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INQUIRY INTO A SUSTAINABLE WATER SUPPLY FOR SYDNEY

Organisation: Centre for Water & Waste Technology, University of New South Wales

Name: Dr Stuart Khan

Telephone:

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Summary

The Case for Water Reuse

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Submission to the Parliament of NSW Legislative Council Inquiry into a Sustainable Water Supply for Sydney

The Case for Water Reuse

Dr. Stuart Khan
Centre for Water & Waste Technology, University of New South Wales, NSW, 2052.

Date: Monday 13th February 2006

Summary

To its credit, The Parliament of NSW Legislative Council has identified the urgency of working towards the provision of a sustainable water supply for Sydney. In this submission, the case is put for substantially increased adoption of water reuse as an important water management practice for the city. In order to facilitate moves towards increased water reuse, necessary improvements and reforms are identified. Many of these are in areas which could be benefited directly by NSW Government policy and action.

Introduction: The Need to Do Things Differently

Throughout most of the 20th century, engineered water management in Sydney comprised dams to collect surface water and outfalls to discharge primary or secondary treated effluents. As populations grew, more dams were constructed and ever-increasing volumes of sewage were discharged into the ocean. In this sense, water has been treated as if it were a free resource with unlimited supplies. Little appreciation for the inter-dependence of all aspects of the water cycle has apparent.

As a result of both population growth and recent droughts, Sydney entered the 21st century on the brink of requiring new urban water resources. The challenges confronting the city are starkly demonstrated by trends in the volume of water stored in the cities eleven main dams as shown in Figure 1 [1].

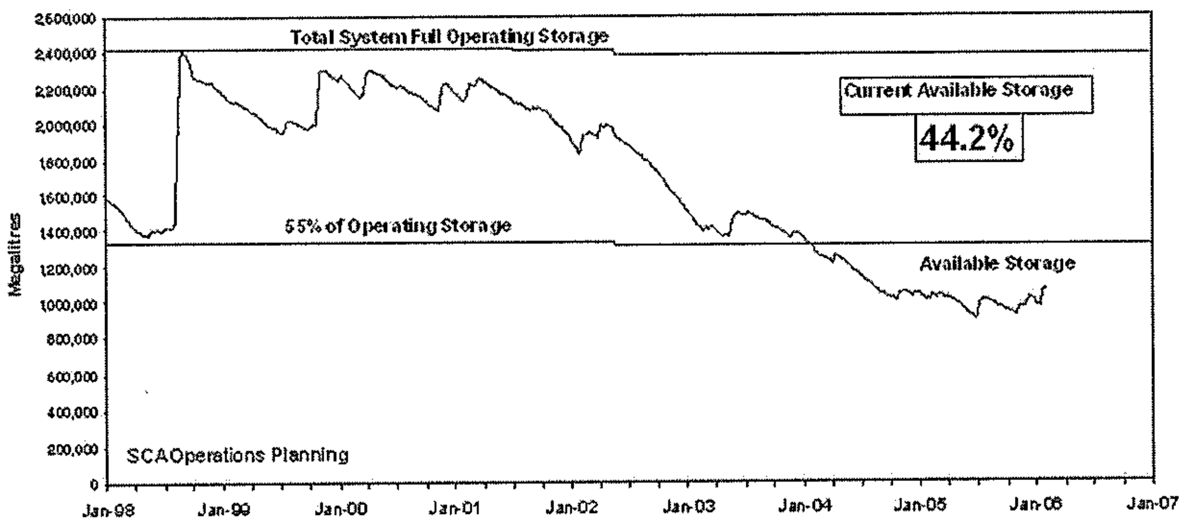

Figure 1 Sydney's stored water supplies Jan 1998 – Feb 2006 [1].

In May 2002, Sydney's dams were at 80 per cent capacity but just three years later (May 2005) levels reached record lows of below 40 percent. Thus it was clear that if no further action was taken and the current weather patterns continued, Sydney could face severe shortages before 2009. Even with extensive rainfalls just over the horizon, long-term security of the city's water supplies would remain uncertain unless significant changes in water management practices were implemented.

The historical response to drought and population growth in Sydney has been to increase storage capacity by building new dams on relatively untapped rivers. However, environmental and economic costs, coupled with the long-term inadequacy of many earmarked future dams, have been cause for governments to reconsider plans for their construction. Appropriately, the NSW Government has announced an indefinite deferral of a long-planned additional dam for Sydney [2].

Adequate clean water is not the only water management challenge confronting Sydney. Marine pollution caused by sewage discharge is recognised as a growing worldwide problem [3]. The discharges from Sydney's ocean outfalls represent a cumulating, and often overlooked, burden on marine flora and fauna. Some of the pollutants found in primary treated effluents include nutrients, suspended solids, organic carbon, pathogens and toxic chemicals. Large volumes of fresh water can also detrimentally alter otherwise saline environments. Furthermore, sewage discharges can carry large quantities of heat to otherwise cooler environments, thereby disrupting local ecosystems.

2,500 tons of total phosphorus and 12,900 tons of total nitrogen was discharged via Sydney's three deepwater ocean outfalls during 2004-05 [4]. Most of the nitrogen load was discharged in the form of ammonia (9,100 tons as total ammonia) which is toxic to marine ecosystems. These nutrients support the growth of plants and phytoplankton in coastal waters. Seagrasses and marine macroalgae have differing requirements for carbon, nitrogen and phosphorus and variations in their supply may change conditions to favour the growth of one species at the expense of others.

The range of toxic chemicals known to persist in primary treated sewages includes heavy metals, aromatic hydrocarbons and organochlorine compounds. Furthermore, more than 30 tons of toxic inorganic cyanide compounds were discharged by the Sydney outfalls during 2004-05 [4]. Estrogenic steroid hormones (including estrone, estradiol and the synthetic ethynylestradiol) have been reported in sediments adjacent to the largest outfall, off Malabar [5]. These compounds, associated with particulates in the sewage, aggregate on contact with high ionic strength seawater and accumulate on the seafloor.

Some Australian cities, such as Melbourne, have highlighted the need to reduce discharges from ocean outfalls and are now actively working to increase the feasibility of ceasing ocean discharge of sewage [6]. Unfortunately, Sydney is not among them.

In 2002 a Federal Parliament Senate Committee was established to conduct an inquiry into Australia's management of urban water [7]. The Committee reported that there were major opportunities for Australian cities to improve on their performance with regard to water reuse. It observed that '*efficient water use is still perceived as an emergency measure to be adopted during drought condition*'. Among the recommendations of the Senate Committee was that '*Australians generally be encouraged and assisted to use less water, recycle more effluent and significantly reduce the impact that urban development and its stormwater collection and transport has on natural systems*'.

In 2003 the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) identified possible mechanisms by which Australian cities could make better use of available water resources [8]. The PMSEIC indicated that a mixture of initiatives appropriate to specific circumstances of each city would be required. However, essential criteria for all initiatives would include maintenance of public health, economic viability, environmental sustainability and social acceptance. With these criteria in mind, recycled water was promoted by the PMSEIC as '*a valuable resource that should not be wasted and which can be used in a safe and sustainable manner to reduce pressures on limited drinking water resources*'.

In 2004 the NSW Government signed on to the National Water Initiative – an agreement between the Commonwealth of Australia and most of the State and Territory Governments [9]. The National Water Initiative provides a framework within which the signatories will operate to address, among other things, urban water shortages. Key actions to be undertaken by 2006 include the implementation of demand management practices and the development of innovation and capacity building to create water sensitive Australian cities.

Why Desalination is the Wrong Choice

Prior to 2004, desalination was practised in Australia with just a few very small brackish groundwater schemes. The Premier of NSW had disparagingly referred to desalinated seawater as 'bottled electricity' noting the considerable energy requirements for its production. However, serious consideration of large-scale seawater desalination schemes began to grow during 2004-05.

In July 2004, the Western Australian Government announced that it would construct a seawater desalination plant to supply Perth with up to 45 gigalitres per year of potable water by 2006. At the time of the announcement, this would have been the largest reverse osmosis seawater desalination plant in the world. Soon after, the NSW government announced plans to build a desalination plant for Sydney on the Kurnell peninsular. Following community anxiety regarding many aspects of the plant and the planning process for it, plans have currently been shelved. However, there have been suggestions that desalination will be considered again if Sydney's water storage levels drop to below 30 per cent of capacity.

A major limitation of desalination compared to water reuse is that it can only address one of Sydney's two major water management problems. That is, it may increase the available supply, but will do nothing to decrease the ongoing discharge of sewage into the ocean. On the contrary, desalination will further entrench the 'use once then discharge' paradigm of water management in Sydney. Ever increasing volumes will be desalinated and ever increasing volumes will be discharged.

In addition to this most obvious limitation of desalination, a few further issues are discussed briefly below. These relate to the impact of desalination on social behaviour and attitudes to water conservation, the extreme energy intensiveness of desalination and problems associated with the discharge of waste brine generated by the process.

Impact on social behaviour and attitudes to water conservation

When a potential water source is envisaged to be as great as the Pacific Ocean, the urgency to implement water-efficient technologies and practices will appear to be reduced. Therefore, a likely social consequence of building a seawater desalination plant in Sydney will be a weakening of the message highlighting the importance of water conservation.

Given that the seawater desalination plant is to be publicly funded, it is furthermore likely that the community may consider that they have an entitlement to use water as they require it, since their taxes are paying for its production.

The French economist Jean Baptiste Say (1767-1832) developed an economic theory commonly known as 'Say's Law'. The popular expression of Say's Law is 'supply creates its own demand'. A Say's Law vicious circle would be an extremely expensive exercise when energy-intensive desalinated seawater is involved.

According to information available on the Sydney Water and Sydney Catchment Authority's websites, from the beginning of the current mandatory water restrictions in October 2003 through to December 2005, total water consumption was **12.6 per cent** below the ten-year average. This is an excellent result for both the NSW Government and the people of Sydney.

On the other hand, the proposed 125 ML/day desalination plant would (when running at full capacity) deliver a mere **9 per cent** of Sydney's daily needs.

If the implementation of a seawater desalination plan does cause people to pay less attention to conserving water, there is clearly significant scope for the water surpluses made by desalination to be severely eroded and even possibly to result in a net deficit. The situation could be even further exacerbated if the availability of desalinated supply creates additional demand for potable water.

Observation of water consumption patterns in regions with similar social conditions to Australia and significant seawater desalination capacity (eg. California, Florida, Spain, Italy) provides no encouragement that desalinating communities are exemplary water conservers.

The types of social concerns expressed here have also been recently raised in the face of expanding reliance on seawater desalination in Spain [10]. However, it is apparent that no serious efforts have been undertaken to really quantify the extent of the conflict anywhere. The potential problem is not even acknowledged in the environmental assessment for the concept of the Sydney plant [11].

Without undertaking serious efforts to investigate this phenomenon, the NSW Government can not be said to have adequately assessed the full scope of environmental implications. At its most severe manifestation, the phenomenon could result in a particularly unfortunate and ironic environmental outcome: increased consumption of potable water from the already stressed traditional Sydney catchments.

The unjustifiable extreme electricity consumption

The energy requirements associated with seawater desalination derive from both the treatment processes (predominantly reverse osmosis) as well as the need to pump the water uphill from sea level to a height sufficient for gravity-fed reticulation. In Sydney, these large energy costs will be predominantly met by fossil fuel-combustion electricity production.

The environmental assessment prepared for the concept of the Sydney desalination plant acknowledges that '*a 125 ML/day plant would have a peak daily electricity demand of approximately 30 MW. A 500 ML/day plant would have a peak daily electricity demand of 110 MW*'[11]. To put these figures in context, the environmental assessment then goes on to acknowledge that a fully operational plant (500 ML/day, 365 days per year) is equivalent to an additional 1.2 per cent of the electricity demand of the entire state of NSW [11].

Regardless of how these energy demands (and associated greenhouse gas production) are offset, such a huge demand on the States (fossil fuel-powered) electricity supply is extremely difficult to justify when alternative lower-energy options are available.

Reverse osmosis technology has developed dramatically during the last decade, decreasing both the energy costs and therefore the financial costs of treatment. However, the major source of energy requirement remains the necessity to overcome the osmotic potential difference across the membrane. That is, the difference in salinity between the purified water and the retained 'brine'. Seawater is roughly an order of magnitude more saline than most conventional wastewaters. Accordingly, as long as the need to overcome osmotic potential remains the principal source of energy requirement, reverse osmosis of seawater will remain more energy intensive than the same treatment applied to conventionally treated wastewater.

Impact of discharged concentrated brine to marine ecosystems

The fundamental principal of reverse osmosis is the employment of semi-permeable membranes to separate a 'purified' component of the water from a waste-stream retaining the concentrated salts. This waste stream is commonly referred to as the membrane 'concentrate' or 'brine'. The sound management and disposal of concentrates has become one of the greatest concerns regarding water desalination (and water reuse), and is often a key factor determining the overall viability of a project. The issues involved include technical challenges, permitting problems and high costs. Concentrate from seawater desalination typically comprises half of the original in-take volume and all of the dissolved salts. Accordingly, it is typically double the normal concentration of seawater. Most commonly, concentrates are discharged via ocean outfalls, however the double salinity renders concentrate plumes denser than seawater and thus they can be difficult to disperse. The potential impact of concentrate plumes on marine species in Australian environments has yet to be properly assessed.

Many marine organisms are highly sensitive to variations in salinity. This sensitivity arises largely from the effect of the osmotic potential across cell membranes. That is, relative salt concentrations internal to and external to living cells. The osmotic potential affects the in-flow and out-flow of water towards a state of osmotic equilibrium. Marine organisms respond to salinity variations as being either osmotic conformers (poikilosmotic or isoosmotics) or osmotic regulators (homeosmotic).

Osmotic conformers have no mechanism to control osmosis and thus their cells conform to the same salinity as their environment. Many simple marine organisms such as plants and invertebrates are osmotic conformers. Large decreases in salinity cause water to enter the cells of these organisms eventually leading to cell rupturing (lysis). Increases in salinity can lead to cell dehydration (plasmolyzation) which can also result in cell death.

A marine ecological assessment for concept of the proposed Sydney seawater desalination plant was undertaken by The Ecology Lab for GHD on behalf of Sydney Water Corporation [12]. The authors reported that "*no studies on the effects of toxicants in desalination plant discharge on benthic communities or species have been found to date*" and that "*the response of fish, fish larvae* *and other planktonic biota to fronts or plumes of concentrated seawater is also unknown*". The authors expected that "*larger, mobile biota such as fish are likely to be able to avoid the zone of higher salinity in the immediate area of the discharge, but smaller invertebrates and some species of fish living in or near reefs and bottom sediments would be unable to escape its influence*". They concluded that "*because the dense, hypersaline plume will tend to sink and disperse slowly, biota likely to be affected are bottom-dwelling or non-mobile species that live on or are physically attached to the reef. These include fan corals, sponges, stalked and sessile ascidians, anemones and attached algae. Little, if any information is available on the salinity tolerances of these species or their responses to chemicals contained in the discharge plume*".

The concerns and lack of knowledge identified by The Ecology Lab were further acknowledged in the Environmental Impact Assessment for the plant concept commissioned by Sydney Water [11]. This report stated that "*the design has therefore sought to dilute the concentrate as quickly as possible by a purpose built diffuser system so that there are minimal effects on the marine environment*". However, the report acknowledged that "*inside the mixing zone, the salt concentration in the seawater concentrate will initially be approximately 65 ppt, compared to background levels in the order of 34 to 36 ppt*".

This approach to rapid dilution of the concentrate stream by effective diffuser design is logical. However, unfortunately, modelling of saline plume dispersal has barely been studied and is very poorly understood. This is acknowledged in the report prepared for the project by the Water Research Laboratory [13]:

'*The science of predicting near field (not far field) dilutions of dense plumes has been subject to only limited study. Physical modelling experiments have been conducted to determine the near field dilution of seawater concentrate discharged into still waters, but little is known as to the additional mixing processes of receiving water velocities and wave activity.*'

As a result of their high salinity, seawater concentrate plumes are denser than seawater and therefore have negative buoyancy and sink towards the seabed. This is in contrast to the more common wastewater plumes which are buoyant and rise to the surface. Accordingly, understanding and modelling desalination plumes involves different challenges to those posed by wastewater discharge plumes. The dense plume has lesser immediate and far field mixing processes than more buoyant plumes [13].

Logically, more research has been undertaken in areas that have been considerably more impacted by seawater desalination brines such as the Mediterranean Sea [10; 14; 15], Red Sea [16] and

Persian Gulf [17]. In particular, Mediterranean *Posidonia* grasslands and their associated ecosystems appear to be highly sensitive to even very small increases in salinity [10; 14; 15]. Furthermore, echinoderms, which are osmoconforming organisms appear to have been severely impacted in an area close to a Mediterranean reverse osmosis desalination discharge [14]. However, the direct applicability of these studies to Australian cases is unknown and highly questionable.

Comprehensive studies on the effects of local marine flora and fauna (especially benthic species) are urgently required before any seawater desalination plant should be approved (even in concept).

Current Practices of Municipal Water Reuse

In 2004, the Australian Academy of Technological Sciences and Engineering (AATSE) published a comprehensive report detailing current practices of water recycling in Australia [18]. This report identified substantial variations in the relative proportions of available municipal sewage effluents that were reused by the various states and territories in 2001-02. Significantly, much greater rates of water reuse were reported for each overall state than for the respective state capitals. This reflects the greater rates of water recycling in rural towns, particularly those in inland areas. The figures are provided in Table 1.

Table 1 Municipal sewage effluents reused in Australian States and their Capital Cities [18].

State/Territory	Reuse in 2001-02 (%)	Capital City	Reuse in 2001-02 (%)
Queensland	11.2	Brisbane	6.0
New South Wales	8.9	Sydney	2.3
Australian Capital Territory	5.6	Canberra	Data unavailable
Victoria	6.7	Melbourne	2.0
Tasmania	9.5	Hobart	0.1
South Australia	15.1	Adelaide	11.1
Western Australia	10.0	Perth	3.3
Northern Territory	5.2	Darwin	Data unavailable

The AATSE report indicated considerable diversity in the approaches taken to reuse water throughout Australia. In many instances, reuse schemes were designed to address localised issues such as the protection of a sensitive aquatic environment or to satisfy a local demand for agricultural or industrial water use. So although overall percentages of water reused in Australia remain low, a wide variety of approaches have been tested. This has provided a considerable knowledge and experience base which will benefit planning for future schemes. The principal approaches to water reuse in Australia are summarised below [18].

Onsite municipal reuse

Onsite municipal water reuse is practised in Australia primarily by the selective capture of greywater sources from laundries and bathrooms. Typically, the greywater is treated by sand filtration and reused for toilet flushing and garden watering.

Very few houses and offices in Australia are capable of treating and reusing blackwater sources (such as from toilet flushings). Such systems require biological amelioration and disinfection. The few systems in existence operate primarily as experimental or demonstration schemes since they are expensive to install and require careful on-going management.

Targeted municipal irrigation

Targeted municipal irrigation schemes are among the most common means of water reuse in Australia. In many cases, secondary or tertiary treated effluent is applied to public parks and gardens, golf courses and playing fields. Such reuse practices are attractive primarily for the generally low levels of treatment required and the need for a relatively small number of distribution pipes to transport the water to the points of use.

An alternative approach has been developed with the introduction of small portable sewer-mining operations. These involve the extraction of untreated sewage from municipal sewer mains. The water is then treated by a small, sometimes mobile, treatment plant (normally using membrane technology) and reused for irrigation. An advantage of portable sewer mining operations is that they may be relocated depending on temporary or seasonal demands. Sewer mines have been trialed in various public locations around Melbourne and Canberra.

Industrial reuse

Brisbane Water operates a successful industrial reuse program from the Luggage Point Sewage Treatment Plant. This plant delivers 10 to 15 megalitres of treated effluent per day to the adjacent BP Amoco oil refinery where is it used as boiler feedwater. In addition to the potable water savings, this scheme allowed for considerable infrastructure savings by eliminating the need to expand potable water mains capacity. Further large-scale agreements for industrial reuse operations have been recently implemented at Kwinana (WA) involving mining, power generation, chemical fertiliser and petroleum companies. Bluescope Steel in Wollongong (NSW) will soon receive 20 megalitres of recycled water per day from Wollongong Sewage Treatment Plant for use in the steel manufacturing plant.

Agricultural reuse

Recycled water from Adelaide's largest water treatment plant is delivered via the Virginia Pipeline to agricultural areas on the Northern Adelaide Plains and the Barossa Valley. The scheme supports one of Australia's most valuable produce markets and provides an alternative source of water to the over-utilised local groundwaters. The Virginia Pipeline scheme was commissioned in 1999 and has a capacity of 110 ML per day delivered via a network of more than 100 kilometres of pipes.

A proposal for a pipeline from Brisbane to supply recycled water to the Lockyer Valley and Darling Downs was once deemed economically and environmentally unviable. However, due to on-going water shortages, the pipeline is again under consideration by the Queensland Government. A similar scheme has been initiated to deliver water from Hobart to the Coal River Valley in Tasmania. Horticulture and pasture irrigation are the focus of major plans to expand water reuse in Victoria over the next couple of decades.

Agricultural reuse has also been successfully practiced by a number of much smaller applications such as the Gerringong-Gerroa sewerage scheme and Shoalhaven Water's Reclaimed Water Management Scheme. Both these schemes supply water for dairy pasture irrigation on the NSW south coast.

Reticulation for household reuse

A small but growing number of new housing development areas in Australia have incorporated 'dual reticulation' systems for the redistribution of treated sewage back to households. These comprise a dedicated system of pipes, taps and fittings, which must be kept entirely segregated from the potable water supply and out-going sewage mains. The water delivered by dual reticulation schemes may only be used for a limited range of applications such as toilet flushing and garden watering.

The first and largest dual-reticulation scheme in Australia began operation at Rouse Hill (NSW) in 2001. The scheme is continuing to expand and is expected to service more than 25,000 properties by the end of 2006. The over-riding purpose of the Rouse Hill scheme was to protect the Hawkesbury Nepean river system from the environmental impact of increasing urban development. More recently, dual-reticulation schemes have been established at Newington (NSW), Mawson Lakes (SA) and Springfield (QLD). Victoria's first dual-reticulation scheme is currently under development at Epping North.

Stream flow augmentation

Stream flow augmentation is among the most common, but least-recognisable forms of water reuse. Effluent discharge into waterways is widespread in Australia, but does not always impart environmental benefits in terms of flow augmentation. However, there are cases where suitably treated discharges may have positive environmental impacts when released to waterways in carefully controlled flow regimes. If managed appropriately, stream flow augmentation can be environmentally beneficial but, in Australia, it rarely relieves pressure on potable water supplies. Generally, it is considered preferable to minimise water removal from streams by maximising the reuse of available wastewaters in place of extracting fresh supplies.

Indirect potable reuse

Contrary to many other parts of the world, indirect potable reuse is not widely practiced on a large scale in Australia. This is, in part, due to Australia's population distribution where most of the largest cities are in coastal areas at the bottom of their relevant catchment systems. Lack of public acceptance for indirect potable reuse is also a significant barrier to its implementation. Nonetheless, there was an apparent increase in interest in such schemes during 2005. During that year, two inland cities, Toowoomba (QLD) and Goulburn (NSW) included measures for indirect potable reuse in water management plans. Toowoomba City declared an interest in replenishing its Cooby Dam [19]. Goulburn investigated the feasibility of supplementing its Sooley Dam catchment [20] and requested financial assistance for such a project.

Future Prospects for Water Reuse

The ability to identify suitable applications for the use of new recycled water in Sydney will be crucial to its success. New applications with potential to make use of large quantities of recycled water may be identified by consideration of current high usages of water.

There is significant potential demand for recycled water in urban households. Around eight per cent of household water is used in kitchens for consumption and food preparation. A further 20 per cent is used in bathrooms, also involving intimate contact. However, the remainder presents an opportunity for much of the potable water usage to be substituted with reuse. A major advantage of household reuse is that the demand location is typically very close to the supply location. This applies to water sourced from municipal treatment plants and even more so for on-site reuse systems.

Agricultural industries are by far the largest consumers of water in Australia. The production of livestock, pasture, grains, sugar, cotton, rice and dairy farming account for the vast majority of agricultural consumption. In theory, every drop generated from municipal sewage could be reused for a secondary agricultural use, thus providing barely 10 per cent of the water consumed for agricultural applications. The major difficulty is that large agricultural schemes are often located considerable distances from large sources of recycled water.

Mining ventures can require very large volumes of water, often in very concentrated areas. Wollongong, within Sydney's water catchment, has extensive coal mining activities located close to sources of municipal wastewaters.

Many manufacturing industries are high value industries for which reliable supplies of large volumes of very clean water are a crucial resource. For example, the need for a sure supply of highly purified water for electronics manufacturing was a major driver for water reuse in Singapore. High value manufacturing applications provide a strong incentive to apply effective treatment processes that may raise the cost of water treatment. Because water needs vary considerably from industry to industry and from application to application, identifying suitable opportunities for reuse will not be a trivial task.

Gas and electricity industries may require a lower grade of water compared with many manufacturing industries and may also be more concentrated in their points of water use. The successful use of recycled water at Pacific Power's Eraring Power Station in NSW provides an example of the mutually beneficial results that can be achieved when water and power sectors cooperate. This is a precedent that could be repeated many times over in Australia.

Sewerage industries are perhaps the most opportune environments for water reuse practices. Unlimited quantities of treated wastewater make reuse an ideal option for many sewage treatment plant applications, such as cleaning operations. Quality considerations are unlikely to be a significant factor for many sewage treatment plant reuse applications. However, it may not be appropriate to use recycled water for some applications requiring close contact with workers.

In promoting water reuse practices, the identification of potential uses of recycled water is merely a first step. Before large-scale reuse can eventuate, changes may be required in the management and regulation of water resources. For example, the advantages of streamlined chains of responsibility for potable water, sewage and stormwater have been promoted [21]. Such integrated water management would naturally lead to more transparent costing and pricing structures for water. The inclusion of costs such as catchment management and sewage treatment in the delivery of water to consumers would be facilitated. This would enable a more realistic comparison of the costs of recycled water and fresh water supplies.

The concept of supplying water of a quality 'fit for purpose' is widely advocated for Australian water management. That is, water would be supplied for various applications at a quality guaranteed to be sufficient for an intended purpose, but no greater. By this means, water could be cascaded from applications requiring high water purity, down to less demanding uses, thus minimising necessary treatment processes in between. Water utilities could offer water of tailored quality to industry at price reflecting the treatment standard. A problem associated with this approach is that communities often tend to expect reuse water qualities that exceed realistic requirements. Furthermore, the risks associated with reuse are often not judged by the same criteria as the risks associated with other water sources and treatment.

Overall, the provision of infrastructure is the most urgent requirement regarding large-scale water reuse in Sydney. Infrastructure is needed to treat water to a suitable quality for intended reuse applications and to transport the water to the point of use for those applications. Most importantly, the infrastructure will need to be strategically located so as to make optimal use of existing facilities in ways that can effectively provide water that has been treated to qualities suited for intended reuse applications.

Improvements and Reforms Required for an Increased Role for Water Reuse

While water reuse initiatives are indeed increasing, a number of institutional reforms and improved practices will be required to achieve a significant degree of growth [22]. The major areas requiring urgent attention are discussed below.

Financial and economic reform to facilitate water reuse implementation

An isolated financial analysis of many Australian water reuse proposals may often appear highly unfavourable. Typically, this is the result of the high infrastructure and operational costs associated with most advanced water treatment and distribution systems. Furthermore, revenue potential may appear low since recycled water is typically priced at a lower rate than the average cost-based rates for traditional potable supplies. Revenue projections in some areas may also suffer from a limited market of potential applications and customers for non-potable water supplies. Accordingly, it is often difficult for agencies such as Sydney Water to make a 'business case' for water reuse projects based solely on an assessment of the agencies internal financial outcomes.

Financial assessments are, of course, very important and are useful for many applications. However, it has been argued that their scope provides too limited a context with which to evaluate the real social worth of many alternative water management options [23]. This is because such assessments focus strictly on revenue and cost streams internal to the water agency, and these internal cash flows are not the same as the true value of most schemes to the greater community and society as a whole. For example, a financial assessment does not include such environmental and social benefits of sustaining an agricultural community during times of limited alternative water supply availability.

Unfortunately, many of the benefits arising from a water reuse project can be difficult to identify and quantify. One reason is that the benefits are often very diverse in type and some may not be immediately obvious to some parties. Many of the benefits can be difficult to explain or to estimate in monetary terms. Furthermore, the beneficiaries are often dispersed across water agency and political boundaries and thus represent significant positive externalities. To address these difficulties, it is necessary to conduct some form of a 'full social cost accounting'-based assessment of the benefits and costs of water reuse projects.

'Full social cost accounting' incorporates efforts to identify all the benefits and costs of a specified action or policy, regardless of who bears the impact, or whether the impact can be valued in terms of market prices. One application of this approach that has been widely adopted by Australian utilities and agencies is the 'triple bottom line' framework. This consists of a financial bottom line that reflects cash flow as well as second bottom line reflecting social impacts and a third 'environmental' bottom line. Recently published Australian guidelines for triple bottom line evaluation of urban stormwater management measures could provide a valuable template for water reuse [24].

A positive triple bottom line analysis of a proposed scheme may indicate an overall worth of a project. However, in most cases it is the single bottom line –the financial one- that will determine an agencies capability to implement such a scheme. A positive financial result for a water reuse scheme will almost always rely on recovering costs from a broader base than simply the sale of new alternative supply. Recovering the costs associated with additional treatment and distribution must be implemented in a manner that is perceived to be fair, sends appropriate price signals and effectively generates the necessary cash flow back to the agency.

Recycled water costs may be distributed between water and wastewater users, both through capital facility charges and usage rates. Carefully applied cost allocations can allow for economic incentives to attract current or future potable water users to replace some of this use with recycled water. The greatest challenge is to identify the most effective balance between pricing recycled water such that it is attractive while maintaining a nexus with the cost of service.

Tertiary treatment costs have historically been recovered from wastewater users (or 'generators'), spreading the costs over the treatment authorities entire customer base. This approach has been logical since much of this tertiary treatment has been to facilitate a means of effluent disposal and thus a cost for managing wastewater. However, in many future situations, tertiary treatment may be implemented primarily to provide recycled water to offset demand on the drinking water supply. In such cases, the cost of tertiary treatment might logically be partially recovered from drinking water customers which may, or may not, be the same as the wastewater customers and may or may not be serviced by the same organisation.

Water pricing may also be adjusted to achieve social and environmental objectives by the implementation of tiered and seasonal rates. Such price-signalling techniques may help fund water recycling programs in a manner that disproportionately targets excessive consumption of the fresh water supplies.

A major obstacle to water reuse in Australia has been the widely acknowledged historic undervaluing and under-pricing of fresh water supplies [8; 18; 21; 25; 26]. The relatively small financial costs incurred in the use and disposal of fresh water supplies have provided little market-force incentive for less competitive water recycling applications.

Sydney's current municipal water charge includes a base rate of $1.20/kL for all water up to 100 kilolitres per quarter, and a higher rate of $1.48/kL for water above that. According to IPART, the average household uses around 63 kilolitres per quarter. While these prices are substantially greater than they have previously been, water remains a very cheaply priced commodity. The low cost is partly the result of there being no requirement in pricing regimes to include catchment management and protection of effluent-receiving environments [7]. In many cases, the consumer also pays sewerage charges that include the cost of treatment to a standard that is acceptable for discharge to the environment. These are separately accounted for and not integrated with the costs associated with producing and delivering potable water. The cost of producing and delivering recycled water is generally greater than the costs for fresh water. However, users are typically charged less for recycled water than for fresh water due it its more limited use.

As part of the National Water Initiative, Australian governments recently agreed in principle to the implementation of water pricing and institutional arrangements which promote economically efficient and sustainable use of water resources [9]. Multi-step 'rising block tariffs' have been implemented in Western Australia for a number of years. Such tiered pricing systems work to reward potable water conservation and discourage excessive use. Progress has recently been made to implement tiered pricing systems in other states including Victoria.

Alternative water-pricing frameworks have been proposed by both the Australian Water Conservation and Reuse Research Program [27] and the Water Services Association of Australia [25]. These 'whole water cycle' approaches acknowledge the importance of applying consistent consideration of externalities associated with potable water, reuse water and sewage. Both proposed frameworks include the provision of price signals that reflect the scarcity of resources as well as the costs associated with water treatment and delivery.

Improved management of microbial and chemical species

Pathogenic microbial organisms, known to be present in raw municipal sewages, include helminths, viruses, bacteria and parasitic protozoa [28]. Of these, enteric viruses are considered to have the greatest potential to spread through the reuse of treated sewage. The high numbers excreted by infected individuals and the difficulties associated with physical removal are both primary contributors to the dissemination of these organisms.

Untreated sewages also contain dissolved chemicals, many of which are not removed during conventional biological treatment processes [29-31]. Significant chemicals which must be carefully managed in water recycling schemes include inorganic salts, ammonia and heavy metals. Furthermore, concern is rapidly growing for an expanding suite of trace organic contaminants, many of which are suspected of environmental implications even in very low concentrations. Examples include pesticides, natural and synthetic hormones, pharmaceutical compounds, industrial chemicals and disinfection byproducts.

Water treatment facilities for recycling schemes must be designed for sufficient and reliable removal of the diverse range of microbial and chemical species of concern. The high water solubility, small molecular size, biological stability and chemical inertness of some species render this a considerable challenge. The difficulties are compounded by the often expensive and complex analytical methods requiring skilled analysts to confirm the continuing veracity of treatment processes.

The water treatment challenge has been addressed largely by the implementation of 'multi barrier' treatment schemes. This involves having systems designed to incorporate a degree of treatment redundancy as a safety factor in case of failure or underperformance of individual barriers. Typically, this would comprise a diverse range of technologies incorporating physical, chemical, photochemical and biological processes. Many of these processes are energy-intensive, high-maintenance, and can require the use of expensive chemicals. Accordingly, costs associated with power and chemical consumption, human resources, and component replacement can be considerable.

Advanced understanding of community acceptance

Community concerns will significantly impact on the way water is ultimately managed in Australia, as they have in other countries [32]. A lack of community acceptance prevented an indirect potable reuse scheme from proceeding in Caboolture (QLD) during the 1990s [33]. The political fallout attributed to this incident has bred some reluctance among other governing bodies to make policy statements on water recycling without assurances of community support.

A survey of residents in a development area incorporating a dual reticulation system indicated strong support for some household water reuse applications such as watering lawns and gardens. However, the support dropped off sharply as proposed uses of the water became more personal. Only moderate support was reported for clothes washing and extremely low support for the supplementation of drinking water [34]. These attitudes will play a very strong role in determining the specific applications for which recycled water will be used and those which are currently unacceptable to communities.

In addition to end-use applications, community attitudes will impact on the 'triple bottom line' viability of water reuse schemes. For example, a qualitative study of Australian households connected to dual reticulation systems found that few would be willing to pay more for water as a conservation measure. The study participants also generally agreed that recycled water should cost less than potable water due to its more limited uses [35].

Improved management and promotion of water reuse schemes will need to be achieved be concerted consultation and communication programs targeting a wide range of stakeholders [36].

It may be expected that desalination schemes will prove to be a significantly 'easier sell' to the community than many water reuse schemes, particularly potable water reuse schemes. However, the experiences of the NSW State Government during 2005-06 have demonstrated that considerable community opposition to major desalination schemes can also be generated or manifest in some circumstances. While no scientifically plausible surveys are publicly available, letters to newspapers, online opinion polls and the community workshops run by Sydney Water [37-39] have all demonstrated wide-spread objection to the Government's stated plans based on a diverse range of factors. The most recurring factors have included the comparably high economic and energy costs to run the plant; the associated greenhouse gas (carbon dioxide) emissions from the energy production; the minimalist approach taken to stakeholder consultation; the minimalist approach to environmental impact assessment; concerns regarding the impacts on aquatic species; concerns that a 'limitless' water supply will weaken the conservation message; and suspicion regarding the terms of the initial public-private partnership arrangements to build the plant. Many vocal community members cited water recycling (even potable recycling) as a preferable approach [37-39].

Advanced understanding of industry acceptance

There is evidence that progress must also be made towards improved understandings with some industry groups rightfully concerned for the safety of their members and security of their industries.

For example, in May 2005 the Queensland branch of the United Firefighters Union of Australia, released a statement rejecting the use of recycled water for fire fighting purposes 'unless there can be assurances that its use will cause no long term or short term ill effects to firefighters' [40]. Thorough reviews and risk assessments have concluded that properly treated and managed recycled water would be acceptably safe for fire fighting [41]. However, without formal assurances, the union ban on the use of recycled water appears set to remain in place.

If the firefighters' concerns cannot be met, they are likely to have a significant impact on a major dual-reticulation development in the Pimpama-Coomera region (QLD). This development aims to significantly reduce potable water demand through the supply of recycled water and the extensive use of rainwater. The intention has been to rely on the recycled water for fire fighting since the potable water would be distributed via reduced-diameter mains. These reduced-diameter mains are unlikely to be sufficient to deliver adequate quantities of water for fire fighting. However, they are considered necessary to ensure the quality of potable water which would otherwise be subjected to unacceptably low linear flow velocities.

The Australian horticultural industry has also expressed trepidation towards the use of recycled water for irrigation [42]. The major concerns are reported to be insufficient knowledge of impacts on market access; commitment to provide continuity of quality and supply to markets; implications of substitution of alternative water sources on security of supply; insufficient knowledge of food safety issues; inadequate understanding of consumer perceptions; and uncertainty about pricing of reclaimed water.

The development of new water storage systems

In order to effectively recycle large volumes of water, considerable water storage capacity will commonly be necessary. This is often particularly the case in agricultural reuse schemes where the demand for water may be highly seasonal. If the recycled water is to be kept isolated from fresh water supplies, new segregated storage solutions will be required.

The CSIRO has conducted extensive research into the management of recharged aquifers to store recycled water in South Australia. Advantages of managed aquifer recharge include favourable economics compared to above-ground dams, enhanced microbial die-off and the minimisation of loss by evaporation [43]. While the process is highly promising, a number of obstacles remain.

Clogging of the aquifers and the need to ensure protection of native groundwater and geochemistry are among the concerns.

Aquifer storage may prove appropriate for some locations, but suitable aquifers are unlikely to be available in all situations. In such cases, surface storage or careful supply control will be necessary.

Improved definition of infrastructure access rights for private enterprise

Failure to recognise the potential value of recyclable sewage streams and to define access rights to them has been an impediment to some potential water reuse activities [21]. During the 1990s, the Commonwealth Government established means for private organisations to seek access to publicly owned infrastructure under reasonable terms and conditions. The Independent Pricing and Regulatory Tribunal of New South Wales has also recommended the introduction of competitive reform to Sydney's water industry [44]. However, little use has so-far been made of the Commonwealth Government's provisions and the few significant applications have met with initial resistance from the NSW Government.

Since 1999 a private organisation has petitioned the NSW Government with a proposal to provide an alternative sewage service in Sydney. This would involve treating a large proportion of Sydney's sewage and then piping it west where it would be used in agriculture and to supplement environmental river flows. The firm would make its money by offering customers an alternative sewage service, selling the reclaimed water and participating in water trading markets. Despite a recommendation from the National Competition Council (NCC), the NSW Government initially refused to allow the company to compete with the state-owned water authority, citing critical public interest issues. However, in 2006 the Australian Competition Tribunal endorsed the recommendation of the NCC with a binding ruling. Accordingly, the NSW Government will now need to negotiate an access regime for third parties to Sydney Water sewage infrastructure.

The level of cooperation forthcoming will have a significant impact on the legal and commercial environment in which water authorities in Australia will operate in the future. Until significant precedents have been established, market uncertainties are likely to act as a barrier to long-term investment decisions of both public and private enterprises.

Reform of complex governance and institutional arrangements

In Australia, water is vested in governments that allow other parties to access and use it for a range of purposes. However, governance covering the various stages of the water cycle is complex and varies throughout the States. The 2002 Senate inquiry into Australia's management of urban water identified this situation as a barrier to achieving greater progress towards more sustainable water management [7]. The inquiry report attributed the source of the barrier to 'the institutional and policy complexities of three jurisdictions of government, the myriad of agencies responsible for planning, health, environment protection, natural resource management and price regulation, and institutional inertia in general'.

The Commonwealth of Australia Constitution prohibits the Federal Government from infringing on the rights of States to the reasonable use of the waters of rivers for conservation or irrigation. Accordingly, responsibility of water management has been shared primarily by State and Local Governments. Water recycling schemes typically aim to integrate various aspects of potable water supply, sewage and stormwater management. Some local governments have emphasised the need to establish strong partnerships with State Government water authorities to overcome major obstacles associated with the division of responsibilities [45].

Reduced reliance on fossil fuel consumption and associated greenhouse gas production

Electricity generation is the largest source of greenhouse gas emissions in Australia, contributing about one third of all emissions in 2002 [46]. This is because most electricity in Australia is produced by the combustion of low cost fossil fuels. Furthermore, in 2004 the 'Stationary Energy' sub-sector, of which electricity production comprises about 70 per cent, was the fastest growing greenhouse gas producer with an expected 43 per cent increase on the 1990 level by 2010.

For overall greenhouse gas emissions to be significantly reduced in Australia, their rapid increase from electricity generation will need to be drastically curtailed and eventually reversed. Changes in national water management practices which include increased or new energy-intensive operations would place significant burdens on the national greenhouse gas targets. Unless alternative, non-greenhouse gas producing sources of energy can be implemented, low energy water management solutions will be necessary.

It is anticipated that a variety of approaches for improved water management will be considered in coming years. In addition to water recycling, these may include rainwater harvesting, increased groundwater extraction, water-transfers between catchments and seawater desalination. Furthermore, the range of approaches to water recycling and potential specific projects are highly diverse in terms of treatment and water-transportation requirements. The options will vary in terms of energy intensiveness and this may significantly impact on ultimate decisions. The PMSEIC has recommended that the capital and recurrent environmental costs should be compared on a whole of life basis [8]. Low energy options such as small local decentralised plants, or those that use renewable energy can be expected to compare favourably.

New national guidelines and the need for consistency in NSW

National guidelines for water recycling are being developed under the auspices of the National Water Quality and Management Strategy. The first stage of the guidelines was released for public comment during 2005-06. These guidelines have adopted the risk management framework approach pioneered in the 2004 revision of the National Water Quality Management Strategy Australian Drinking Water Guidelines. They cover recycling of treated sewage effluent, greywater and stormwater for non-drinking purposes such as agricultural uses, garden watering, car washing and toilet flushing.

National guidelines based on appropriate risk and system management criteria have been urgently required in Australia to complement existing guidelines on quality requirement for particular applications. System management criteria include guidelines on community consultation, system design, risk management, operation and maintenance, monitoring and communication related to both treatment and distribution systems. The absence of satisfactory national guidelines has, until now, been a hindrance to long-term planning and development of reuse schemes. The lack of definite system management criteria and the singular focus on water quality parameters has been a deterrent to many potential users and suppliers of recycled water, cautious of legal implications

The national guidelines are anticipated to be finalised during 2006. However, the initial draft released for comment suggests that the guidelines will be quite ambitious and adopt a radically different approach to previous state and national guidelines. It will thus be essential for the NSW Government to update the existing guidelines for municipal water reuse [47] as a matter of urgency to bring them in line with the new national approach.

A Downhill Water Reuse Plan

Water recycling schemes can be optimised if they are carefully planned. Without careful planning they may suffer from some of the same problems as the proposed desalination scheme. For example, Australian parliamentarian, Malcolm Turnbull, has been a vocal proponent for a water recycling scheme that would take water from some of Sydney's coastal sewage treatment plants, treat it, and pump it back towards Western Sydney. However, both the NSW Government and Malcolm Turnbull have ignored a fundamental property of all liquids including water: All liquids are subject to the force of gravity and therefore flow downhill, not uphill.

Water naturally follows the pattern of what is known as the hydrologic cycle. Water from the ocean evaporates and is desalinated in the process. As clouds move inland across Sydney, some of the water falls as rain on the mountains to the west. From there, much of it flows downhill back to the ocean via streams and rivers. The path from the mountains to the ocean relies fundamentally on the force of gravity. The cycle gets its energy is from the sun, which is a sustainable energy source and does not add to greenhouse gas emissions.

Sydney's current water collection and distribution practices continue to make use of the hydrologic cycle. The cities dams and reservoirs are merely temporary, artificial diversions. It continues to rely heavily on gravity to transport the water down-gradient to industrial and household consumers. Gravity is almost entirely responsible for the flow of sewage from Sydney's homes to sewage treatment plants. This arrangement requires minimum pumping to transport the water from the cities highest altitudes to sea level.

Seawater desalination and Turnbull-style recycling would work against the hydrologic cycle. The source water would originate at sea-level and then pumping stations would be needed to deliver the water up to higher gradients. This water would travel in the opposite direction to current distribution systems. Gravity would hinder not help.

A more intelligent approach to water recycling would be to continue working within the natural hydrologic cycle. Ideally, small-scale treatment plants would capture sewage upstream and prepare it for secondary non-potable uses. The process would be repeated multiple times until the water reached sea level. Each secondary use would replace water that would otherwise be sourced from fresh supplies. And each would make use of water that would otherwise be discharged to the environment.

This downhill water recycling would encourage the development of decentralised onsite water reuse systems. It would also facilitate the fit for purpose water supply concept. That is, water would be supplied for various applications at a quality guaranteed to be sufficient for an intended purpose, but no greater. By this means, water could be cascaded from applications requiring high water purity, down to less demanding uses, thus minimising necessary treatment processes in between. Water utilities could offer water of tailored quality to industry at prices reflecting the treatment standard.

As with all engineered systems, the most effective, most efficient and most sustainable are those that are designed to mimic or work within nature's constraints.

Conclusions

Water reuse has significant scope for rapid growth in Sydney. The necessity to implement such schemes to address freshwater shortages and environmental degradation associated with wastewater discharge is clear. Furthermore, there is significant evidence that authorities now recognise these needs and are beginning to implement policies and actions aimed at encouraging alternative water management strategies.

While water reuse constitutes somewhat of a 'technological' approach to water management, it is clear that for the most part it is not the technology that is lacking. Suitable water treatment technology for most applications is already in existence and is constantly undergoing improvements in terms of effectiveness and efficiency. To a much greater extent, improvements and reforms are required in social and economic realms. Changes which would facilitate improved water management have been identified in terms of institutional structures; government policy; accounting methods; and levels of understanding and communication with stakeholders. This observation serves to drive home the point that water is so fundamentally central to our existence, that no aspects of its management can be legitimately considered in isolation to all others.

The future of water management in Sydney must encompass a significantly more holistic vision to that which we have become accustomed. One aspect of this is to consider the close interconnectedness of all stages of the hydrologic cycle. It must then become clear to all that terms such as 'wastewater' are artificial since all water has a value and will eventually have some future environmental, social and possibly economic significance. A second important aspect then will be to fully consider the diverse environmental, social and economic implications of all potential water management practices. It is only such a broad level of consideration that can suitably guide decision making for truly sustainable water management in Sydney. It is then that water reuse which may appear economically expensive or socially unpalatable, will be provided its full advantage to greater benefit of all the city's residents.

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