The water services conundrum

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Abstract The current crisis in provision of urban water supplies has its origin in the technological choices made in the nineteenth century when Australian cities developed their water services systems. This paper builds on recent research into domestic water consumption in Sydney to argue that the issue is not one of shortage of water, as it is popularly presented, but is more related to the choices made in that city about the way sanitary services are provided and the ways in which socio-cultural values and behaviour have led to increases in consumption. The paper asserts that the current approach to urban water services cannot be sustained without increased stresses in the eco-systems from which water is abstracted to supply Sydney, in the eco-systems into which waster flows are currently discharged and on the eco-system on which the city is built. It offers a schematic solution to provide water services in a way which is sustainable and capable of bring progressively introduced.

Introduction

By the 1860s Australian cities were experiencing problems with their water supplies generally facing four problems:

1. They had poor supplies of potable water, resulting in infections from water borne contagions,
2. They were unsanitary and with increasing difficulties, including threats to health, of dealing with the disposal of human and other wastes of urbanisation,
3. They suffered periodically from poor drainage of storm-water,
4. They experienced crises due to lack of convenient supplies of water to fight fires.

While all four were important the health of their population was the prime consideration in securing new water supplies. The mid century recognition in England, documented by the sanitation reformer, Edwin Chadwick, that many health problems were directly related to the lack of secure supplies of potable water (Flinn 1965) was followed by pressure in Australian colonies to develop such supplies.

From settlement, Colonial administrations had tried to secure reliable supplies of potable water by exploiting sources ‘beyond’ the urban boundary, but growth of each colony was such that often the urban area quickly grew beyond the area reserved and supplies were compromised. Households harvested and stored rainfall from roofs in tanks and occasionally from surface runoff in underground cisterns these supplies often failed in long summers or drought periods. In addition it became increasingly apparent that underground cisterns provided poor quality water because of infiltration of runoff and due to seepage of sewage effluent into the cistern (Lloyd et al 1992). ‘New’ sources periodically had to be sought from further a-field to provide the secure supplies of potable water.

As the cities grew the demand for the reticulation of secure supplies of potable water increased. Underlying the development of these supplies was the assumption that the demand for water could always be met by seeking/developing new supplies. The initial assumption, in 1878, for demand in Newcastle, which was similar to Sydney and advised by the same engineers, was that personal consumption of 20 gallons (91 litres) per head per day was sufficient to meet the demands for consumption, food preparation and personal hygiene (33.2kL pa) but that this might rise to 50 to 80 gallons per head per day to meet the needs of manufacturing and garden watering (Lloyd et al 1992).

While potable water was needed for health reasons, the supply seemed reliable and generous enough to allow households to use water for sanitation, to water gardens and for other uses. The seemingly adequate supply also meant that domestic bathing and laundry practices changed with consequent dramatic increases in the discharge of waste water from households.

By 1880 the issue of managing waste disposal assumed greater proportion as urban populations grew. The world-wide popularity of Edwin Chadwick’s ideas for improving urban sanitation (Melosi 2000) and the development and increasing take-up of water closets exacerbated the sanitation problems in Sydney and Newcastle but also offered the idea for its solution in the form of the development of a piped sewerage system.

There was a neat symmetry in this. The supply of water met all the needs of households for potable water and there appeared to be water enough to provide the medium for the transport of wastes. This was seen as an elegant solution and in the original Chadwick proposal offered the first environmental solution to the management of human body wastes because it proposed to collect them and transport them to be used as fertiliser on nearby farmlands – a solution that was experimented with in Sydney but only seriously adopted in Australia by Melbourne.

The virtuous circle that was ultimately taken in most Australian cities was to develop a reticulated water supply and later a piped sewerage system to remove sewage. This solution was made more financially attractive for water authorities with the banning of rainwater tanks and the preferment of waste management technologies that relied on water transport to the exclusion of technologies that did not. The attractions of water based sewerage systems were so compelling that a networked sewerage system was developed to transport waste water, human excreta and other wastes. This seemingly felicitous solution to the problem of sanitation ultimately led to a large environmental problem in the form of discharges of sewage to the ocean. Property owners were required to connect to the public water supply and later to the sewerage system on public health grounds. Water consumption rose as households took advantage of the apparently abundant supplies for their flush toilets and for personal hygiene.

Storm-water runoff became more problematic as the cities grew and more of their area was covered with impervious surfaces. The volumes of water were so great that it was infeasible to manage the runoff by using the sewerage system so separate storm-water drainage systems were developed. They, too, drained directly into rivers, harbours, bays and oceans that abutted the cities.

The early decision to develop separate systems for sewerage and storm-water drainage meant that waste water flows could avoid the peaking problems associated with storms – problems that would only be exacerbated as development of the cities led to the increasing coverage of drainage catchments by impervious surfaces. Although sufficient water falls as rain in the urban areas to meet their water requirements, this approach to storm water management means that even today, storm-water is discarded and treated as a ‘problem’.

The net effect of these nineteenth century ‘solutions’ now is:

1. The per capita consumption of water is now three times the level the original systems were designed to provide.
2. Stresses in the eco-systems from which water is abstracted to supply the cities.
3. Extreme stresses on the eco-systems into which waste waters are discharged.
4. Storm-water runoff systems that are the major sources of pollution of the rivers, bays and harbours on which the cities are built.

The combined effect of rapid increase in population and massive increase in per capita consumption meant that the demand for water soon outstripped supplies but the attraction and seeming felicity of the ‘scientific’ approach to water management fostered the engineering systems needed to increase supply – usually in the form of more dams which impounded the water in eco-systems further from the cities for transport to them. There was a comforting belief that there were always additional supplies available and all that was required was application of engineering skills to deliver them to the cities.

By mid twentieth century Sydney, like most Australian cities, had exploited all the water resources available in its near hinterlands. The increased consumption of water that had been encouraged by water authorities that had long since been less concerned with their original public health remit and were more exercised by the financial rewards of commodification of water was reflected in the increase in water using facilities and equipment. By the end of the twentieth century the situation became critical because the apparent reduction in long run rainfall over dam catchments meant that reservoirs were operating with small reserves.

The response has been to seek ways of increasing supply and, as a temporary measure, to introduce water restrictions aimed particularly at reducing water consumption on uses outside the dwelling. These measures have not allayed anxieties but the current drought has brought underlying problems in the management of national water resources into high relief and led the Commonwealth Government to initiate national water policy reform.

Features of demand and supply of urban water

Two aspects of the water system need to be borne in mind. Firstly, the demand for water has some seasonal variation with summer demand being higher than winter, but the pattern of consumption is fairly constant year on year for conventional housing and especially throughout the year for higher density forms of housing (Troy, *et al,* 2005). Secondly, the supply of water through the water catchments is highly variable depending as it does on rainfall. This was not a concern when the storage was large enough to allow for several years of consumption, but is now because the increase in population together with the increase in per capita consumption produces a high and relatively constant demand while rainfall over the catchments in several of the larger cities: Brisbane, Perth and Sydney, appears to have declined.

Attitudes to personal hygiene and cleanliness practices had been changing since the Middle Ages (Vigarello 1988). Moreover, cultural and behavioural norms in domestic water use changed considerably during the nineteenth century, all adding considerably to increased *per capita* water use. This meant that people used flush toilets and flushed them with each use more often compared with earlier toilet practices. They also washed themselves more frequently. At first this was by bathing, but this was replaced by the increasing popularity of showering which led to greatly increased domestic water consumption (Shove 2002 Shove 2003 – this is a discussion of UK experience but accords well with Australian experience) and waste water generation. To some degree the popularity of showering is related to the pleasure of the act – especially once heated water was more readily available – as much as it was to notions of personal hygiene (Gilg & Barr 2006, Hand *et al* 2003, Allon and Safoulis 2006).

A recent survey of Sydney households' attitudes (Troy and Randolph 2006) revealed their strong determination to maintain their level and nature of shower use and considerable reluctance to reduce toilet flushing suggesting that programs designed to reduce consumption from both activities may encounter strong passive resistance. That is, much contemporary water consumption practice is life style and fashion driven and only tangentially related to concerns for hygiene (Safoulis 2005).

This is paradoxical because the early campaigns for potable water for drinking and hygiene were the main reasons for the development of reticulation of high quality potable water which drove consumption up to levels from which the shift to life style behavioural factors could affect consumption.

Had the initial increase in consumption due to the development of reticulated systems for potable water and hygiene not occurred it is unlikely that the later increase in consumption for life style reasons would have been possible.

It is ironic that the, the increase in showering has been accompanied by an increase in skin diseases (Shumack 2007*).* Contemporary consumption is also a consequence of the form of development of the city. The traditional separate house in its own garden was (and remains) a strong expression of the felt needs of households for a degree of independence (Gaynor 2006).

This form of accommodation not only provided the opportunity for a high level of domestic production (Mullins 1981a, 1981b &1992) it also 'explains' why it was such an effective cornerstone of the conservative philosophy expressed by Menzies in the 1940s and 1950s (Brett 1992) who successfully built on the desire of households for a home of their own with a small garden to gain and retain office nationally and to shape the policies which guided the massive growth of Australian cities in the 1950s and 1960s. Freestone (2000) documents how the garden city movement shaped the nature of Australian cities although Hall (2007) also documents the disappearance of gardens in the contemporary city.

The widespread take up by households since the 1940s of washing machines led to increased water consumption. In earlier periods clothes washing was a tedious affair. The advent of new machines offered to take some of the labour out of the washing task. The higher level of workforce participation by women and the increasing degree of consumerism since the 1940s was accompanied by a significant fall in the cost of clothing and manchester items in household budgets which in turn meant that people were able to change their clothing and manchester items more often and meant that there were more clothes to wash. The ability of machines to wash, rinse and extract most of the water from the cleaned clothing whenever it was convenient significantly increased water consumption.

Water consumption in the kitchen has also increased although it remains a small proportion of internal household consumption. External consumption of water also increased with the increasing popularity of swimming pools and more recently of spas. Garden usage is also important, but because most Sydney households rely heavily on rainfall to maintain their gardens, it is less significant than might be assumed (Troy and Randolph, 2006).

Development of supply – Sydney
Water services are provided by Sydney Water Corporation which is a government corporation and monopoly supplier. Until recently it also set regulations and prices for its services. It has a strong engineering culture overlain by a strong economistic approach to water management issues. In the face of occasional criticism it has developed a strong defensive institutional culture.

Sydney Water Corporation's response to the increasing demand for water has been to follow the traditional 'project and provide' approach to water services. That is, from its origins as a colony the city has for the last two centuries responded by projecting the demand without any fundamental review of the services it provides and then setting out to provide the supply.

It is now clear that Sydney cannot simply continue to harvest waters from sources outside its immediate region to meet what appears to be an unquenchable demand without serious environmental consequences and without failures in supply. This is acknowledged in the Metropolitan Water Plan (DIPNR 2004), which was been developed in part to meet the increased demand for water from a predicted increase in Sydney's population of around 1m over the next 25 years. The Plan implicitly assumes an ever increasing supply to meet demand.

The focus on increasing supply of water in the 'traditional' way will eventually prove problematic and unmanageable because of the environmental stresses associated with the approach and, not least, on cost grounds. A more fruitful way of continuing to meet reasonable demands for potable water from Sydney Water Corporation's *existing* storage facilities such as Warragamba Dam lies in encouraging residents to accept greater responsibility for security of their own supply and waste water management in a manner that improves the sustainability of the city and simultaneously enables the government to meet new environmental targets.

There is an urgent need for a major change in the way demand for water should be managed at the level of the individual household, together with new measures to reduce the consumption of potable water in the home. Such an approach is built on the assumption that initiatives need to be taken to minimise the environmental stresses that accompany the present consumption of water and the management of waste water flows (Guy et al 2001). It is also assumes that we cannot simply turn to a new system and ignore the path dependency effects of the water supply and sewerage systems in place. A new approach would need to be phased in as part of a new water demand management model which would lead to less reliance on the traditional reticulation system and reduce the per capita consumption of potable water supplied by Sydney Water Corporation.

Reduction in demand for potable water
The present approach to water supply is to search for some 'new' source with no review of the existing shape of the demand. Given the fact that all 'natural' sources are now fully exploited and in such a manner that there is little spare capacity to allow for the variation in rainfall and therefore of runoff from the dam catchments the currently favoured solution is to develop desalination plants. Desalination plants are not only expensive in environmental terms they cannot easily be run efficiently in low flow conditions (SMH 2007). The residents of Sydney are now being advised that the desalination plants now under construction will cost all households in Sydney an estimated $110 per year which together with other measures the Sydney water corporation proposes would increase water bills by $275 per year which is equivalent to an increase of 33% in the average water bill (SMH 2007).

No human consumption of recycled water
There is popular resistance to the human consumption of recycled water (Sydney Morning Herald 2005b) because of anxieties about the efficiency of systems to eliminate the bacteria, protozoa and viruses commonly found in sewage as well as the many biologically active molecules such as drugs taken to control fertility, infection, hypertension, cholesterol, depression etc and the presence in the sewage of preservatives added to food and beverages to which a significant, if minority, of people have allergic reactions and whether those systems can be maintained. The strategy proposed here does not entertain the idea of human consumption of recycled water.

Transition
Few aspects of our approach to the development and management of cities have lasted 150 years. We no longer have the same building regulations, we have consigned the miasmatic theory of disease transmission that existed in Chadwick's time to the dust bin of history, we live and work in our cities in very different ways now than we did then, and we communicate with one another in ways that were unimaginable then. The governance of our cities is different now and we pay for a whole range of services in ways that were inconceivable then. Our concern for the environment demands a very different approach to the way we use natural resources now. We accept that we live in a state of flux. It is time that we acknowledge that state of flux in relation to water supply and sanitation services and developed a new approach that recognises our fundamental need for potable water and our need to manage human body wastes in a felicitous manner but one which does not necessarily involve the use of water.

Currently the additions to the built environment run at about 1-1.5% per year depending on the stage in the building cycle. By mandating al new developments to install rainwater tanks, grey water recycling systems and dry composting toilets would reduce the demand for potable water by up to 70% per dwelling. By identifying areas where it would make sense to retrofit developments with rainwater tanks, grey water recycling systems and dry composting toilets the rate of change of a new approach to water services could be doubled. Pursuing such a program for a decade would mean that after ten years 30% of the urban development was using 70% less water per dwelling. Such savings would continue to be obtained as the older parts of the cities were progressively modernized. This would mean that the path dependency effects of the present systems were recognised and taken into account as the city renewed itself. In the longer term this would lead to a continuing and substantial reduction in demand for the publicly provided supply of potable water.

Such a strategy would also lead to a significant reduction in the environmental stresses on the ecosystems into which waste waters are currently discharged. It would also lead to significant reduction in the storm water runoff in the city with consequential reduction in the pollution of Sydney Harbour and Botany Bay.

Chadwick had, through his work on the Poor Law Commission, insisted on evidence in challenging the conventional wisdom of his time. His empirical research and that of others was based on the assumption that there was an inexhaustible supply of water. It was also based on the understanding that households consumed small volumes of water for all their wants. Nor did he or any of his colleagues understand the great increases in the urban populations, partly as a result of the effectiveness of his reforms of sanitation, would lead to the burgeoning cities that followed.

Even if it is acknowledged that present uses of water cannot be sustained and that the current approach to the water crisis by searching for ways of increasing supply is ultimately self-defeating it would be impossible to arrange for a rapid transition from the way water services are currently provided. The 150 years of development of the water supply and sewerage systems have shaped and been shaped by the development that has occurred in Australian cities. This creates a significant degree of path dependency in the way in which services are provided and must be taken into account in trying to find ways of continuing to provide a supply of potable water. A similar situation exists in relation to the provision of waste management services.

While it is conceivable that alternative approaches to the provision of water supply and waste management services could lead to significant reductions in the consumption of water any transition from the way these services are currently delivered must be pursued taking into account the rate of growth of the urban areas served and the rate of obsolescence of the existing reticulated services.

This suggests that changing the existing services may take some time and that two strategies may be pursued simultaneously. The first would focus on the new additions to the urban stock for which new services could be introduced at the time of construction. the second would focus on the development of a retrofit program to gradually change over the existing development with the rate of change being dependent on the rate of obsolescence of the services. This approach would minimise the problem of stranded assets that would be created if the rate of change to new systems was too rapid. The actual rate of change would be decided for different areas within the city following a detailed analysis of the water consumption in those areas and the efficacy of introducing new waste management services and the costs of doing so. It would, of course, also explore the savings to be obtained from reducing water supplies and consumption and of reducing the management and treatment of waste flows.

An equitable pricing regime
Politically the first initiative would be to mandate the installation of rain water tanks and dry composting toilets in new developments, especially those on the cities' fringe. Such initiatives would need to be buttressed by the development of a retrofit strategy focusing in the first instance on areas where the present systems are obsolescent and or in such a state of disrepair that they need to be replaced. The regulatory and retrofit strategy would need to be buttressed by a pricing policy which ensured that water was supplied to households at the minimum guaranteed volume per person (30kL per person per year) at an equitable price. In this way lower income households and lower consumption households would not be penalised.

The price charged for consumption volumes above the minimum guaranteed volume should be set at a rapidly escalating rate to ensure that those who used more than the minimum paid significantly more for water. This would mean that those with high external consumption would pay significantly more.

Present water consumption patterns
A recent ABS report revealed that in 2001, 25% of water consumption in NSW was for outdoor or external purposes (Table 1). This was approximately the same as the proportion used in the bathroom (26%) and for toilets (23%). Kitchens and laundry uses accounted for the remaining 26%. No regional breakdown' of this consumption within

Table 1: Average annual per capita water consumption by location of use in 2001 (kL)

	NSW	VIC	QLD	SA	WA	ACT
Bathroom	26.3	26.5	26.0	18.5	22.4	23.4
Toilet	23.2	19.4	16.4	16.0	14.5	16.4
Laundry	16.2	15.3	13.7	16.0	18.5	11.7
Kitchen	10.0	5.1	12.3	12.3	10.6	5.9
Outdoor	25.3	35.7	69.0	62	66.0	64.4
Total	101	102	137	123	132	117

Derived from Tables 9.6 and 9.7 in ABS 2004

NSW is offered in the ABS report (2004), but given that the great proportion of this consumption is accounted for by households in Sydney, the NSW figure can reasonably be taken as a close proxy for the Sydney Metropolitan Area at that time. It is highly likely that these proportions have changed a little since the introduction of water restrictions in 2004, although no comparable date is available. Recent research showed that, water restrictions on garden watering and car washing, the main targets of these restrictions, at best impacted on a minority of Sydney residents, namely those who had gardens and bothered to water them, or those who regularly washed their cars at home (Randolph and Troy 2006)).

These turned out to be minority pursuits across households in Sydney, even before the introduction of restrictions.

The other key fact to note here about water consumption, as evidenced in several recent studies (IPART 2004a, Troy et al 2005, Eardley et al 2005), is that the size of household is a key determinant of domestic water consumption. A number of studies indicate that on a *per capita* basis, Sydney households in different forms of accommodation have, for all practical purposes, similar annual demand for water, at approximately 100kL (IPART 2004a,& b, ABS 2004, Troy et al 2005). The IPART research also indicated that there were considerable economies of scale in domestic water consumption in Sydney. This implies that, *per capita* water consumption is not dependent on the residential built form. Falling household size is likely to be accompanied by an increase in average per capita consumption.

It is only by reducing the consumption of potable water *inside* the home that real gains in winding back the growing demand for water services in Sydney can be made.

Whatever the cause of the increasing inability of the water supply system to meet current demand, whether it is due to growth in demand exceeding the supply, the need to maintain environmental flows, reduced runoff in the dam catchments due to long run climatic cycles or to global climate change, there is an urgent need to re-examine Sydney's water services systems. This is needed to make the city more water independent without at the same time creating unacceptable stresses on the regions from which water is abstracted or of creating environmental stresses in the water bodies around Sydney into which waste waters are discharged.

Sydney Water Corporation has undertaken a major exercise in demand management (Turner et al 2005) which significantly reduced consumption most of which has been achieved through improved efficiency in commercial and industrial activities. Mandatory restrictions on domestic water consumption with severe penalties for those breaking the restrictions were also introduced in 2003 (Sydney Water Corporation 2003).

The New South Wales government has also introduced higher charges for higher volume consumers to reduce demand. The NSW Building Sustainability Index (BASIX) building code system, introduced by the Department of Planning in 2005 which applies to all new residential development and housing subject to major renovation, includes measures designed to reduce consumption of water from the reticulated system. The totality of these measures, however, remains insufficient to be able to rely on Warragamba Dam as the major supply.

A variety of alternative sources of water have been proposed, including increased extraction from the Shoalhaven River south of Sydney, large scale recycling, extraction from aquifers in the Sydney region and building a major desalination plant. All proposals imply continuation of the nineteenth century solution to meet the demand for water by increasing supply. Before adopting any of these 'solutions' it would be apposite to review the nineteenth century decision making to try to understand how Sydney has reached the current crisis and to explore alternative methods of providing essential water services.

One of the paradoxes facing water managers is that although they have been successful in providing a reliable supply of drinking water, little of it is actually drunk (approx 1%). The volume of potable water actually consumed, used in food preparation or cleaning or cooking equipment and utensils, cutlery and crockery is about 10% of household consumption.

The development of Sydney's reticulated water supply and sewerage systems in the late nineteenth century led to improved personal hygiene and improved sanitation which was reflected in dramatic improvements in the health of communities. This success has coloured the approaches to water supply and management ever since.

Sydney Water Corporation has been too successful in delivering water of a quality, quantity and reliability exceeding its original undertaking. Its performance has raised community expectations that it can continue to do so. Unfortunately it can not. A different strategy is now required to significantly reduce consumption of potable water. The strategy must acknowledge that the need to supply potable water for drinking and basic health reasons remains. The question is: How can this be achieved at the same time as the use of potable water for purposes and activities that do not need to use water of drinking quality is reduced in an equitable manner?

Two basic approaches suggest themselves:

1. Measures to reduce consumption of potable water and encourage consumers to accept some responsibility for their consumption by making use of locally available water resources

Reducing the supply obligation
As only 10% of total consumption is used in the kitchen for drinking, food preparation and cleaning utensils, this suggests that only 10% of the water used by households needs to be at the highest quality. If we allow that some of the consumption for personal hygiene should also be of the highest standard, e.g. the bathroom hand basin and the shower/bath, we might settle on a need to supply potable water up to 20% of

present total consumption: say, 10% for kitchen use and 10% for bathroom use. If we allowed another 10% for laundry purposes this could become the supply obligation of Sydney Water Corporation. It may be appropriate to see this level of consumption (30Kl per person per year) as an inalienable environmental right to potable water for all residents – which was the original design consumption. This could be achieved by reducing reliance on the reticulated supply of potable water for domestic consumption for discretionary activities and uses such as waste management that do not need to use potable water. The low price of water also means that they are under little economic pressure to reduce consumption.

The tendency among decision makers is to argue for increases in pricing to moderate demand, but there are significant equity issues in this approach. Apart from the impact on low income households many dwellings have water service installations that have no or little elasticity in their demand. That is, many dwellings are fitted with toilet flushes and shower installations that do not readily enable households to reduce their consumption. This is most obvious in the case of rented accommodation, especially in multi-unit housing.

A high proportion of household water services bills is the fixed charges for water supply and sewerage services that do not encourage economy in consumption. There is, moreover, a case for arguing that households should not be allowed to impose financial costs or environmental consequences on others which is one outcome of present management of waste water.

The challenge is to develop a water supply system that encourages people to accept responsibility for their behaviour while pursuing public health objectives and do so without penalising or excluding low income households from the benefits of a high quality, low cost water supply while simultaneously reducing consumption by up to 70%. The most obvious way to make households responsible for much of their own consumption would be to make use of local water resources.

Two possible sources suggest themselves:

A. Rainwater tanks

Rainwater tanks were, until the 1890s, the most common supply for most city households. They were made illegal to ensure the financial viability for the then developing water supply authorities. They were also banned because of alleged health risks. Whatever the justification for the position taken then, the current situation is that it is now possible to discard the first rainfall to flush the roof clean ensuring that contamination of the tank water by bird and animal droppings is negligible. The second health argument was that tank water had high levels of lead in it. This was alleged to be from the lead flashing used in roofing and from the lead paints used. Neither have been allowed for over fifty years so this cannot be a source of contamination now. The banning of lead additives to petrol also eliminated the possibility of lead being 'washed' into storage tanks through rainfall.

If collected rainwater was reserved for use in the bathroom by plumbing the rainwater tank into the bath, shower and hand-basin, using the figures for NSW (ABS 2004a) as a guide, it would need to be able to supply, on average, 16 kL per person per year (26kL – 10kL from the potable water supply), equivalent to 1.3kL per person per month. Assuming the average size of households is that for Western Sydney, i.e. 3.05 persons, this would equal 4kL per month.

A roof area of 140 square metres (Although there are no accurate estimates of average roof areas for house in this is significantly less than the average roof area of houses built in Sydney over the last 30 years) would yield 56kL if the tank it fed stored 60% of the 668mm rainfall falling in the worst drought year (1994). Assuming relatively equal distribution of rainfall throughout the year, this would require a 4.7kL storage tank to meet all the needs of the average Western Sydney suburbs household (Sydney Water Corporation recommends a minimum size tank of 5kl). Increasing the storage to 10kL, would allow for the contingency of unequal rainfall or of a larger than average sized household. A larger rainwater storage tank would give households a greater security of supply which means that some of it could be used for garden watering. Rainfall in non-drought years would be more than sufficient to meet the bathroom consumption of the average household. Larger roof areas would give greater reliability of supply.

B. Recycling and storage of treated of grey water

Assuming that the bathroom consumption was stored the volume available to be treated for on site recycling would be 26.3 kL per person per year. Laundry consumption is approximately 16.2kL per person per year which would also be recycled assuming a net recovery of 80% of the laundry water. The volume available for toilet flushing would be 39.3 kL per person per year which exceeds the 23.2kL per person per year used in toilet flushing. That is, assuming a relatively constant rate of toilet flushing a tank of 6.1 kL capacity would be needed to store grey water for toilet flushing for the average house. A tank of 10kL would enable the 'extra' available treated grey water (i.e. 3.9kL) to be used for garden watering. Toilet flushing water, i.e. 'black water', would be discharged to the sewerage system.

The household system would then have, in addition to the reticulated supply of potable a tank of 5kL capacity for storage of rainwater for use in the bathroom plus a tank of 10kL capacity for storage of treated grey water for use in toilets and in garden watering. There are several grey water treatment systems commercially available that could be installed to treat grey water before storing it for use as toilet flushing or gardening. Collection of rainwater, including that stored in the recycled water tank, would significantly reduce the storm-water runoff peaking problem.

The 'recyclability' of washing machine water would be improved if households used only low phosphate detergents and other cleaning agents. That is, household behaviour would directly affect the volume and quality of the recycled water supply available for their own laundry and other uses.

2.Employment of technologies that enable the community to maintain sanitation objectives and meet its ambitions of comfort and convenience without consumption of potable water.

Currently 23kL (23,000 kilos) of the per capita average annual consumption of potable water is used to clear the toilet basin but this is not sufficient to transport the approximately 500 kilos of urine, faeces and paper 'produced' per capita annually (note that this is about twice the amount estimated to have been 'produced' at the time of the Chadwick report on Sanitation (Flinn 1965:p123)). One of the problems was that while the Chadwickian solution to sanitation was based on water borne transportation of wastes it assumed a relatively low flow of water. The sewers themselves had relatively high gradients.

Changes in water using behaviour increased the waste water flows which had two consequences: The first was that with higher flows the sewerage lines could be laid at lower gradients leading to significant economies in the construction and operation of sewerage systems. One consequence of this approach is that presently the sewers need water in addition to that required to flush toilets to transport wastes to the treatment plants. This means that there is a tendency for sewerage system managers to be less enthusiastic about measures to reduce 'waste water' discharges to the sewer. The problem of dwellings 'producing' less sewage and waste water flows on average thus leading to tendencies for sewers to 'block' may be seen in areas where only small proportions of dwellings serviced by a sewerage system are occupied at one time. This has necessitated release of potable water directly to the sewers to ensure that the system functions. Examples of this 'problem' may be seen in holiday and retirement areas that have rapidly expanded.

The second was that sewage treatment plants are required to treat ever increasing volumes of water to increasing standard to minimise the environmental stresses from the urine and faeces as well as other wastes discharged to the sewer. The fact that approximately forty percent of the potable water delivered to dwellings (some of it being bathroom and laundry discharge) is now used to transport toilet wastes should itself cause questions to be raised about the efficacy of the present approach to sanitation services.

Assuming that the average size of households is that for Western Sydney suburbs and that they continue with a water borne waste disposal system but one that uses recycled grey-water for flushing the toilet and further assuming that their use of the toilet is the same each month the size of recycled grey water tank to meet the total demand for toilet flushing would be 6.1kL. To store all the recycled water for the average household from the bathroom and net laundry use, the tank would need to be 10kL capacity. That is, 3.9kL of water would be available each month for external uses or provide additional security in supply of water for toilet flushing.

Other waste management systems
At the time the sewerage system was developed in major cities like Sydney there were several patented methods for managing human body wastes in place in some local government areas but these were ignored and the water based system was adopted. The preference for water borne sewerage systems meant that little encouragement has been given to other methods of managing human body wastes. In

spite of the lack of encouragement a variety of waterless toilets including dry composting toilets, are now available the installation of which could save as much as 23% of present consumption.

There is a wide variety of approaches to provision of waterless or dry composting toilets with many systems developed in Sweden and USA. Some of these separate the urine flow and many require low powered air venting of the composting chamber. A number of similar systems using different ways of managing or recovering the compost have been developed in Australia. The system developed by GHD (2003) for medium density housing in Melbourne shows that such systems could be developed for urban areas and achieve very significant savings in water use. Using such a system would mean a saving of about 19% water in Melbourne. Use of dry composting toilets would mean that the recycled grey water would be available to maintain gardens and for laundry use. The use of dry composting toilets would not only reduce water consumption but would enable the recovery of the composted material for use as garden or farm fertiliser. Use of a dry composting system that enabled separate collection of urine flows would not only simplify the composting process but would provide a supply for processing to higher grade fertiliser or, suitably diluted could be used in gardens. It is important to acknowledge that the contemporary dry composting toilets are very different from the earlier manual systems for removal of sewage.

Households are under minimal pressure to reduce their consumption or to desist from discharging difficult or dangerous material to the sewage stream which complicates or makes difficult the operation of sewage treatment systems.

Providing a subsidy and/or mandating the installation of dry composting toilets in all new developments would quickly substantially reduce water consumption.

Summary

Water 'supply' for a house in Sydney would then have the following components:

1. A connection to the reticulated water supply for use in the kitchen and bathroom basin.
2. A 10kL rainwater storage tank plumbed into the bath, shower and bathroom basin.
3. A grey-water recycling treatment system for each house.
4. A recycled storage 10kL water tank plumbed into the toilet and laundry with an upper level 'take off' for garden watering.
5. No use of potable water for gardening
6. A connection to the storm-water management system for surplus treated grey water and for excess rainfall.

Water savings would be: 23 kL for toilet use plus 25kL from garden use = approximately half the present per capita water consumption.

Waste management system would have the following components:

A. For a water borne waste management system:

1. A connection to the sewerage system for 'black water' waste.
2. A connection to the grey-water storage tank for flushing water.

Sewage savings would be: bathroom waste 26kL plus 16 kL for laundry use.

B. For a dry composting toilet waste management system:

1. A dry composting toilet

Sewage savings would be: 26kL for bathroom use plus 16kL for laundry use plus 23kL for toilet flush plus 10kL for kitchen use = 75kL

Separating the water supply services from the sanitation services would lead to significant reductions in water consumption and on sewage flows. The new approach would require dwellings to install a rainwater tank, a grey-water recycling system and a storage tank for the treated grey water. These components would increase the cost of dwellings but there would be significant savings in the dwellings' plumbing and in their water supply system.

Installation of a new waste management system would lead to significant reductions in sewage flows that would lead to economies in the development and operation of the sewerage system. Reduction in the sewage discharge from dwellings would lead to smaller volumes requiring to be treated at sewage treatment plants and in turn smaller volumes to be discharged into receiving ecosystems.

Installation of dry composting toilets would greatly reduce the need for sewerage services as well as reducing water consumption. Such toilets would be cheaper to install than the present water based flushing systems, moreover they would greatly reduce the environmental stresses currently experienced in the water bodies into which sewage is discharged.

The significant savings in the water supply system, the sewerage system and the storm-water management systems could be used to subsidise the installation of the new approach to water services. The reduction in the volume of potable water supplied by the water supply network would leave more water to be applied to maintain environmental flows and to provide a more secure supply in dry periods.

Multi-Unit Development
Securing a similar degree of water independence for households in multi-unit developments would, in principle, be no different although the collection of rainwater and the processing and storage of recycled water would present slightly different challenges. A similar approach to the water supplied to new and existing industrial and commercial undertakings would also reduce the demand on potable water supplies and lead to similar economies in the water supply, sewerage and storm-water management systems.

Households, industry, commerce and public facilities would use significantly less potable water which in turn would mean that the construction of new storage and large scale treatment plants could be delayed, possibly indefinitely. There would be less need for high volume reticulation of water supply systems as well as for sewerage system and treatment plants. A major benefit would be that households and industrial and commercial undertakings would become more responsible for managing their own affairs.

An additional benefit would be that the storm water runoff problem would be reduced which in turn would reduce the pollution load in Sydney Harbour, Botany Bay and the Hawkesbury River systems. The water supply system would also be less vulnerable to attack or other disruption.

The reduced storm-water runoff could also be captured for treatment and recycling for industrial use as well as for irrigation of public parks and gardens. It could also be used to maintain the environmental flows in rivers and other water bodies. Capturing and treating the reduced storm-water runoff would lead to reduction in the environmental stresses currently experienced by near coastal and river waters into which untreated storm-water currently drains.

The nature of the water supply services would change from on focused on large scale catchment management to a much more localized set of catchments operated in a quasi cascade form. Using the water resources on each block for the developments on them would not only ensure that residents and businesses became more aware of and responsible for their own supply as much as possible it would also ensure that the provision of local water services for parks and public gardens made better use of the local drainage flows including storm water runoff. In this way the present problem of the pollution of the cities' bays, rivers and harbours would be greatly reduced.

Institutional arrangements
The adoption of the approach outlined here would require changes to existing institutional arrangements. The first step would be to revise the powers of Sydney Water Corporation to prevent it from banning the installation of dry composting toilets or grey water treatment and recycling systems. Such institutional revision would also enable households to refrain from connecting to the sewerage system.

The present health regulations governing rainwater tanks, dry composting toilets and grey-water recycling systems would need to be reviewed. Clearly, health objectives need to be secured but innovations in these technologies need to be recognised and improvements acknowledged in revised regulations controlling the installation and management of rainwater tanks, dry composting toilets and grey-water recycling systems. The powers of Local Government Authorities would need to be revised to enable them to approve developments using modern water services and sanitation facilities.

Sydney Water Corporation might sensibly be able to revert to its original role as a 'health authority'. In doing so it would resolve the conundrum created by the enthusiastic adoption of the Chadwickian approach to the supply of potable water and the provision of sanitation services. At present quarterly visits are made to each property to record water consumption. It would be appropriate to train such meter readers so that they could regularly inspect rainwater tanks, composting toilets and grey-water recycling systems to ensure that appropriate health standards were maintained

We have made use of evidence largely from Sydney but in principle the same argument may be made for other major cities in Australia. Some changes would be needed to allow for their rainfall, their propensity to maintain gardens etc and for the socio-cultural differences they may have compared with Sydney.

Conclusion
The point has been reached where it would be timely to reconsider the water services supplied to dwellings in Australian cities. It would also be timely to reconsider the ways in which waste management services are provided. The situation facing all cities in Australia is that the water used to maintain their sewerage systems now accounts for almost half the water consumed inside the dwelling. This is putting the cart before the horse. The failure to reconsider the present water supply and waste management systems is leading to a moral panic in desperate searches for 'new' sources of water. All the options for these 'new' sources of water are expensive and environmentally damaging. The cities would be better served if more attention was paid to ways of reshaping the demand for water including reconsidering the ways in which wastes are managed.

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