recycling the city's sewage and wastewater

The reuse of treated wastewater, for example in irrigated horticulture, would allow higher quality water to be retained for high-value uses and may allow the development of new sources to be postponed.⁵⁰

- Recycled water can provide a supply of nutrients useful when irrigating crops.

Disadvantages of water recycling

Disadvantages include the cost and the community perceptions of risk that may arise from the use of reclaimed water. These mostly relate to food safety and the long-term sustainability of such schemes as well as the costly management of salinity, sodicity, or nutrient levels.⁵¹ These issues are discussed later in this paper under sections on public policy and health considerations that need to be taken into account when implementing projects.

Recycling water today – need for accurate statistics

In Australia, application of reused water has dramatically increased in volumetric terms from that measured in the 1990s. This is set to climb further from 2000–01 levels (see Table 1).⁵² However, the data available for recycled water are limited and recent data are not yet

available. This is anticipated to be the subject of further investigation and audits by the National Water Commission.

The agriculture industry was the largest user of recycled water in 2000–01, accounting for 423 264 megalitres (ML) (or 82 per cent of all reuse water use).⁵³ This was followed by other industrial uses (35 859 ML or 7 per cent of total water reused), and the water supply industry with 23 056 ML or 4 per cent of total water reused.⁵⁴

Table 1: Estimates of water reuse by State and Territory from water utility sewage treatment plants in Australia 2001-2002 in gicalitres (GL).

Region	Wastewater (GL/yr)	Reuse (GL/yr)	Percentage
Queensland	339	38	11.2
New South Wales	694	61.5	8.9
Australian Capital Territory	30	1.7	5.6
Victoria	448	30.1	6.7
Tasmania	65	6.2	9.5
South Australia	101	15.2	15.1
Western Australia	126	12.7	10.0
Northern Territory	21	1.1	5.2
Australia	1824	166.5	9.1

Source: Radcliffe, 2003.⁵⁵

Note that these statistics are limited by definitional issues—calculation of water reuse is frequently carried out using differing methodologies. These inconsistencies are anticipated to be addressed in the near future by the National Water Commission.

Advances and developments

There are many successful schemes in operation. Several more are planned or under construction. The potential for urban water conservation in Australia is illustrated here by four new urban developments.

Pimpama Coomera

The Pimpama Coomera development on the Gold Coast is expected to be fully operational by mid-2007.⁵⁶ It will use the latest technologies to provide high quality recycled water for reuse in the local areas, receive wastewater from the Pimpama, Coomera and Upper Coomera areas, and treat up to 13 megalitres of wastewater per day. This development will incorporate third-pipe water supplies that use recycled water for outdoor use and toilet flushing. Trickle-fed rainwater tanks will be mandatory, and regional stormwater harvesting employed.⁵⁷

Rouse Hill

Rouse Hill is a development area in Sydney's north-west that includes more than 15 000 properties experimenting with recycled water using third-pipe systems. This scheme is an example of the successful reduction of environmental impacts of nutrients on a waterway caused by the discharge of treated wastewater to the Hawkesbury-Nepean River system.

Sydney Olympic Park

The Olympic Park development in Sydney is a world benchmark demonstration of innovation by the urban water industry.⁵⁸ This Water Reclamation and Management Scheme (WRAMS) is a system producing highly treated wastewater and stormwater.

Mawson Lakes

The unique \$16 million Mawson Lakes Recycled Water System in Adelaide's north is expected to be completed by 2010.⁵⁹ The system uses artificial wetlands and aquifer recharge to store stormwater for recycling for residential, industrial and agricultural purposes.

Process chains

A large range of water reclamation treatment processes and associated technologies currently exist to provide water of almost any quality desired within the limitations of costs, delivery rates and scales of application.⁶⁰ This leads to the selection of possible treatment schemes to produce so-called '*designer reclaimed water*' or water customised for specific end uses. There are many different technologies available to achieve this objective. The most efficient schemes appear to be those tailored to highly site-specific requirements producing water quality fit for a particular purpose.

Equipment and instrument makers, as well as industry and academic researchers constantly announce new ways to monitor quality, remove contaminants and recycle water. In this context, finding the appropriate alternatives at the right price can be bewildering. Ultimately, there are no universal solutions. Technologies are generally examined on their individual merit, knowing that real breakthroughs occur when bundling these together to ensure that arrangements fit particular circumstances. Some businesses even offer mobile reverse osmosis units. To provide some assessment of this range, CSIRO Urban Water has generated a database of available treatment technologies in which data are collated on performance characteristics, cost and level of development.⁶¹

Integrated water cycle management

Variability of system solutions

A move towards more integrated urban water management involves the consideration of water supply, stormwater and wastewater concurrently as components of the total urban water cycle. Whilst the concept is not new, it has not been widely applied. As recently as 1999 it was suggested that:

we are beginning to talk not only about some new isolated technologies but instead about new total system solutions.⁶²

Fortunately, this is rapidly changing and all recent State water strategies are embracing the concept.⁶³

Of particular importance to effluent water management is the need to maintain a balance between the extent of treatment available and quality requirements for water to be reused.⁶⁴ For example, the irrigation of food crops and toilet flushing demand very different quality standards. Some applications with limited human contact may not require a high level of treatment for the removal of contaminants and these may also be prevented by high treatment costs and energy requirements.⁶⁵

Monitoring of standards

To ensure that treatment schemes (individually or centrally-operated) continue to meet required standards and guidelines, monitoring programs are essential. Thus another consideration is the cost and feasibility of adequate monitoring systems, especially those that may become labour and time intensive. Some advanced control systems now incorporate real-time remote monitoring systems. These can also employ multi-layered alarm response protocols coupled with early warning devices.⁶⁶ Such adaptive technological advances can control system operation from almost any location at any time and will possibly enable urban recycling operations to be more easily monitored in the future.⁶⁷

Scale of recycling systems

Broadly there are four scales of recycled water systems:

- **Individual** water reuse systems in which wastewater discharged by one building or complex is treated in-house and reused in the same building. This may include single household systems or multi-unit developments. For example, domestic roof runoff, domestic greywater, air conditioning system water, and effluent from onsite treatment of domestic wastewater.
- **District** water reuse systems in which wastewater from multiple buildings is collected in one location then treated and supplied to other buildings for reuse. This may include large housing developments and industrial zones. For example, island communities, caravan parks, and mining settlements using stormwater, sewage effluent, water mining from sewers⁶⁸ and bore water. Take for instance, the introduction of dual water systems to the Manor Lakes development in Melbourne's Wyndham Vale which will make recycled water available to residents for watering gardens, flushing toilets and washing cars.
- **Wide-area urban/agricultural** reuse systems in which water treated by a sewage treatment plant is recycled. These include large centralised dual reticulation schemes such as those currently in operation in the Rouse Hill development area in NSW and agricultural irrigation schemes such as the Virginia Pipeline Scheme in South Australia—

possibly the largest wastewater reuse scheme in the Southern Hemisphere.⁶⁹ Other examples may include national parks and forests using groundwater, brackish water and agricultural wastewater.

- **Industrial** water use systems, involving recycling within the industrial enterprise using effluent from onsite treatment, industrial wastewater ponds or tanks.

Economics of water recycling

A common misconception in planning for wastewater reclamation and recycling is that reclaimed wastewater always represents a new low-cost water supply. This assumption is true only when treatment facilities are conveniently located near large agricultural or industrial users and when little additional processing is required.

Transportation

Transportation of water is a primary consideration for recycling schemes since the locations where water is to be reused may not yet be serviced by pipes. Existing pipes often cannot be used because recycled water needs to be kept separate from standard drinking water due to its different quality. Moving water to these locations could therefore require significant capital works expenditure and subsequent pumping costs or alternatively trucking costs to meet immediate service needs. Plumbing an existing subdivision with new pipes to deliver recycled water is unlikely to be economic.

Greywater

Greywater, which is wastewater from a household or small commercial establishment (e.g. laundry water) that does not include water from toilets, also quickly becomes uneconomic when not treated close to its origin and transported long distances. Some communal greywater recycling systems designed to service clusters of 1200 and 12 000 households seem to be the most economically viable.⁷⁰ Thus, the question of scale for treatment operations and transportation are closely linked.

Centralised versus decentralised schemes

At present, urban water reuse usually involves large-scale networked schemes based on new or existing centralised sewage treatment plants. However, centrally-based urban treatment schemes generally require extensive and sometimes distant water transportation from the fringe of cities or towns. Taken as a single solution, centralised systems are often too costly and rigid for some applications.

The alternative (which involves decentralised, smaller operations) has the advantage of requiring less infrastructure in terms of connection costs and transport distances (e.g. at a scale of less than 1000 connections, the cost becomes economic).⁷¹ However, the applicability of such scales cannot be applied to all urban situations since they are limited to very particular contexts. Several tools are available to assist the asset management of

decentralised schemes such as those produced by the National Decentralised Wastewater Research and Capacity Development Project in the USA.⁷²

Consumer reaction

The shortest recycled loop—within a group of homes as compared to more distant transport—can be difficult to accept because people are more aware of the link with previous uses of influent water. For example, in a survey of the Mawson Lakes population in South Australia, there was a significant decline in support for water recycling as the proposed use became increasingly personal (i.e. uses with minimal contact were considered more favourable than those involving close contact like bathing).⁷³ Nevertheless in some cases the option of on-site treatment and recycling for personal use may be the cheaper and safer alternative.

Economies of scale

In other cases, economies of scale come into play where increases in the plant size assessed in terms of litres of water produced per day bring decreases in the unit fresh water cost (price per litre). These benefits must be evaluated against the need to consider the ultimate safety of smaller and individually-operated systems. This is especially so with regard to the management of stable toxic allergy-causing substances owing to issues associated with adequate monitoring, cleaning, and maintenance of some of the smaller plants.⁷⁴

Technical issues—scales of operation

It is uncertain whether some of these small, localised high-tech schemes are better able than large plants, to deal with contaminants. Breweries frequently utilise efficient and self-contained schemes which have the facility to contain wastewater on-site. For example, the small Yatala brewery on the Gold Coast has more than doubled its water efficiency in 5 years and now uses less water per litre of beer than any other brewery in the country.⁷⁵

For urban applications, pharmaceuticals and the substances these produce as they degrade are of interest since these are among the substances most expensive and difficult to remove from wastewater.⁷⁶ It is also unknown whether, in the unlikely event of a plant breakdown, clean-up operations for smaller plants will always be localised compared with the operation of large-scale sewage treatment plants.

Advocates of some water recycling technologies claim smaller schemes are less energy intensive, less expensive, have smaller ecological impacts and enable risk sharing between owners and operators.⁷⁷ In contrast, opponents claim that individual supplies may be more difficult to regulate, maintain and monitor, and the quality of output is likely to be highly variable since most schemes are tailored for specific purposes.

Public participation

The direct participants in water recycling are business, plumbing operators, regulators, government, scientists, water service providers and wastewater agencies. More importantly,

the impacts on and decisions about the nature and acceptability of water recycling projects must take into account the views of the users, the public at large.

Public consultation

The public bears part or whole of the financial burden, experiences possible exposure to recycled water, and may experience aesthetic or other impacts from water recycling projects. Public concerns over cost and health are usually the most prominent, but underlying issues of environmental justice or impacts from urbanisation have also been evident. For water recycling projects to enjoy public support, reviews and surveys indicate that all stakeholders must be involved in partnerships and decision-making processes.⁷⁸

Public support for water recycling has generally been very strong and many projects have been implemented without hindrance. For example, Toowoomba Council announced in early July 2005 the intention to proceed with indirect potable reuse following completion of the current upgrade on the Weetalla sewage treatment plant. It intends to treat approximately 5000 megalitres per year of secondary effluent, by ultrafiltration, followed by reverse osmosis, and ultra-violet light treatment.⁷⁹ The basis of the urgency is that if existing water storages are not replenished within two years, then the city will be out of water. So far, there has been little opposition.

On the other hand, of some concern to project developers are cases where there has been enough public opposition to halt implementation of similar projects in recent years.⁸⁰

Controversy

Where there has been controversy, it has generally focused on indirect potable water recycling projects rather than uses with limited personal contact. Indirect potable recycling is where recycled water replenishes the source of drinking water from either groundwater basins or surface water reservoirs. For instance, in Queensland the Caloundra/Maroochy dam recharge project was modified because of a campaign by citizens against indirect potable water recycling.

The Caloundra case was characterised by a perceived lack of adequate consideration of stakeholders in the decision-making process and particular concern about the risks associated with feminising and masculinising hormone-affecting substances (EDCs). Nevertheless, the local council still voted to implement an indirect potable recycling strategy.⁸¹

Depending on the scale of operations, the decision to undertake indirect potable water recycling is ideally a local decision based on community values, complete and accurate information, and an assessment of the water supply options.⁸²

General principles for ensuring adequate public participation include:

- Transparency of decision making processes
- Opportunities for involvement in all phases of project planning & development

- Problems clearly defined—i.e. goals for improvement stated
- Concerns and fears considered real and valid, noted and responded to appropriately (embracing potential conflict and opposition to schemes)
- Social values and needs are incorporated into decision criteria
- Alternatives are openly stated for comparison—choices are open
- Accurate information and adequate research is made available
- Projects justified by real needs
- Environmental principles applied e.g. prevention of water pollution, and
- Costs and benefits of projects are equitably shared.

Health considerations

It is difficult to make broad statements about the health safety of using recycled water. As noted above, the level of public concern depends on the nature of its use. Non-potable use is associated with a low level of concern, while indirect potable use is intermediate and there is greater concern for direct potable use of recycled water.

Water quality factors of particular concern include:

- Disease-causing organisms
- Total mineral content (e.g. total dissolved salts)
- Heavy metals
- Pharmaceuticals like antibiotics⁸³ and pain killers (e.g. paracetamol)
- Radionuclides (e.g. chemotherapy by-products), and
- Concentrations of stable organic substances,⁸⁴ pesticides, hormone-affecting and cancer-causing compounds excreted into the sewerage system.

In Australia, river water is used for town drinking supplies several times on its journey to the sea in systems such as the Murray/Darling and Condamine Rivers. Internationally, examples of indirect potable recycling include the Seine, Rhine and Thames Rivers in Europe and the Mississippi River in the USA. Some countries like Singapore have large-scale reuse programs where some recycled water is returned to potable reservoirs but most is supplied to industry.⁸⁵

Australia takes the position of using the best source of water possible and using recycling to free up drinking water in preference to directly replenishing supplies. Reasons for this approach include the unknown long-term outcomes from ingesting recycled water and the expense involved in programs that monitor the quality of treatment to avoid the possibility of adverse effects.

Prudent consideration of concerns

A conclusion from a recent conference of the Australian Water Association exploring the topic of '*Contaminants of Concern*' was that it would be prudent to wait before producing recycled water for direct drinking water use. This would ensure that we are not inadvertently facilitating the expansion of another as yet unknown long-incubation period malady.⁸⁶ It also provides more time to clarify the science of little known interactions of recycled water with soils and biofilms. This can be achieved by further scientific research and expert input.⁸⁷

In Australia, response to controversial water recycling projects have shown that risks both to the environment and human health need to be adequately understood or controlled in the context of existing organisations.⁸⁸ The issues surrounding public health need to be addressed together with increased education and outreach directly linked to information and the latest scientific research about recycled water.⁸⁹ There is a need to provide facts early on in project planning and involve the public early in decision-making to ensure adequate transparency.⁹⁰

Many water utilities have already moved from simply approaching other agencies and the public when approval or pre-chosen solutions are required to more full engagement in the process of searching for the most effective solutions. Such utilities usually benefit from the strengthened support they receive when engaging actively and making use of community decision making in planning water recycling projects.

Perceptions

Perceived risks may be as important to deal with as the risks themselves and must be addressed.⁹¹ Public acceptance of recycled water is dependent on the confidence that its use is safe. Naturally, there is a public expectation that regulatory agencies will establish sound criteria to protect public health. Nevertheless:

The science-public interface is one that often presents itself as a perplexing chasm when dealing with the communication of hazard and risk ... In the final analysis, regardless of how safe recycled water can be made (and proven to be made), all that matters is whether the public will embrace it. In communicating risk, perception is reality.⁹²

To establish such criteria, it is necessary to identify the hazards that might be present in recycled water. It is also necessary to determine the pathways of human contact, to determine the mechanisms for reducing harmful constituents through treatment, and to calculate risks.

At present, experts are rarely able to agree on risk levels. When technical experts cannot agree, it is unlikely that the general public will have confidence in the results. Therefore more

research is required about the way in which contaminants operate. This may involve modelling studies where contaminant flow data are combined with water flow data to compare potential impacts or studies on the contaminants themselves.

Energy intensity and greenhouse emissions

Energy efficiency

Treating wastewater to a high level, using secondary through to advanced processes, can be very energy intensive. Wastewater recovery from water with less total dissolved solids than seawater has lower energy costs for reverse osmosis.

Per kilolitre of potable water produced, the standard requirements for energy consumption are:

- 3 to 5 kilowatt hours (kWh) for reverse osmosis of seawater⁹³
- 0.4 to 0.6 kWh for conventional water treatment⁹⁴
- 0.7 to 1.2 kWh for brackish reverse osmosis⁹⁵, and
- 0.8 to 1.0 kWh for wastewater reclamation⁹⁶

Thus the type of water targeted for reclamation as well as improved environmental efficiencies are important considerations.

Greenhouse emissions

The energy efficiency of plant operations and the type and source of energy, including renewables, will be crucial steps during planning stages as Australia attempts to reduce its greenhouse gas emissions (GHG). For example, the Water Corporation (in Western Australia) is attempting to move toward carbon-neutrality by reducing energy use and GHG from its water treatment and wastewater treatment plants.⁹⁷ Similar moves towards water recycling by other utilities will need to take these kinds of energy considerations into account.

Substantial GHG emissions, particularly methane, are also generated from wastewater treatment plants and sewers.⁹⁸ Reductions can be achieved through a series of initiatives including improved energy efficiencies, increasing use of renewable energy, capture and combustion of methane, capture and storage of carbon dioxide, fuel switching, and water education media and enforcement campaigns.⁹⁹

Externalities

Presently the ability of States and Territories to charge for externalities efficiently is limited by constitutional constraints on State and Territory taxing powers.¹⁰⁰ Also, the pollution input to the water resource, by storm runoff and sewage discharge, is not costed. Harvesting water,

using waterways for waste transport, turning wetlands into urban development, causing greater runoff of stormwater or releasing effluent into the ocean are social costs that have not routinely been recorded in the urban water management balance sheet. These costs to society are referred to as 'externalities'.¹⁰¹

The current cost analysis for providing potable water supplies to cities, largely considers infrastructure and distribution costs, maintenance and capital costs. The water resource itself is considered to have little value. The change of the flow regimes for the water resource and how it effects the receiving environment is not fully costed.¹⁰²

If it were recognised that environmental externalities do not stop at State borders, a consistent national approach to cost environmental externalities in an efficient way could be adopted.¹⁰³ The development of a nationally consistent approach to costing environmental externalities would also relieve lingering doubts as to the ability of the states to implement a water abstraction charge that includes externalities which potentially has 'tax' characteristics.

Business case evaluation: the Triple Bottom Line

As mentioned above, because water prices do not incorporate externalities, some water recycling schemes stall because, in isolation, they do not appear economic and are difficult to justify. However, when the whole water cycle is taken into account, these schemes may become attractive propositions. Thus the way in which water recycling projects are assessed is of vital importance.¹⁰⁴ This has traditionally been done on an economic and financial basis that has tended to result in low cost land disposal options being favoured.¹⁰⁵

While economic analysis of water recycling projects allows full and transparent accounting of costs and benefits to society, financial analyses tend only to determine cash flow and the feasibility of securing sources of funds to pay for project capital and operating costs. Examples of benefits that may not be included in standard financial analyses are:

- Savings in the form of expenditures that are no longer required for developing new fresh water sources, and
- Lower fertiliser costs in cases where it is possible to extract nutrients in recycled water

On the cost side, however, there are capital costs as well as operations and maintenance charges. Together, these are known as *market* benefits and costs since there is an observable market price to quantify both costs and savings.

Though more difficult to quantify, an economic analysis must also consider the *non-market* benefits and costs, like environmental impacts. Non-market benefits and costs are so named because markets do not yet exist where one can buy and sell them for a price (as in some emissions trading). Analysing non-market benefits and costs helps cast a wider net in identifying stakeholders and developing collaborative partnerships in project planning processes.

A tool of evaluation in this context is Triple Bottom Line (TBL) assessment which incorporates environmental and social benefits issues in addition to economic considerations.¹⁰⁶ This tool has been used to examine opportunities at Melbourne's Eastern Treatment plant¹⁰⁷ and Canberra's future water supply options.¹⁰⁸ The assessment involves economic costing of various proposals to determine the financial recycling cost (\$/megalitre/yr) as well as a qualitative assessment of the environmental and social impacts via a multi-criteria analysis to determine TBL scores. The objective is a ranking of available recycling opportunities on a TBL score and a financial (\$/megalitre/yr) basis.

Funding programs and financial assistance

There are several financial mechanisms to assist water recycling ventures that are potentially available in Australia including:

- Investment incentive schemes
- Grants
- Research funding, and
- Loans.

Although ahead of many OECD countries, there is a need for greater investment in water, sewerage and drainage in Australia and the reasons for this situation have been identified as regulatory failure (e.g. adequate price setting), lack of fiscal commitment, and failure to properly develop markets.¹⁰⁹ According to the managing director of Adelaide-based private water company, United Utilities:

Water recycling, at a large scale, should have been on the agenda in all of our big cities¹¹⁰

It has further been suggested that State water utilities have been compelled by legislation to pay dividends to governments, starving them of funds for capital works.¹¹¹

Incentives, funding and grants

Incentives

Incentive schemes encourage particular investments and ultimately positively influence changes in behaviour. Without incentives from governments it is difficult to implement projects. An example of an incentive scheme operates in Brisbane where residents who purchase and install a rainwater tank between 1 July 2005 and 30 June 2006 may be entitled to a rebate from the Brisbane City Council.¹¹²

Grants

The Australian Government Community Water Grants programme (\$200 million) that was announced in the 2005–06 Budget will be funding water recycling projects that use rainwater, greywater, treated effluent or stormwater to maintain open space and sporting fields or as components of water sensitive urban design. Grant recipients may include community groups such as service clubs, sporting associations, environment groups like Rivercare, indigenous and multicultural groups and the community care sector.

A total of \$1.6 billion over 6 years has been allocated to implement the Water Smart Australia Programme focussing on investments to accelerate the development and uptake of smart technologies and practices in water use such as:

- On-farm water use efficiency improvements
- Desalination of water for use in cities and towns
- Recycling and reuse of stormwater and greywater
- Alternatives to ocean outfalls and better management of sewage, and
- Improvements in irrigation infrastructure.¹¹³

On 30 June 2005 Goulburn Mulwaree Council made a submission for funding of the Goulburn Mulwaree Council Sustainable Cities Project. This \$32 million project aims to increase the secure yield of Goulburn's water supply by reclaiming effluent and returning it to the Sooley Dam catchment.

At various times, the Commonwealth Government has contributed financially to a number of recycling projects through the Natural Heritage Trust-Coasts and Clean Seas program, Landcare programs, Better Cities program, and The Urban Stormwater Initiative. The National Action Plan for Salinity and Water Quality may also be contributing.¹¹⁴

Funding for research and practical implementation

Since the cessation of Commonwealth funding for the Urban Water Research Association of Australia in the early 1990s there has been less coordinated research directed towards water conservation and recycling. Exceptions include the Integrating Technology Implementation and Risk Management in Water Recycling at the University of Wollongong and the Australian Water Conservation and Reuse Research Program established by Australian Water Association and CSIRO in 2003.¹¹⁵

Recently, a Raising National Water Standards programme (\$200 million) has been announced that extends over 6 years and commences in financial year 2005–06 to invest in Australia's national capacity to measure, monitor and manage its water resources.¹¹⁶ Projects that could

be eligible include those facilitating a nationally consistent system for collecting and processing water data or strategic assessment of groundwater resources.

Other practical implementation schemes may involve working with local communities to improve the conservation of water systems with high environmental values through measures such as planning, voluntary conservation agreements and improved knowledge. In addition there are those establishing and promoting the Water Efficiency Labelling Scheme for household appliances, and implementing the Smart Water Mark regime for household gardens.

Loans

In addition to existing funding programs, revolving loans programs could be developed which consist of loans from an agency to recycled water customers, for on-site conversion costs, and acting as an incentive for the customer to convert to recycled water.¹¹⁷ Repayment of the loan would allow funding for additional customers to retrofit their sites.

Pricing of recycled water

The functional utility of water is the most important consideration before cost. If water is really needed in an area for survival, price is secondary to implementation. In other situations where urban areas are running out of water, there may be competing options for delivery of adequate water services, for example water piped from remote dams or water from a local recycling plant.

A major hurdle and expense for most wastewater reclamation in Australia is the salinity level of secondary treated effluent which is costly to remove. Increased salt levels may result from saline seepage into sewers (e.g. Bolivar, South Australia) or alternatively, from industrial and domestic discharges through disposal of substances like detergents (e.g. Western Treatment Plant, Victoria).

Major urban water providers in Australia have achieved low cost recovery pricing for storage and delivery but most have some way to go before achieving a commercial rate of return on capital (See Table 2).¹¹⁸ One issue is that cost-effective wastewater recycling initiatives may not be considered financially viable due to unfair competition with underpriced drinking water. Another issue is that while Australia and the UK reflect the full capital cost of supply in water charges, limited progress has been made to incorporate environmental costs into water charges.¹¹⁹

Australian recycled water prices depend on the location of the treatment plant in relation to:

- Point of use (transport distance)
- Scale of use (local or regional system), and
- Extent of treatment required to manage contaminants

Table 2: Comparison of the costs of some recycled water schemes with the price charged and prices of drinking water.

Note that the price of water is far below the real cost of production. There is also considerable variability in current and anticipated water pricing arrangements throughout Australia.

Location	Use of recycled water	Recycled price/kL	Real cost estimate of recycled water	Drinking water price/kL
Springfield, QLD	Residential—toilet flushing, garden	43c	\$1.45	Per quarter: 90c for 100–150kL
Rouse Hill, NSW	Residential—toilet flushing, garden	28c	\$3.00-\$4.00	98c
Olympic Park, NSW	Residential supply—toilet flushing, garden, laundry	83c	\$1.60 (operating costs only)	98c
Mawson Lakes, SA	Residential—toilet flushing, garden watering	77c	Not available	\$1.03 for >125kL

Sources: Australian Academy of Technological Sciences and Engineering, 'Water recycling in Australia', Melbourne, 2004; D. Hatton MacDonald 'The economics of Water: Taking full account of first use, reuse and return to the environment' CSIRO Land and Water Client Report, Adelaide, 2004; A. Hurlimann, J. McKay, G. Geursen 'Pricing of drinking water vs recycled water: fairness and satisfaction' in *Water*, March 2005, pp.30–34.

Another issue is that water prices may need to vary according to the quality and application of water from particular sources. This is the standard product differentiation approach used in the commercial world. The ability and willingness to pay for recycled water varies depending on urban, agricultural, and industrial uses. Only selected agricultural industries could afford to pay the costs involved in treated water:

The gross margins for selected crops with regard to the ability to pay for water are a major issue in relation to treated water. By and large, we believe we can treat the water for about \$300 per megalitre ... So you do have a problem with what you can pay. Generally speaking, it is wine grapes, apples and other intensive agriculture [that can afford recycled water].¹²⁰

Changes in pricing structures will need to consider the range of users.

Tariffs throughout the developed world have long reflected the concerns of policymakers that the basic human needs of water and sanitation should be enjoyed by all members of society regardless of financial circumstances.¹²¹

Without a coordinated and standardised approach across jurisdictions, governments are likely to encounter resistance to pricing reform. One method for addressing this problem might be

for the issue to be taken up by the NRMMC with decisions based on high quality research into the pricing of water including the factoring in of externalities.

Project implementation

There are numerous interlinked social, environmental and economic factors that ultimately influence the success of water recycling ventures. Even with thorough consideration of impinging factors, the estimation of the future potential of recycled water use is speculative. One significant source of uncertainty with any such estimates is the continuing need for water planners to evaluate and adapt the operation of plants via upgrading and streamlining to ensure ongoing cost-effectiveness and feasibility.

Before implementing new recycled water projects the following factors may need consideration (not necessarily in order of importance):

Social

- Public and employee perceptions
- Potential lack of information (e.g. research, technological expertise)

Environmental

- Offline time—disposal issues from continuously running schemes when water not required
- Energy efficiency
- Contaminants of concern—e.g. sun screens, detergents, pesticides and so on
- Water quality impacts on groundwater and aquifers at recharge
- Reductions in environmental flows
- Requirements for ecologically sustainable development

Human health

- Performance monitoring and control options—remote, logged, early warning systems
- Protection against indiscriminate use (e.g. corrosion and leakage, increased salinity)
- Indirect/direct health impacts (e.g. aerosolisation—high pressure showers, misters)

Economic

- Extent of demand for supply
- Relative cost of alternative supplies (e.g. potable water supply)
- Plant maintenance costs
- Potential lack of incentives
- Availability of governmental financial assistance
- Flow-on effects from pricing scales (e.g. devaluation may lead to a boom for some agricultural crops)

Practical implementation and engineering

- Feedwater sources for recycling plants (e.g. industrial or municipal)
- Available technology
- Scale of operations
- Delivery, reliability and fall-back supply options
- Design of disposal, flows, pipelines, plants
- Possibility of synergistic schemes compared with independent operations (e.g. in Geelong, both the Shell refinery and Barwon Water face significant expenditure in order to upgrade their water and sewerage infrastructure and are considering a jointly funded reuse scheme)
- Feasibility of retro-fitting—greywater systems cannot be retro-fitted to houses on concrete slabs or some multi-storey developments due to no access to separate pipes from wet areas
- Ease of retro-fitting (e.g. pressure sewers employing small diameter pipes)

Legal

- Potential liability (e.g. adequate insurance)
- Ensuring that the water recycling system is designed to minimise the risk of improper use is a useful way to reduce and avoid legal liability issues.¹²² This can be achieved by colour coding pipes, installing different hose fittings, running awareness and education programs, keeping abreast of scientific knowledge and acting on this new research.
- International treaty obligations (e.g. Ramsar Convention on Wetlands)

Conclusions

Australia, like so many countries of the world, has a water availability and supply problem. The reasons include drought, increasing demand from industrialisation and urbanisation, waste management, as well as increasing salinity problems. In this context, the politics of water management are crucial in Australia's federal system. As outlined in the Barton Group's *Water Industry Roadmap*, strategies will likely involve developing a robust, efficient, consistent regulatory regime and tools that are sufficiently cross-jurisdictional in nature.

One initiative is increasing water recycling. The arguments for pursuing this option include boosting the reliability of current water supplies, improvement of water quality, better environmental health and new supplies that can maintain environmental flows, and irrigation. The arguments against include the expense of implementation and upkeep, possibility of dealing with negative community perceptions, as well as food safety and health monitoring.

From the above discussion it is concluded that consultation with water users is vital to ensure that the provision of recycled water services is really what people want and are prepared to pay for. In relation to this issue, any perceived risks need to be seen as social as well as physical issues. This means that stakeholder preferences must play a role in establishing risk mitigation priorities and practices.

Where possible, a goal should be to provide immediate and early improvements to the standard of service (water quality, pressure etc). This helps offset the unpopularity of price increases accompanying new water services. Further, there is a need to ensure that the benefits of water recycling are distributed equitably and that users are protected from unfair and excessive costs. Price increases for potable water may be warranted in some areas of Australia to make recycled water more competitive.

Surplus revenue from water price increases could be reinvested into recycling schemes as a priority. Water inefficiencies would also have to be addressed to improve the value of such services. Further, a balance needs to be found between environmental and demand management imperatives to determine more realistic prices that take into account externalities. However there is a countering political imperative of 'not charging too much more' that needs to be taken into account.

There is no single technology that should be applied where water recycling schemes are to be implemented—requirements are site-specific and combinations of technologies need to be tailored to particular needs. Central and decentralised schemes both have advantages and disadvantages. Neither option offers a complete solution. Taking an integrated approach to the planning of water supply, sewerage and stormwater service provision can offer new solutions.

Investment in scientific research is needed—particularly in relation to how contaminants and pathogens can be inactivated, improving treatment plant and pipe system cleaning operations, and improving efficiencies.

Endnotes

1. M. Albrecht (Theiss Pty Ltd), 'Stewardship of our water for responsible growth'. Australian Academy of Technological Sciences and Engineering Symposium, November 2000. Last accessed 2 August 2005. Available at: <http://www.atse.org.au/index.php?sectionid=301>
2. C. Barber, 'Priorities submission 13 to Department of Education, Science and Training National Research Priorities Taskforce by the Centre for Groundwater Studies', 2 August 2002, p. 5.
3. Australian Bureau Statistics, *Engineering Construction Activity, Australia*, Catalogue no. 8762.0 March 2005, p. 16.
4. P. Dillon, 'Massive new water resource "found"' *Online opinion—Australia's e-journal of social and political debate*, posted Monday, October 21 2002. Last accessed: 2 August 2005. Available at: <http://www.onlineopinion.com.au/view.asp?article=1188>
5. Dr Peter Dillon, CSIRO. In 'Australia – water running to waste down under' Environment News Service, July 25 2002. Last accessed: 10 August 2005. Available at: <http://www.waterconserve.info/articles/reader.asp?linkid=13608>
6. M. Frondel, J. Horbach, K. Rennings, 'End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries', *Discussion Paper* No. 04–82, Centre for European Economic Research, p. II. Last accessed: 2 August 2005. Available at: <http://opus.zbw-kiel.de/volltexte/2005/2887/pdf/dp0482.pdf>
7. Allen Consulting Group, 'Climate change risk and vulnerability' report to the Australian Greenhouse Office, Department of the Environment and Heritage, March 2005, p. vii.
8. C. Howe, 'Climate change scenarios, implications for the Australian urban water industry' Ozwater watershed—the turning point for water. Townsville 5–7 May, Brisbane 8–12 May 2005.
9. *ibid.*
10. R. Jones, 'Climate change and the sustainability management of Australian water resources', Ozwater watershed, *op. cit.*
11. C. Howe, 'Climate change scenarios, implications for the Australian urban water industry', Ozwater watershed, *op. cit.*
12. F. Chiew, M. Peel, A. Western, 'Application and testing of the simple rainfall-runoff model SIMHYD', *Mathematical Models of Small Watershed Hydrology and Applications*. V. Singh, D. Frevert (eds) Water Resources Publication, Littleton, Colorado, 2002, pp. 335–367.
13. R. Young, 'Projections for the future—managing the urban water deficit', Ozwater watershed, *op. cit.*

14. C. Howe, 'Climate change scenarios, implications for the Australian urban water industry', Ozwater watershed, op. cit., p. 6.
15. C. Howe, 'Climate change scenarios, implications for the Australian urban water industry', Ozwater watershed, op. cit., p. 6.
16. B. Williams, 'Recycling answer to water woe,' *Courier Mail*, 6 May 2005, p. 9.
17. S. Merrett, *The price of water—studies in water resource economics and management*, International Water Association (IWA) Pub., London, 2005, p. 2.
18. California Department of Water Resources—Recycled Water Task Force, 'Water Recycling 2030: Recommendations of California's Recycled Water Task Force', June, 2003.
19. *OECD Observer* No. 236, March 2003. Last accessed: 20 July 2005.
Available at: http://www.oecdobserver.org/news/printpage.php/aid/941/Managing_water.html
20. Queensland Environmental Law Association. 'Legislative environment—water recycling background study', Prepared for Queensland Government, Department of Natural Resources, June 2000. Last accessed 2 August 2005.
Available at: <http://www.epa.qld.gov.au/publications?id=422>
21. L. Moore, 'Reclaimed water: managing the legal risks', *Water*, 2003, pp. 70–74.; G. Workman, R. Herbert, G. Tink, (eds), 'Overview of plumbing legislation reform needed for urban water recycling', *Proceedings of the 2nd National Conference, Water Recycling Australia 2003, September 1–3*; A. Maxey. 'Greywater Regulations' *ReNew*, no. 90, 2005, pp. 19–21.
22. Prime Minister's Science, Engineering and Innovation Council (PMSEIC) report 'Recycling water for our cities', 28 November 2003. Last accessed: 2 August 2005. Available at: <http://www.dest.gov.au/NR/rdonlyres/076C55AA-FB04-42A6-8794-B6760767ED5E/1997/Recyclingwaterforourcities.pdf>
23. M. Bartley, 'National water trading—implementation of the COAG National Water Initiative', Ozwater watershed, op. cit.; Department of the Environment and Heritage, 'Council of Australian Governments Water Reform Framework, Water Reform Framework', 2005. Last accessed: 2 August 2005. Available at: <http://www.deh.gov.au/water/policy/coag.html>
24. J. Higgins, J. Warnken, P. Teasdale, 'Quality criteria in Australian reclaimed water guidelines and effluent discharge licences: How consistent are we?', *Australian Journal of Environmental Management*, vol. 11, 2004, pp. 227–236.
25. Department of the Prime Minister and Cabinet, *Government Initiatives—Water Reform—National Water Initiative*, 2005. Last accessed: 2 August 2005.
Available at: <http://www.pmc.gov.au/nwi/index.cfm>
26. *ibid.*; J. Radcliffe, 'Water recycling in Australia' for Australian Academy of Technological Sciences and Engineering, 2004. Last accessed: 2 August 2005. Available at: <http://www.atse.org.au/index.php?sectionid=597>
27. New South Wales Environmental Health. Interim Guidance for Greywater and Sewage Recycling in Multi-Unit Dwellings and Commercial Premises. Document no. GL2005_051, 27 January 2005. Last accessed: 2 August 2005.
Available at: http://www.health.nsw.gov.au/policies/GL/2005/GL2005_051.html

28. Natural Resource Management Ministerial Council Communiqué, *NRMMC* 8, 15 April 2005. Last accessed 2 August 2005. Available at: <http://www.maff.gov.au/releases/05/nrmmc805.html>
29. Prime Minister's Science, Engineering and Innovation Council (PMSEIC) report 'Recycling water for our cities', op. cit.
30. *Health Stream News Items* Issue 38, June 2005. Last viewed 29 June 2005. Available at: http://www.waterquality.crc.org.au/hsarch/HS38_5.htm
31. Queensland Environmental Law Association. 'Legislative environment—water recycling background study', op. cit. Available at: <http://www.epa.qld.gov.au/publications?id=422>
32. S. Khan, M. Muston, A. Schafer (eds) 'Integrated concepts in water recycling', *Proceedings of the ICWR 2005 Conference (2005: Wollongong)*, February, pp. 0–786; E. Kazi, 'NSW to toughen director liability laws', *Australian Financial Review*, 22 June 2005, p. 3.
33. C. Daughton, 'Groundwater Recharge and Chemical Contaminants: Challenges in Communicating the Connections and Collisions of Two Disparate Worlds', *Ground Water Monitoring & Remediation*, vol. 24, no. 2, Spring 2004, pp. 127–138. Last accessed: 2 August 2005. Available at: <http://www.epa.gov/nerlesd1/chemistry/ppcp/images/water-reuse.pdf>; Queensland Environmental Law Association. 'Legislative environment—water recycling background study', op. cit.
34. R. Harding, *Environmental Decision-Making: The roles of scientists, engineers, and the public*, The Federation Press, Sydney, 1998; J. Radcliffe, 'Water recycling in Australia', op. cit.
35. The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 146 Contracting Parties to the Convention, with 1458 wetlands sites, totalling 125.4 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance. See: <http://www.ramsar.org/>
36. E. Kazi, 'NSW to toughen director liability laws', *Australian Financial Review*, 22 June 2005, p. 3.
37. M. Beaufoy, "'Purple piped water'" and the protection of water quality: recycling water and the production and supply of biosolids—legal risks and liabilities, paper presented at Contaminants of Concern in Water Conference in Canberra, 22–23 June, 2005. Case available at: <http://www.austlii.edu.au/cgi-bin/disp.pl/au/cases/nsw/NSWLEC/1997/169.html?query=title+%28+%22+%20+gardner+%20and+%20on+%20%22+%29>
38. Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water, 'Urban water reuse: Why do we need to re-use water?', 2005. Last accessed: 2 August 2005. Available at: <http://www.clw.csiro.au/priorities/urban/reclamation/index.html>
39. J. Radcliffe, 'Water recycling in Australia', op. cit.

40. K. Shaw, 'Wastewater: an increasingly valuable commodity', *Waste Management and Environment*, 8 May, 2005. Last accessed: 2 August 2005.
Available at: http://www.wme.com.au/categories/water/may8_05.php
41. Western water, 'Recycled Water Annual Review 2003/04', last accessed: 4 August 2005.
Available at: <http://www.westernwater.vic.gov.au/downloads/Recycled%20Water%202003-04%20Annual%20Review.pdf>
42. Stockholm International Water Institute (SIWI), 'Making water a part of economic development: the economic benefits of improved water management and services', Stockholm International Water Institute and United Nations Commission on Sustainable Development, Stockholm, 2004; S. B. White, S.A. Fane, 'Designing cost effective water demand management programs in Australia.', *Water Science Technology*, vol. 46, 2002, pp. 225–232.
43. G. Mitchell, 'Integrated Urban Water Management: a review of current Australian practice', report for CSIRO and AWA Australian Water Conservation and Reuse Research Program Stage 1 Review CMIT-2004-075, April 2004.
44. 'Recycling dairy farmers survive record drought', *Irrigation and Water Resources*, Spring, 1 September 2004, p. 36.
45. G. Reynolds (ed.), 'Commonwealth marine funding: a major catalyst for water recycling', *Proceedings of the Water recycling Australia (2000: Adelaide)*, CSIRO and AWA, October 2000, pp. 131–132.
46. National Heritage Trust, Australian Government, 'Programs of the first phase of the Natural Heritage Trust: Clean Seas Program', 2005. Last accessed: 2 August 2005.
Available at: <http://www.nht.gov.au/nht1/programs/csp/index.html>
47. A. Hurlimann, J. McKay, 'Attitudes to reclaimed water for domestic use: part 2. trust.' *Water*, 2004, pp. 40–45; M. Po, J. Kaercher, B. Nancarrow, 'Literature review of factors influencing public perceptions of water reuse', CSIRO Land and Water Technical Report 54/03 December 2003. Last accessed: 2 August 2005.
Available at: <http://www.clw.csiro.au/publications/technical2003/tr54-03.pdf>
48. K. Bristow, P. Charlesworth, 'Effective water management vital to the long term economic viability of the Lower Burdekin', ANCID 2002 paper, CSIRO pubs. Last accessed: 2 August 2005. Available at: <http://www.clw.csiro.au/lbi/publications/ANCID2002paper.pdf>
49. A–M. Boland, A. Hamilton, D. Stevens, J. Kelly, J. Marks, B. Nancarrow, M. Po, M. Wos, R. Faggian, S. Jarwal, S. Engleitner, F. Stagnitti, 'Use of recycled water in Australian Horticulture' Ozwater watershed, op. cit.
50. Environmental Protection Authority Perth, Western Australia 'Strategic Advice on Managed Aquifer Recharge using Treated Wastewater on the Swan Coastal Plain—Draft Section 16(e) report and recommendations of the Environmental Protection Authority', July 2005, p. 18. Last accessed: 2 August 2005. Available at: [http://www.epa.wa.gov.au/template.asp?ID=45&area=Reviews&Cat=s16\(e\)+Managed+Aquifer+Recharge](http://www.epa.wa.gov.au/template.asp?ID=45&area=Reviews&Cat=s16(e)+Managed+Aquifer+Recharge); E. Dortch, 'Give water recycling priority: EPA chief. The West Australian 5 April, 2005, p. 14.

51. A–M. Boland, 'Alternative water sources—the key to horticulture sustainability?', *Irrigation and Water Resources*, 2005, p. 29.
52. Australian Bureau Statistics (ABS), 'Water Account 2000–01', *Catalogue number 4610.0*, 2004, pp. 45–54.
53. *ibid.*
54. *ibid.*
55. J. Radcliffe, 'Water: second/third time around', *Proceedings of the ATSE 2003 Symposium—Water the Australian Dilemma*. Melbourne. November 17–18 2003.
56. Gold Coast Water, 'Pimpama Coomera Water Futures Master Plan Options Report', *Gold Coast Water*, vol. 1, July 2003. Last accessed: 2 August 2005. Available at: <http://www.awa.asn.au/Content/NavigationMenu/Information/SpecialInterestGroups/AssetManagement/StrategicAM/GCW.pdf>
57. G. Mitchell, 'Integrated Urban Water Management: a review of current Australian practice', report for CSIRO and AWA Australian Water Conservation and Reuse Research Program Stage 1 Review CMIT-2004-075, April 2004.
58. E. Cooney, 'Wastewater reclamation plant a green winner for Olympic site', *Proceedings of the AWA Workshop on Recycling Water in 2001*, Sydney, June 2001; J. Radcliffe, 'Water recycling in Australia', *op. cit.*
59. 'Water recycling system launched at Mawson Lakes', *Land and Water News*, 22 June 2005.
60. Ozwater watershed, *op. cit.*
61. A. Speers, 'CSIRO Urban Water', Built Environment Innovation and Construction Technology No. 16, December 2000. Last accessed: 2 August 2005. Available at: http://www.dbce.csiro.au/inno-web/1200/urban_water.htm
62. J. Niemczynowicz, 'Urban hydrology and water management—present and future challenges' in *Urban Water*, vol. 1, 1999, pp. 1–14.
63. Barton Group, 'Australian Water Industry Roadmap: a strategic blueprint for sustainable water industry development', Canberra, May 2005. Last accessed: 2 August 2005. Available at: <http://www.bartongroup.org.au>
64. J. Higgins, J. Warnken, P. Teasdale, 'A review of quality criteria in Australian reclaimed water guidelines and effluent discharge licences', Griffith Centre for Coastal Management, 2004. Last accessed: 2 August 2005. Available at: <http://www.gu.edu.au/centre/gccm>; Victorian Government 'Guidelines for Environmental Management: Use of Reclaimed Water.' Environmental Protection Authority (EPA) Victoria. Melbourne, 2002. Last accessed: 2 August 2005. Available at: [http://epanote2.epa.vic.gov.au/EPA/Publications.nsf/2f1c2625731746aa4a256ce90001cbb5/64c2a15969d75e184a2569a00025de63/\\$FILE/464.2.pdf](http://epanote2.epa.vic.gov.au/EPA/Publications.nsf/2f1c2625731746aa4a256ce90001cbb5/64c2a15969d75e184a2569a00025de63/$FILE/464.2.pdf)
65. R. Hirsch, T. Ternes, K. Haberer, K. Kratz, 'Occurrence of antibiotics in the aquatic environment.', *The Science of the Total Environment*, vol. 225, 1999, pp. 109–118; D. Nghiem, A. Schafer, M. Elimelech 'Removal of natural hormones by nanofiltration membranes:

- measurement, modelling, and mechanisms by wastewater effluents', *Environmental Science and Technology*, vol. 38, 2004, pp. 1888–1896.
66. N. O'Connor, 'Review of early warning detection and monitoring technologies for water supply protection' Proceedings of Contaminants of Concern in Water, CD-Rom, 2005; Citiwater, Townsville, Garbutt Operations Centre, 'Magnetic Island Water Recycling' November 2002. Last accessed: 2 August 2005.
Available at: <http://www.townsville.qld.gov.au/services/citiwater/docs/brochureMIWR.pdf>
 67. R. Otis, 'On-site '05: Performance Assessment for On-site Systems: Regulation, operation and monitoring. International Keynote Unlocking the Shackles of Tradition: A Bright New Future for On-site Treatment', 2005. Last accessed: 2 August 2005. Available at: <http://www.lanfaxlabs.com.au/onsite05/Abstracts-2005-mar.htm>. R. Attwater, J. Aitken, S. Booth, C. Derry, J. Stewart. 'Adaptive systems management and risk communication in the Hawkesbury water recycling scheme' Ozwater watershed op. cit.
 68. H. Mallia, M. Muthukaruppan, S. Torre, 'Investigations for a major water mining project at Princes Park, Melbourne', 67th Annual Water Industry Engineers and Operators' Conference, Sports and Leisure Centre—Wodonga, 1–2 September, 2004, pp. 101–109; P. Baggoley, 'Actew offers to run Qbn sewerage to get grey water', *Canberra Times*, 14 May 2005, p. 13.
 69. B. Kracman, R. Martin, P. Sztajnbock, 'The Virginia Pipeline: Australia's largest water recycling project', *Water Science Technology*, vol. 43, 2001, pp. 35–42.
 70. N. Booker, 'Estimating the economies of scale of greywater reuse systems', Program report FE-88, CSIRO Molecular Science, 1999; S. Fane, N. Ashbolt, S. White 'Decentralised urban water reuse: the implications of system scale for cost and pathogen risk', *Water Science and Technology*, vol. 46, no. 6–7, pp. 281–288, IWA Publishing; N. Booker, 'Economic scale of greywater reuse systems', *Built Environment Innovation and Construction Technology*, 16 December 2000.
 71. Brisbane Institute, 'Water for the people', 20 February 2003. Last accessed: 2 August 2005.
Available at: http://www.brisinst.org.au/resources/brisbane_institute_lehmann_water.html
 72. The National Decentralized Water Resources Capacity Development Project (NDWRCDP) is a cooperative effort funded by the U.S. Environmental Protection Agency (USEPA) which supports research and development. Organizations collaborating in this effort include the Coalition for Alternative Wastewater Treatment, the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT), the Electric Power Research Institute (EPRI), the National Onsite Wastewater Recycling Association (NOWRA), the National Rural Electric Cooperative Association (NRECA), and the Water Environment Research Foundation (WERF). Last accessed: 8 August 2004. Available at: <http://www.ndwrcdp.org/>
 73. J. McKay, A. Hurlimann, 'Water resources management at Mawson Lakes, South Australia, an innovative dual water supply system: development of the scheme and community attitudes', International Water Resources Association 11th World Water Congress, Madrid Spain, 6–11 October 2003.
 74. D. Deere, A. Davison, 'Bacterial endotoxins in recycled water', Proceedings of Contaminants of Concern in Water, CD-Rom, 2005.

75. WME, 'Gold Coast brewer goes hard on water efficiency', *WME Environment Business Magazine*, vol. 16, no. 6, July 2005, pp. 38–39.
76. Proceedings of Contaminants of Concern in Water, CD-Rom, 2005.
77. A. Dangeard, 'Alternative water management systems will create new types of markets' in *Guidelines for Municipalities and Enterprises*, September 2004. Last accessed: 2 August 2005. Available at: http://www.cerna.ensmp.fr/cerna_globalisation/Documents/dematedee-guidelines-report.pdf
78. M. Po, B. Nancarrow, Z. Leviston, N. Porter, G. Syme, J. Kaercher, 'Predicting community behaviour in relation to wastewater reuse—what drives decisions to accept or reject?', Report for Water for a healthy country: national research flagship, CSIRO Land and Water, 2005, Perth. Last accessed: 2 August 2005. Available at: <http://www.cmis.csiro.au/healthycountry/reports/PredictingReuseBehavior.pdf>.
79. W. Frew, 'For one city, drinking sewage is not a waste', *Sydney Morning Herald*, 15 July 2005, p. 1.
80. M. Po, et al., 'Predicting community behaviour in relation to wastewater reuse—what drives decisions to accept or reject?' op. cit.
81. Rivermouth Action Group, 1999. Last Accessed 2 August 2005. Available at: <http://www.rag.org.au/sewage/waste.htm>
82. The WateReuse Foundation 'Best Practices for Developing Indirect Potable Reuse Projects: Phase 1 Report,' WateReuse Foundation's Project Profile, Project No. WRF-01-004, Product No. 01-004-01, 2004. Last accessed: 2 August 2005. Available at: http://www.watereuse.org/pdf/profile_01004.pdf
83. A. Watkinson, S. Constanzo, 'Antibiotics as pollutants: do they pose a risk to the environment and recycled water', Proceedings of Contaminants of Concern in Water, CD-Rom, 2005.
84. D. Deere, A. Davison, 'Bacterial endotoxins in recycled water', *ibid*.
85. B. Swinton, 'Membrane technology', *Water*, May 2005, pp. 36–41.
86. N. Ashbolt, 'Water quality contaminants—bacteria, viruses and other pathogens', Proceedings of Contaminants of Concern in Water, CD-Rom, 2005.
87. Queensland Government Department of Natural Resources, 'Wastewater recycling health effects scoping study prepared on behalf of Queensland water recycling strategy by Queensland health scientific services, national research centre for environmental toxicology and envirotest', 2000. Last accessed: 2 August 2005. Available at: http://www.epa.qld.gov.au/publications/p00421aa.pdf/Wastewater_recycling_health_effects_scoping_study_prepared_on_behalf_of_Queensland_Water_Recycling_Strategy_by_Queensland_Health_Scientific_Services_National_Centre_for_Environmental_Toxicology_and_Envirotest.pdf; S. Khan, 'Identifying impediments to municipal water recycling in Australia', Water: Planning for the Future, Australian Water Association Conference, Presentation e4107, Enviro 2004 Convention and Exhibition, Sydney, Australia, 28 March to 1 April 2004.

88. N. Steneke, A. Schäfer, N. Ashbolt, 'Community involvement in water recycling—issues and needs', A.I. Schaefer, T.D. Waite & P. Sherman (eds), *Recent Advances in Water Recycling Technologies*, Workshop Proceedings, 26 November 2001, Brisbane, QLD, Australia.
89. R. Attwater, C. Derry, 'Engaging communities of practice for risk communication in the Hawkesbury Water Recycling Scheme', *Action Research*, vol. 3, no. 2, 2005, pp. 193–209.
90. California Department of Water Resources—Recycled Water Task Force, 'Water Recycling 2030: Recommendations of California's Recycled Water Task Force', June 2003. Last accessed: 2 August 2005. Available at: <http://www.owue.water.ca.gov/recycle/docs/TaskForceReport.htm>
91. C. Daughton, 'Groundwater Recharge and Chemical Contaminants: Challenges in Communicating the Connections and Collisions of Two Disparate Worlds', *Ground Water Monitoring & Remediation*, vol. 24, no. 2, Spring 2004, pp. 27–138. Available at: <http://www.epa.gov/nerlesd1/chemistry/ppcp/images/water-reuse.pdf>; A. Clarke, 'Scientists must make themselves heard', *Australian Financial Review*, 7 May 2005, p. 62.
92. C. Daughton, 'Groundwater Recharge and Chemical Contaminants: Challenges in Communicating the Connections and Collisions of Two Disparate Worlds', *ibid.*
93. Perth's seawater desalination plant, Last accessed: 8 August 2005. Available at: http://www.watercorporation.com.au/Docs/desal_faq.pdf
94. B. Swinton, 'Membrane technology', *Water*, May 2005, pp. 36–41.
95. B. Swinton, 'Membrane technology', *Water*, May 2005, pp. 36–41.
96. B. Swinton, 'Membrane technology', *Water*, May 2005, pp. 36–41.
97. R. Humphries, M. Waite, P. Rogoysky, P. Huxtable, M. Hess, 'Moving towards carbon-neutrality', *Water*, vol. 32, no. 4, June 2005, Michael Flynn award for best paper, pp. 36–38, & pp. 67–68.
98. *ibid.*
99. *ibid.*
100. Phillips Fox and Queensland University of Technology, 'Trading in Water Rights—towards a national legal framework', May 2004. pp. 21, 23, 92. Independent competition and regulatory commission submission on the productivity commission's review of National Competition Policy Reforms, p. 7.
101. Stormwater Industry Association, Submission 37, Chapter 7—Economic Instruments. Last accessed: 10 August 2005. Available at: http://www.aph.gov.au/senate/committee/ecita_ctte/completed_inquiries/2002-04/water/report/c07.pdf
102. *ibid.*
103. A. Brunton, 'Water reform and National Competition Policy update', *Australian Environment Review*, vol. 20, no. 6, June 2005, pp. 10–13.
104. 'The Alternative Technology Association response to the Draft Decision by the Essential Services Commission (ESC) Water Price Review into Metropolitan and Regional Businesses',

- Water Plans for the Regulatory Period July 2005 to June 2008*, 2 May 2005. Last accessed: 2 August 2005.
Available at: http://www.ata.org.au/policy/esc_water_price_review.pdf
105. A. Chapman, R. Reichstein, 'TBL Assessment of water recycling opportunities', Ozwater watershed, op. cit.
 106. B. Maxwell, 'Water governance from the Australian Governments' perspective'. Ozwater watershed, op. cit.; D. McRae, P. Northey, M. Lee 'Unique industrial reuse opportunity—TBL benefits for both Shell and Barwon water', ibid.
 107. A. Chapman, R. Reichstein, 'TBL Assessment of water recycling opportunities', Ozwater watershed, op. cit.
 108. ACTEW Corporation, 'Canberra's Future Water Supply Options Implementation Plan', May 2005.
 109. Econtech prepared for AusCID report, 'Modelling the economic effects of under-investment in Australian Infrastructure', 6 July 2004.
 110. 'No shortage of water, just foresight', *The Advertiser*, 18 June 2005. Last viewed: 4 August 2005. Available at: <http://www.theadvertiser.news.com.au/printpage/0,5942,15644265,00.html>
 111. A. Wahlquist, 'Private investment 'the solution to water crisis'', *The Australian*, 16 June 2005, p. 7.
 112. Rainwater Tanks—Brisbane Water. Last accessed: 8 August 2005.
Available at: http://www.brisbane.qld.gov.au/BCC:BRISWATER::pc=PC_1460
 113. Department of Environment and Heritage, Australian Government, Commonwealth of Australia 'Environment budget overview', Canberra, 2005, p. 30.
 114. ibid.
 115. ibid.
 116. ibid.
 117. Department of Water Resources, Sacramento, California, 'Water Recycling 2030: Recommendations of California's Recycled Water Task Force', June 2003; C. Freeman, 'Water recycling in California: A survey of motivating factors and financing mechanisms' pp. 1–18. Available at: <http://www.ttemi.com/html/water.pdf>
 118. Allen Consulting Group for NCC's submission to the Productivity Commission Review of National Competition Policy Reforms. 'Microeconomic Reform in Australia—comparison to other OECD countries', December 2004.
Available at: <http://www.ncc.gov.au/publication.asp?publicationID=197&activityID=41>
 119. OECD, *Environmental Performance reviews: Water*, OECD Publications, France, 2003, pp. 28–31.
 120. House of Representatives Standing Committee on Agriculture, Fisheries and Forestry, 'Future water supplies for Australia's rural industries and communities', Mr Forrest in response to Mr Lawson. Melbourne, 7 April 2003, p. 227. Last accessed: 2 August 2005.
Also available at: <http://www.aph.gov.au/house/committee/primind/watering/report/chap5.pdf>

121. J. Sawkins, V. Dickie, 'Affordability of household water and sewerage services in Great Britain', *Fiscal Studies*, vol. 26, no. 2, 2005, pp. 225–244.
122. A. Davison, D. Deere, 'Risk management and due diligence in the water industry' *Water*, May 2005, pp. 56–59.

© Copyright Commonwealth of Australia 2005

Except to the extent of the uses permitted under the Copyright Act 1968, no part of this publication may be reproduced or transmitted in any form or by any means including information storage and retrieval systems, without the prior written consent of the Department of Parliamentary Services, other than by senators and members of the Australian Parliament in the course of their official duties.

This brief has been prepared to support the work of the Australian Parliament using information available at the time of production. The views expressed do not reflect an official position of the Information and Research Service, nor do they constitute professional legal opinion.

Acknowledgements

I gratefully thank the following colleagues for their assistance and advice in the preparation of this paper: Greg Baker, Rowena Billing, Fred Cook, Peter Hicks, Matthew James, Angus Martyn, Bill McCormick, Brian Murray, Gerry Newman, Ann Palmer, Rosemary Polya, Angela Pratt, Mike Roarty, Alex Tewes, June Verrier, Richard Webb, and Bill Williams. Judy Hutchinson kindly offered to edit the paper. Professor Paul Perkins, Chair of The Barton Group (Environment Industry Development Action Agenda), Adjunct Professor Centre for Resource and Environmental Studies of The Australian National University, Chair of the National Environmental Education Council, Chair CRC Contamination Assessment and Environmental Remediation provided valuable expertise. Dr Carol Howe, Director—Future Cities CSIRO Manufacturing & Infrastructure Technology kindly provided a figure and background information. Dr Grace Mitchell, Senior Research Fellow at the Institute for Sustainable Water Resources, Department of Civil Engineering, of Monash University generously provided references, information, and advice. Pat Feehan, Manager Environment and Natural Resources for Goulburn-Murray Water and CRC for Catchment Hydrology Focus Catchment Coordinator in Victoria took time to discuss the implementation of guidelines and development of specific risk management plans.