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Water Conservation and Harvesting in Adelaide, SA: Four Case Studies

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Figure 1: Green roof micropond at Christie Walk. The intensive green roof on the apartment block at Christie Walk (see p11) is a South Australian first.

ABSTRACT

Adelaide has a relatively long history of innovation in wastewater treatment and water conservation, spurred on in response to South Australia's predominantly arid environment.

Examples of innovation range from those in private sector developments in the inner city to suburban neighbourhood-scale projects. Treatment systems range from mechanical filtration to extensive reedbeds. Storage approaches include underground tanks and aquifer recharge.

Most of the projects link water treatment to vegetation establishment as part of broader urban planning strategies. Although such techniques are still the exception rather than the rule, their increasing adoption is being driven by both legislation and perceived environmental necessity. This will impact on the design of the built environment and there is likely to be an increasingly strong imperative to integrate such measures into design thinking from the concept stage onwards.

The original version of this note, CAS 25, was published in 2001 and co-authored by Claire Fulton.

Introduction

Water conservation in urban residential environments can be a challenging prospect because of the dominance of impervious surfaces. These case studies describe solutions for achieving rational and responsible water management where the entire immediate environment is a human artifice and the natural water cycle of a place cannot be maintained without active intervention. The examples are from the very dry State of South Australia, but they have relevance to any development where water management has to be integrated with the urban form.

Best practice water management can be achieved by a combination of appropriate design of individual buildings, the application of broader urban design principles, and intelligent engineering.

As we move towards a better understanding of what is involved in the sustainable management of complex water systems in urban environments, the processes of water management will necessarily become more integrated. There will be a need for improved communication and design processes that will blur the 'traditional' boundaries between the architect, planner, and engineer.

The studies below deal with a range of systems in both suburban and inner-urban environments. In addition to the 'on-the-ground' practical issues addressed, these projects have played a role in community education, helping to raise general awareness about the potential for augmenting potable water supplies with recycled water.

Although each of the case studies was an exception from the norm at the time of their instigation, the relevance of the techniques they developed for wider adoption in our water-stressed environment has led to them become increasingly common models for sustainable urban water management.

Location and Climate

Adelaide's climate is nominally 'Mediterranean', with warm to hot summers and cool winters. While South Australia is frequently described as the driest state in the driest (inhabited) continent, the climate of the Adelaide region differs from the rest of the State's arid lands. The Mount Lofty ranges, adjacent to Adelaide, are South Australia's major urban water catchment, and provide some 40 per cent of the local water used on the plains, with the balance piped from the Murray River. Although this area has higher rainfall than other parts of SA, Adelaide City has a relatively low average rainfall of around 500mm/year.

Design Philosophies

Sources of high quality water in Adelaide are becoming increasingly scarce, while treatment and storage (or more usually disposal) of stormwater and effluent present serious environmental problems.

Building and urban infrastructure design has been focused on removing and disposing of run-off and sewage via extensive networks of sewers and culverted creeks. The centralised, large-scale approach to water supply, sewage and stormwater disposal has been described as 'big pipes in and big pipes out' engineering (Newman 1993), with up to 85 per cent of costs incurred from piping alone. The strategy of swiftly pumping used water off-site is increasingly understood to be inappropriate resource management. The alternative, which is to slow down run-off, and to capture, use and re-use water on-site, has implications for architectural programs and urban design.

The 'source control' philosophy (Argue, 2008), demonstrated in the following case studies, seeks to capture rainfall where it falls, and where possible to treat and reuse greywater and sewage locally. This inherently decentralised approach – although mostly initiated, installed and operated by central water utilities – can enable local communities to be involved in the design and management of their own water systems, as in the Christie Walk example.

Most of the following case studies place emphasis on economic benefit and cost minimisation, with a secondary objective of reducing environmental harm to waterways, aquifers, rivers and catchments, and irrigated public spaces. For some, particularly the Regent Gardens residential estate, the primary concern was reducing demand on public potable water supply and water management systems.

Christie Walk places particular emphasis on environmental education and water use in an arid environment, with fact sheets and site tours. It encourages locals to recognise and use appropriate water use strategies – including reconsidering what a garden should look like in this climate. On the other hand, and despite the 'water-wise' ethos of its infrastructure planning, Mawson Lakes development, with extensive lawns and non-endemic plantings, does little to remind residents that they are living in a semi-arid place, promoting as it does an aesthetic which is energy consuming and unresponsive to the patterns of natural systems in the area.

Urban infrastructure designers are increasingly working with catchment boards, which were formed to promote the health of rivers and catchment systems. Such alliances contribute to urban water management systems being considered within a broader ecological perspective, with the potential for developing a more integrated and sustainable overall approach. Several of these case studies show examples of built environment design conditioned by broader ideas about environmental sustainability.

Water Reuse Issues

While the volume of greywater and sewage produced over the year remains reasonably constant, in SA's temperate climate rainfall occurs mostly in the winter months. Gardens and lawns require most irrigation in the heat of summer. This means that if stormwater is to be reused to maintain parks and gardens, some means of storage must be used.

Space and aesthetics are considerations in designing water storage systems, particularly in urban settings. Large tanks can be unsightly if not carefully designed, screened or sited. Underground storage methods can have the advantage of saving visible space, but are relatively expensive and raise other issues (e.g. excavation for the Christie Walk tanks just reached local perched water tables). The case studies here use a variety of storage techniques, including sending treated water to aquifers, either via infiltration from soakage trenches and swales (New Haven Village), underground storage tanks (Christie Walk), or using ASR technology to inject filtered effluent directly into the groundwater system (Regent Gardens, Mawson Lakes).

With increasing density, the implications for architectural and urban design will vary and the location of water storage volumes becomes more critical, as it can critically affect the location and configuration of built form volumes.

Case Studies

Regent Gardens

Project outline

Client: AV Jennings and the SA Government

Year of completion: 1993

Project type: Urban stormwater harvesting and reuse, including wetlands and aquifer storage and recovery

Size of project: Low-density urban development of 1250 home sites on 77 ha, including 10.6 ha open space

Figure 2: Oakden, previously Regent Gardens, with wetland visible in bottom left corner

(Source: Wikimedia Commons)

Background

The urban water management system employed at Regent Gardens was an Australian first, and remains a leading national example of sustainable water management.

Regent Gardens was established as a housing estate on former Department of Agriculture land in the early 1990s. Now known as the suburb of Oakden, it was the first stage of the Northfield development and is located 8km northeast of Adelaide. Prior to the development, the land had been open paddocks, with reasonably high stormwater infiltration and low run-off. Most of the capacity of the stormwater infrastructure existing near the Regent Gardens site was already utilised by residential and industrial developments downstream. This led the developers to incorporate technologies to retain and reuse stormwater on site. Technologies include a reedbed and wetlands system, and aquifer storage and recovery.

Water Systems Design

Stormwater Management

The Regent Gardens estate uses a development-wide stormwater management infrastructure. Stormwater is collected by street drains and directed through reedbeds to a series of wetland detention basins. The wetlands are designed to act as both flood control basins and a means of improving water quality. Low salinity stormwater drawn from the wetlands is pumped into the aquifer during winter, enabling it to be withdrawn and used the following summer. The process of pumping into the underlying aquifer and storing it there for reuse is known as aquifer storage and recovery (ASR).

Standard roadside entry pits are used to collect stormwater. The series of reedbeds act as gross pollutant traps (GPTs), minimising the silt entering the wetlands. Silt accumulation in wetlands decreases their storage capacity, and requires labour for maintenance. With the reedbed gross pollutant trap system used at Regent Gardens, it was estimated that de-silting would need to take place every 15–20 years (Smith 1997). At the time of writing, after seventeen years of operation, no de-silting of the system had been required.

After passing through the GPTs the stormwater travels via swales to a series of detention basins, where it follows a winding flow path through large-growth reedbeds and ponds of various depths. The reeds calm the velocity and turbidity of the water and accelerate the decomposition of sediment particles.

Separate ponds make it possible to isolate contaminants that may enter the system. While stormwater can be reused with minimal treatment, water collected from roads may include serious pollutants such as petrol and lead, and any other contaminants that are spilled on the catchment surface. The water is retained for approximately ten days, to ensure that it meets health and environmental criteria set by the national framework for water quality.

The wetland is also designed as habitat for nesting birds, and is stocked with endemic fish species. A diverse and stable community of plants and animals indicates the health of the wetlands system, and helps ensure the survival and proliferation of species that are beneficial for water processing.

The Intelligent Home

The 'Intelligent Home' at Regent Gardens was a showcase research project that incorporated two water management systems in its design. A rainwater collection system harnessed roof run-off, which supplied the hot water to the house, with mains used as a back up. Meanwhile greywater from bathrooms and laundries was treated in a submerged gravel-based reedbed system and reused for toilet flushing and garden irrigation.

Roofs provide an easy to collect stormwater catchment, which can be stored in household rainwater tanks, as in this example, or directed to collective treatment and reuse systems (such as at Christie Walk).

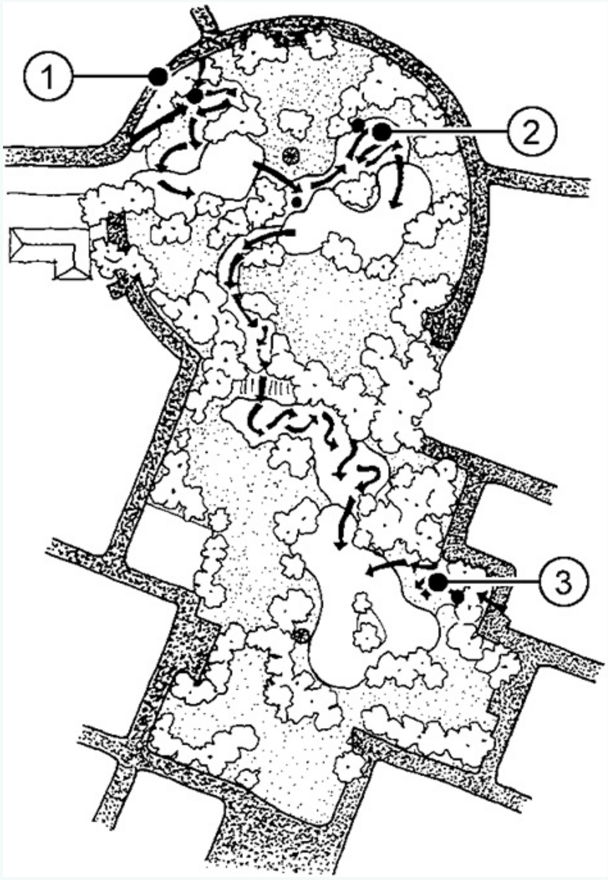


Figure 3: Regent Garden wetlands

1. **Water from roads enters the lakes from a series of reedbeds**
2. **As the water passes through the reedbeds it is naturally cleaned**
3. **After water is cleaned, it is pumped underground to the natural aquifer**

(Source: South Australian Department for Water Resources)

Untreated stormwater harvested from roofs is not potable as it may contain organic materials from leaf litter and bird droppings, as well as pollution from surrounding vehicles and industry.

The Urban Water Resources Centre at the University of South Australia and the Australian Water Quality Centre extensively monitored the Intelligent Home's reedbed treatment system during 1996–1997. The effectiveness of reedbed vegetation, the extent of nutrients and metals present in the water, types and numbers of microbes, and biological oxygen demand were analysed. The studies showed that the reedbed system met all public health requirements, and achieved successful environmental quality (UWRC 2001). However, the reedbeds took up most of the backyard and despite its success, and the original residents' satisfaction with the system, a change of owners led to the reedbed being removed and replaced with lawn (Allen and Pezzaniti 2001).

Aquifer Storage and Recovery (ASR)

At Regent Gardens, a 35m long gravity diversion system is used to inject the treated stormwater into the underlying aquifer so it may be stored until needed. At the point of injection a water-quality 'trigger' prevents water entering the aquifer unless it has achieved a satisfactory level of treatment.

'The 80m injection well comprises gravity operated pipe work and a control valve fitted with a filter for injection of stormwater from the wetland into the aquifer. Recovery of water for delivery to the irrigation system used in the reserve is achieved through a pumping station housing the controls for the submersed bore pump situated approximately 35m down the injection/ recovery well.'

Smith 1997

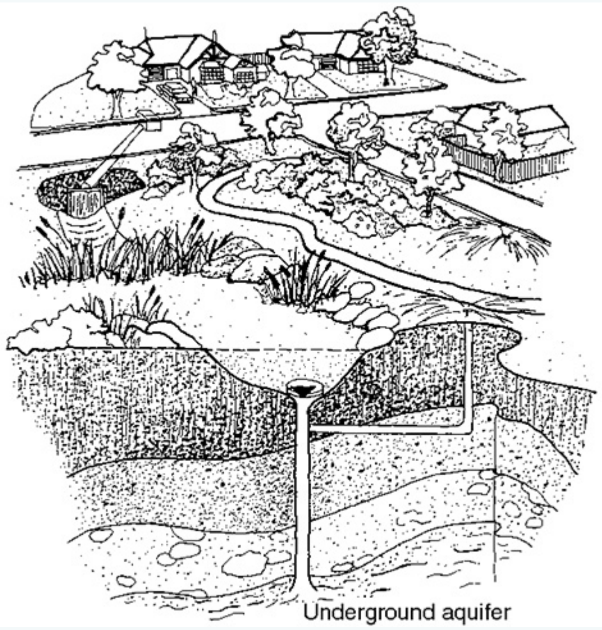


Figure 4: Aquifer storage and recovery
(Source: South Australian Department for Water Resources)

Aquifer Storage and Recovery (ASR) presents both potential benefits and risks. Aquifers can be recharged by infiltration from swales and drainage basins, and by injection through bores. It was anticipated that ASR technologies would help restore the aquifer pressure and reduce salinity of groundwater so it would be suitable for irrigation. However the Australian Conservation Foundation (2000) and others believe that groundwater systems are among the most complex and least understood of all natural systems, and are unsuited to human manipulation. They advocate a precautionary approach when managing groundwater.

'We can't always anticipate where [aquifer] pollution is going to turn up in our water, or how long it will be from the time it was deposited until it reappears. Because groundwater typically moves very slowly - at a speed of less than a foot a day in some cases - damage done to aquifers may not show up for decades. In many parts of the world, we are only just beginning to discover contamination caused by practices of 30 or 40 years ago... And once it gets into groundwater, the pollution usually persists: the enormous volume, inaccessibility, and slow rate at which groundwater moves makes aquifers virtually impossible to purify.'

Sampat 2000

The appropriateness and specifications of ASR systems require extensive local research, and vary according to soil types and geology. ASR may be used in a variety of geological environments, but is most suited to locations where there is low permeability of the formation between the land surface and the aquifer (Pavelic and Dillon 1997). In all cases, issues which must be addressed include avoiding the clogging of the injection well, protecting existing beneficial uses and the ecological integrity of groundwater systems, and ensuring that water being stored in aquifers meets relevant standards (Dillon et al. 1997).

Allen (1994) suggests that the cost of installing ASR systems may be neutral. However there are reports that costs of this kind of water are high in comparison with costs of surface detention and use of stormwater and there are time lags inherent in the systems that can make them relatively slow to respond quickly to flow events (Dillon et al. 2010).

Other points of concern include hydraulic control (i.e. pressure), and aquifer quality being compromised due to chemical or microbiological reactions from different waters mixing. Increased groundwater levels resulting from small-scale ASR systems may also affect soil moisture levels, which is of particular concern in Adelaide's 'Bay of Biscay' soils, known for their seasonal movement and the impact of this on buildings. Some of these issues may be overcome with adequate design, maintenance and operation. It should also be noted that after 17 years of operation, none of these potential concerns appear to have been reported as operational problems.

Water quality testing has focused on meeting ANZECC irrigation water guidelines, which means that water injected into the aquifer must be no worse than the existing ground water quality. During 1993 the water in the aquifer was sampled over a 158-day period, with approximately 10 per cent of the injected recharge water recovered and tested. At peak levels, the salinity levels were 550 mg/L less than the ground water (Smith 1997).

In 1994 further tests were made that involved extracting water from the aquifer after first injecting 10 megalitres of storm water. With repeated pumping periods of six hours the water quality dropped, with salinity rising from 500 to 800 mg/l to over 1,000 mg/l. It was anticipated that this problem would lessen when much larger volumes of storm water were injected (Gorges 2000).

New Haven Village

Project Outline

Client: Several public and private sector organisations and individuals including the SA Housing Trust and MFP Australia (now defunct)

Consultants: Woods Bagot

Year of completion: Commenced late 1992, completed with 64 houses in 1999

Project type: Black, grey and stormwater harvesting and reuse

Size of project: 64 medium density dwellings on 2 ha of land

Cost at completion: Capital cost of water recycling plant $162,000, with cost of estimated recycled water at $0.88/kL (Allen and Pezzaniti 2001)

Background

New Haven Village is a housing development 20km northwest of Adelaide. It was opened in 1995 and featured pioneering on-site treatment and reuse of stormwater and household black and greywater. The intention was to ensure that virtually no wastewater was left the site, and this is what has been the reported. The project was intended to test, develop and evaluate technologies for potential use in larger scale developments.

Water Systems Design

Stormwater

Much stormwater run-off is created by roads and paved areas. This water may be harvested either by increasing infiltration where rain falls (by limiting and narrowing roads, or by roadside swales or trenches), or by directing stormwater through roadside entry pits and drains to collection and treatment systems such as wetlands.

At New Haven Village, street widths were reduced from the standard 12.4m to 6.8m, reducing the impermeable ground area. Stormwater run-off is collected from streets and directed through underground mains under a central spoon drain. Roof run-off is also directed to these drains. The sump inlets are grated, trapping litter and other large pollutants before they enter the system. The stormwater system has a first-flush diversion system with directs the first 40,000Ls of a rainfall to an underground concrete tank. This water is later directed to the wastewater treatment system. Once the tank is full, stormwater, minus many of the pollutants present in the first flush, bypasses the tank and flows to a soakage trench. From the trench, excess water flows to a sports field, which acts as a retention basin for stormwater in very heavy rainfall (New Haven 1997).

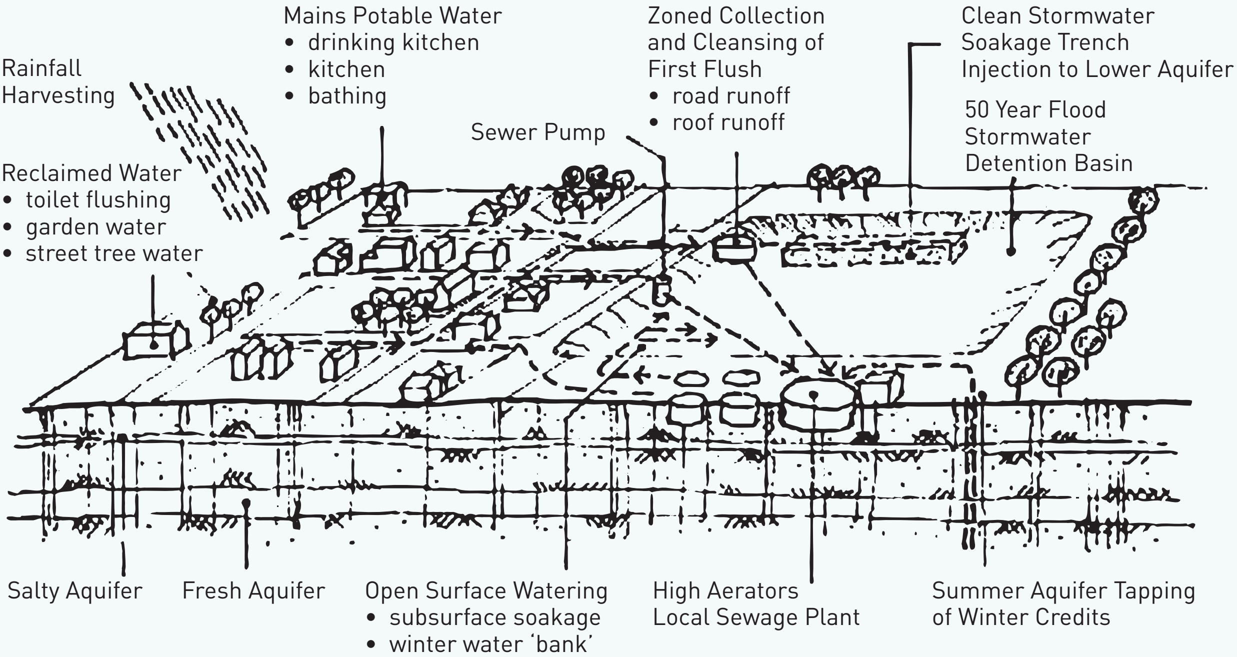


Figure 5: On-site water/wastewater management at New Haven Village
(Source: AMCORD Design and Development Practice Note PND 2)

Sewage

All household black and grey water is piped to a pumping station beneath an adjacent reserve. Water is treated conventionally: filtered through sand and treated with UV light. It is stored in two 22,500L underground concrete tanks. The treatment plant is automated, with manual process monitoring required on a weekly basis. The Central Board of Health approved it with stringent conditions on the quality of water, and required continuous testing. Sludge is directed to a sludge-thickening tank. Some of the houses at New Haven have been constructed partly with bricks made from sludge residue and clay (New Haven 1997).

Wastewater Reuse

Water from the sewage system is used to water public land, for household irrigation systems and for toilet flushing. The water is further filtered and directed to the system of sub-surface drip irrigation in the reserves.

Residential gardens were installed with subsurface irrigation systems fed by reclaimed water. Residents were able to adjust the system with a control unit in their garages. The system was designed to reduce evaporation and eliminate resident contact with reclaimed water, as well as be proof against accident and vandalism. However the system did not work as well as was hoped.

According to Rabone (2006) since September 2000 the reticulated non-potable water supply has not been operating as designed and the New Haven Village waste water treatment plant (WWTP) has failed to reliably meet the reclaimed water guidelines set for reuse.

In addition, although all irrigation systems on the estate were originally subsurface, after three years approximately 50 per cent of the houses had installed above ground irrigation, increasing health risks. As a result, the system was modified considerably so that the treated effluent is now delivered to the oval via subsurface irrigation while toilet flushing and garden watering requirements are met from potable mains water.

Based on data for the 5 year period 1999/2000 to 2003/04, the average household potable water use is 110kL. The average effluent use is 22 megalitres/year and 100 per cent of effluent is treated, but since September 2000 all treated effluent is used for irrigation of the playing field and not for domestic purposes. The current irrigation regime applies more water than is necessary to maintain healthy turf (Rabone 2006).

The then-Commonwealth Department of Primary Industries and Energy set up a monitoring program to evaluate the energy consumption and economic cost-benefit of the project. Rabone (2006) reports that the cost effectiveness of the ongoing management and maintenance of the system has not been demonstrated and the cost of supplying recycled water for non-potable use is about twice the cost of mains water.

It would seem clear from this example that:

1. Close monitoring of effluent re-use systems is essential to ensure that the water quality is maintained at the level necessary for the use of the system as designed.
2. Even if sub-surface irrigation is provided from the outset, the activities of residents cannot be constrained sufficiently to guarantee that they will continue to use the system as designed.
3. The cost of recycled water, even for non-potable use, is much higher than conventional mains water.

Mawson Lakes

Project Outline

Client: Joint venture between the South Australian Government and Delfin Lend Lease Consortium (Mawson Lakes Economic Development Joint Venture)

Year of completion: 2009

Project type: Black, grey and stormwater harvesting and reuse

Size of project: 620 ha housing development comprising approximately 3400 dwellings housing around 10,000 people. 30 per cent of the development is set aside as open space, including 70 ha of lakes and waterways. The initial area was expanded to a catchment area of 810 ha in which land uses include residential, commercial and industrial.

Cost at completion of water system: The capital cost of $10.5 million (plus wastewater reclamation plant and operating costs) for the completed recycled water scheme works out to approximately $3,000 per dwelling (Philp et al. 2008). Operational costs are approximately $470,000 per annum (Lend Lease 2006).

Background

Mawson Lakes is located in the northern suburbs of Adelaide around 12 kilometres north of the Central business district. Much of the suburb was previously known as The Levels, and as such was non-residential, housing a campus of the University of South Australia and Technology Park Adelaide.

Figure 6: Mawson Lakes

The Mawson Lakes urban development has one of the largest water recycling projects in Australia. It incorporates a number of water management strategies, including the on-site processing of stormwater and household effluent.

Mawson Lakes features a dual water supply system, supplying drinking water and recycled water to homes via completely separate mains. The recycled water is sourced from the Bolivar Sewage Treatment plant approximately 8km away, which then has stormwater added to it from the Salisbury wetlands before it is treated to Class A standard recycled water for use on gardens, reserves and the toilets in each residence.

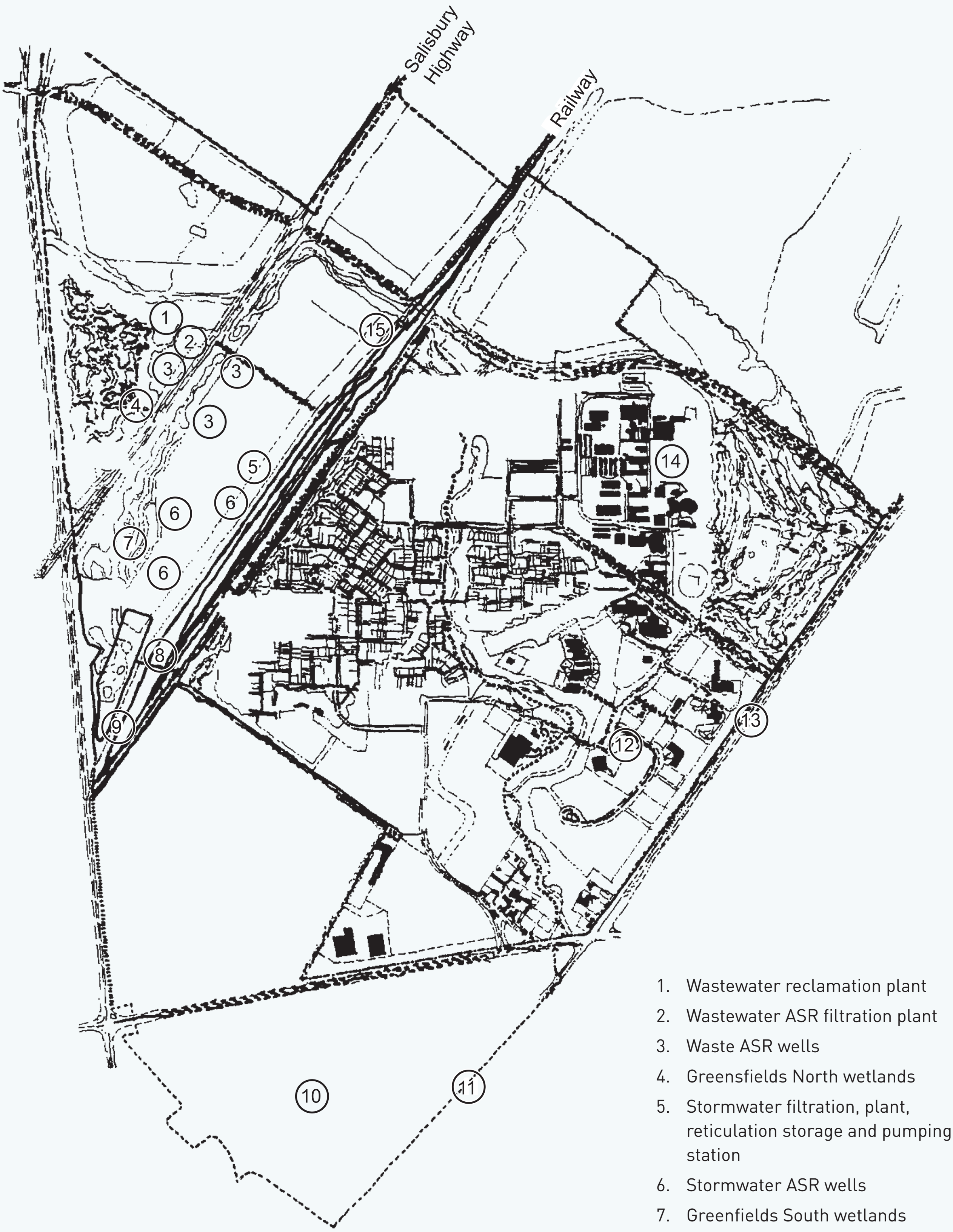
SA Water provides a comprehensive audit of homes within the area to ensure that cross connection between the recycled water and drinking water does not occur. Guidelines (which apply to all these case studies) for the use of recycled water are published by the South Australian Environment Protection Authority (EPA).

Mawson Lakes is characterised as low and medium density and its development goals include providing a recycled water supply system to provide at least 50 per cent of household water and all irrigation water for public open space. End use includes irrigation of lawns, parks and gardens, flushing toilets, washing cars, filling ornamental ponds and water features (Gardner et al. 2001, DeBlas 2000).

Water Systems Design

Household effluent (grey and blackwater), and rainwater run-off are treated separately, and then combined and distributed together to meet irrigation and household demand. A dual reticulation system, where residents can switch between reticulated grey water and mains supply, enables households to easily utilise reused water for irrigation, toilet flushing, and (possibly) clothes washing, and to supplement it with mains water when supplies are low.

Surplus water is discharged via a standard bore into one of two 180m-deep aquifers, to be recovered when needed in the drier months. Several cleansing techniques are used at Mawson Lakes, including wetlands systems, ultraviolet light and chemical treatment. The integrated system forms an educational focus of urban water issues for primary and secondary schools, universities, TAFE, and the community (Marks 2001).



1. Wastewater reclamation plant
2. Wastewater ASR filtration plant
3. Waste ASR wells
4. Greenfields North wetlands
5. Stormwater filtration, plant, reticulation storage and pumping station
6. Stormwater ASR wells
7. Greenfields South wetlands
8. Culvert under railway
9. Greenfields South wetland extension
10. Pooraka produce markets
11. Southern catchment boundary
12. Technology Park
13. Development boundary
14. University of South Australia
15. Reserve

Figure 7: Mawson Lakes recycled water system: works locations
(Source: Richard Marks, Mawson Lakes Development)

1. Wastewater reclamation plant
2. Wastewater balancing storage
3. Wastewater ASR injection pumping station
4. Wastewater ASR filtration plant
5. Wastewater ASR wellfield, 2 wells plus 1 standby
6. Wastewater ASR injection and recovery pipework
7. Reticulation pumping station
8. Reticulation balancing storage
9. Stormwater filtration plant
10. Stormwater ASR injection and recovery pipework
11. Stormwater ASR wellfield, 2 wells plus 1 standby
12. Stormwater capture dam 23ML
13. Capture dam pumping station
14. Optional intake from Greenfields South wetland
15. Control weir to Greenfields South wetland
16. Stormwater ASR injection pumping station
17. Culvert to Greenfield wetland St 3
18. Southern catchment wetland 2.8ha (Greenfield South wetland extension)
19. Wetland internal dividing bank

Figure 8: Mawson Lakes recycled water system: layout of headworks

(Source: Richard Marks, Mawson Lakes Development)

Stormwater

Stormwater run-off is harvested from roofs, paths, roads and the general area. It is treated in wetlands and passed through gross pollutant traps and a series of sediment settling basins before being treated in a 3 ha wetland over a period of nine days. See the Regent Gardens case study above for more detail on wetlands treatment systems.

Effluent

Wastewater from the sewerage system is locally treated in a water reclamation plants and stored with treated stormwater in groundwater aquifers for reuse. The wastewater reclamation plant was developed in stages to reach its capacity for 10,000 people. Reclaimed water from the plant is Class A quality under the South Australian Reclaimed Water Guidelines (Treated Effluent) and meets requirements for discharge to an aquifer storage and recovery system.

The first stage of the plant was a proven advanced conventional design activated sludge plant with nutrient reduction, tertiary filtration and disinfection. Later stages incorporated advances in treatment technology. The project was designed to provide opportunities for comparison with the original, conventional plant, to directly assess their relative performances under identical conditions. Treatment processes utilised are non-odorous or provided with odour control facilities, and have low noise levels (Marks 2001).

Effectiveness

The effectiveness of the systems has been demonstrated and the project remains a focus for research by universities and others. It is constantly monitored and evaluated.

Estimated Potable Water Savings are 487 megalitres/annum from on-site stormwater harvesting (80% of the catchment yield). An additional 128 megalitres/annum comes from a separate local stormwater treatment wetland and 506 megalitres/annum from wastewater use. This totals 1,121 megalitres, which matches initial expectations set for the project.

Maintenance of the system is undertaken by SA Water's contractor, United Water. All on-property maintenance is the responsibility of the property owner. Residents are obliged to ensure that any alterations they want to make to the recycled water pipes within their property must be undertaken by a licensed plumber and be audited by SA Water. Billing for water use is via two accounts from SA Water, each of which is identified with its own prefix (Mawson Lakes 2004).

The capital headwork cost of the water reuse project was $10.5 million, excluding the wastewater reclamation plant. The yearly operation and maintenance cost was estimated at half a million dollars (Gardner et al. 2001). The expected cost of the reused water was $0.88/kL. This compared with potable mains water tariffs, at around $1.12/kL for households and $0.91/kL for open space irrigation (2001 figures).

In the 2004/05 financial year the price of recycled water was set at 75 per cent of the price of mains drinking water, i.e. 77c per kL. This would appear to make it very competitive compared with New Haven Village, but given that it is set at a percentage of mains water price it is unclear to what extent the price is subsidised.

Christie Walk

Project Outline

Client: Wirranendi Inc, a non-profit co-operative

Consultants: Ecopolis Architects Pty Ltd

Year of completion: 2005

Project type: Inner-city development with stormwater harvesting and reuse

Size of project: 27 dwellings on 2000 square metres with community facilities

Cost at completion of water system: Not available

Background

Christie Walk is a community-based ecological development in inner-city Adelaide. The project is on a T-shaped site of 2000 square metres that is small and severely constrained, with buildings hard on or close to most of the boundaries. The site was a former bottle recycling depot.

The development includes community facilities on the ground floor of the five-storey apartment building, which contains shared laundry facilities for reduced water and resource use, and community gardens irrigated from stormwater captured on site. The site was lacking in vegetation at the commencement of the project but now provides over 700 square metres of vegetation in a project with a density of over 200 people per hectare.

The architect for the Christie Walk project (the present author) was heavily involved in the project from inception through to completion, and was involved in advocacy and negotiation to maximise environmental outcomes for the project, including discussions with the water utility. Extensive negotiations promised support from the utility for on-site sewage treatment but the utility changed its priorities and the project was cancelled.

Figure 9: Townhouse and apartment block (with roof garden visible) at Christie Walk

Water Systems Design

Stormwater

All water shed by the roofs, balconies and other impervious surfaces is collected for use on site in two 20,000L underground tanks situated beneath the carports. After mechanical filtration the captured water is used for irrigation and toilet flushing, thus reducing total water importation to the site. No data was available to the author to confirm the level of reduction.

Greywater and Blackwater

On-site sewage treatment was planned, easements were negotiated, and a system design was undertaken in conjunction with the local water utility and with the support of the Adelaide City Council. The system would have delivered treated water from the Christie Walk community to irrigate a nearby (200 metres approx) public parkland (the quantity of treated water would have been in excess of on-site irrigation requirements). Although this did not eventuate, the set of designs and negotiations achieved demonstrated that innovative, cross-sectoral, community-private-public partnerships to achieve water efficiencies are possible.

Christie Walk is notable for its density and the integration of its water storage in a high-density urban environment. It demonstrates that responsible water use and intense development can be reconciled without loss of amenity. The processes of design, development and implementation were linked to community education programs and workshops that connected water management and use to permaculture, sustainable garden design and the relationship between landscaping and passive solar building design. The end result is an exceptionally diverse and productive landscape that includes South Australia's first intensive roof garden.

No PVC products are used to collect and transport water. PVC piping has been reported as presenting problems for water quality (see Kruszewska 1996) and its use is an issue of concern for environmentalists and policy makers. Both San Francisco and New York State have banned PVC pipe (Healthy Building Network 2006).

Demand Management

Creating less grey water, sewage, and stormwater run-off is preferable to recycling it once it has been created. The co-housing approach of Christie Walk helps to minimise demand for water by balancing privacy with shared facilities. The community facilities include a shared laundry, so many of the dwellings do not have individual laundry facilities (although the BCA requirements meant that the houses had to demonstrate the capacity to provide laundry facilities). Shared outdoor areas, including the very popular and successful roof garden – irrigated with stormwater – also facilitate the implementation of ecological values in landscape design.

Christie Walk features water-use reduction strategies at the household level, including water efficient appliances, flow-restricting shower roses and low-flush toilets, however lack of funding for research

Figure 10: The two 20,000L underground tanks being installed beneath the carports at Christie Walk

means that there has been no systematic monitoring or collating of data on actual water use and the exact level of water use reduction cannot be confirmed.

To have a significant impact on water and energy use, water recycling needs to be accompanied by water-sensitive garden design, reduced lawn areas and food growing at homes and community spaces. The community garden at Christie Walk produces herbs, flowers and vegetables for residents, irrigated by captured rain and storm water. Residents pay close attention to plant selection and gardens utilise mulch and drip irrigation.

Many Australian cities, particularly Adelaide and Perth, have semi-arid climates, yet there is a cultural tendency towards large areas of lush, green lawns around bungalow-style housing. Lawns are often over-watered and over-fertilised (Anda et al. 1997), and require constant labour and petrochemical inputs. The community education initiatives at Christie Walk provide an example of working towards place and water sensitive urban landscape design.

Cost Effectiveness

Installation of the underground stormwater tanks had to take place early in the project's construction, adding a significant up-front cost to the development program. The developer's non-profit structure enabled the project to be realised with dwelling prices at or near 'normal' market values by subsuming the profit into the hardware of the project. A more conventional development approach at this scale of development would require that the dwellings be priced to produce a profit. At a larger scale – perhaps 50 dwellings or more – economies of scale should make it possible to fund and sell such a development within the profit-oriented structure of the private sector.

The Australian Water Conservation and Reuse Research Program reports economies of scale with respect to stormwater and rainwater harvesting such that 'the cost of stormwater harvesting falls rapidly as the scale grows from one to 100 connections and then levels out between 1000 and 10,000 connections'. For stormwater capture and use alone, there would thus need to be between 100 and 1000 connections, at least, to achieve economies of scale (Philp et al. 2008).

Conclusion

The cost effectiveness of the kind of solutions demonstrated by the case studies is a function of both the internal financial structuring of the relevant development entity and the extent to which government monies and assistance is forthcoming.

An economic disincentive for smaller scale adoption of on-site water management systems is that, compared with other countries the price of potable water in Australia is very low. This has been 'a major reason for the lack of economic feasibility of recycled water' (Philp et al. 2008).

All of these projects have been achieved or proposed within the existing legislative framework of South Australia, where applications for sewage recycling systems are assessed on a case-by-case basis by the Department of Human Services. There is growing support for more effective water management after the State Government introduced a requirement for all new dwellings to be connected to a rainwater tank (albeit a tokenistic 2000L capacity).

According to the report by Philp et al. (2008) 'a significant obstacle to widespread implementation of stormwater use is a lack of reliable and affordable treatment techniques.' Nevertheless the case studies seem to support the view that there are no major social or technical barriers to ecologically responsible water management in urban environments. Legislative demands (e.g. compulsory provision of rainwater tanks in new developments) and growing concern about water scarcity is beginning to create an imperative to consider integrating such measures into design thinking from the concept stage onwards.

Although stormwater harvesting occupies land that cannot be sold, it may increase the overall value of a residential estate. It is an established fact in the real estate industry that residences adjacent to or overlooking water have substantially higher value than those without water views. The concept of replacing some allotments with stormwater harvesting areas, including wetlands and detention basins, has been proposed as a model for urban redevelopment, 'particularly where flood prone areas could be replaced with wetlands that increase protection for surrounding land'. As well as adding financial value, benefits include provision of water supply, improvement of stormwater quality, and flood mitigation downstream. Urban consolidation with multi-storey dwellings also has the potential to further increase the amenity value of open space and water views (Dillon et al 2009).

There are a growing number of projects around Australia that employ water capture and recycling approaches and technologies, and while the techniques described in the case studies are still the exception rather than the rule, their use is only likely to become more widespread.

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