DOI: 10.1007/s00267-004-0252-1

Applying Integrated Urban Water Management Concepts: A Review of Australian Experience

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ABSTRACT / This article explores recent Australian experiences in the application of the concept of integrated urban water management (IUWM) to land development sites through the review of 15 case studies. It discusses IUWM's emergence and comments on the success or otherwise of Australian experience in its application. The understanding of IUWM is maturing within the Australian water industry, an occurrence that has been facilitated by demonstration sites such as those reviewed. Successes include the translation of IUWM concepts into well-functioning operational urban developments, significant reductions in the impact of the urban developments on the total water cycle, and the increasing acceptance of the concept within the water and land development industries. However, there is still room for greater integration of the water supply, stormwater, and wastewater components of the urban water cycle, improved dissemination of knowledge, enhancement of skills in both public and private organisations, and monitoring the performance of systems and technologies.

Cities around the world face the challenge of managing their impact on the natural environment and the stresses on aging infrastructure. As a result, the sustainable cities concept is an international movement, with the major objective of making cities greener and healthier places for their inhabitants, with sustainability involving economic viability, social stability, and wise use of resources while protecting and nourishing the natural environment (Leitmann 1999). An important component of any urban area, be it a city or regional centre, is the water system, providing water supply, sanitation, and drainage services to its inhabitants. However, in many cases, the conventional approach to the provision of these services does not comply with the more recent aspirations of ecologically sustainable development. There is great interest in approaches to providing water systems that lower the impact on the natural environment and cotrol expenses.

In order to reorientate urban areas towards sustainability, it is recognised that the different aspects of urban water systems should be viewed in relation to each other, which requires the adoption of an integrated approach to urban water system planning, provision, and management. Integrated Urban Water Management (IUWM) takes a comprehensive approach to urban water services, viewing water supply, drainage, and sanitation as components of an integrated physical system, and recognises that the physical system sits within an organisational framework and a broader natural landscape.

KEY WORDS: Integrated urban water management; Sustainable development

Published online February 20, 2006.

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The purpose of this article is to critically review the recent experiences in implementing IUWM within the Australian urban water and land development industries. This is done through a combination of literature review and case study analysis. Each of the case studies have, to varying extents, incorporated IUWM concepts into the development.

Emergence of Integrated Urban Water Management

The traditional paradigm of centralised urban water supply, sanitation, and drainage systems dates back to the mid to late 19th century, as a response to typhoid and cholera epidemics that swept European and American cities between the 1830s and 1870s, with the centralised urban water services dramatically improving the hygiene of urban areas (Harremoes 1997, Chocat and others 2001).

However, the technical literature contains many examples of adverse economic and environmental impacts associated with this traditional approach to water service provision (Butler and Maksimovic 1999, Lawrence and others 1999, Bertrand-Krajewski and others 2000, Mouritz 2000, Marsalek and others 2001, Vlachos and Braga 2001, Mitchell and others 2003). These include the following: impairment of aquatic habitat and modifications to natural ecosystems due to reduced environmental flows; increased waste disposal, resulting in negative consequences for native flora and fauna and stream flow quality of river basins and coastal waters; inadequate handling of contaminants and nutrients; significant energy and chemical usage (e.g., chlorine); and high economic cost of rehabilitation and replacement of aging water infrastructure in highly developed urbanised areas, which in many cities is approaching the end of its useful service life. In addition, in areas of urban growth, population increases may well outstrip gains in water use efficiency, producing a need for additional water supply. Historically, water authorities have developed water resources to meet the growth in demand. However, satisfying increases in demand for urban water by sources outside an urban area is facing increasing environmental constraints and competition for water (Marsalek and others 2001), along with uncertainty associated with climate change and the potential for decreased yield from existing water supply catchments. As a result, there is considerable potential for conflict over meeting increased urban water demands through traditional means of supply augmentation.

Internationally, the appropriateness of the traditional centralised urban water supply, sanitation, and drainage systems, each separately designed and operated, is being questioned. Vlachos and Braga (2001) state that if one looks at cities of both developed and developing countries, it becomes apparent that rather urgent decisions must be made with regard to the way in which urban water services are provided. The emergence and eventual widespread acceptance of the paradigm of IUWM has occurred globally during the last 25 years or so (Marsalek and others 2001). Several North American authors have attributed the origins of IUWM, in part, to the activities of the Urban Water Resources Research Council of the American Society of Civil Engineers, during the late 1960s and early 1970s (Grigg 1999, Heaney and others 2000). Certainly, the Council's head, M. B. McPherson, was a strong advocate of applying the idea of a water balance to urban water resource issues, and implied the need for a more holistic and integrated understanding about the way water supply, sanitation, and drainage systems operated.

The origins of the "paradigm shift" that has occurred in Australia is largely attributed to a group of key individuals in Western Australia, who in the early 1990's were calling for a new approach to urban planning and design, based on the premise that conventional water supply, sewerage, and drainage practices that rely on conveyance and centralised treatment and discharge systems cannot be sustained in the long term (Mouritz 1996). So, this "new paradigm" of IUWM places an emphasis on demand-side management as well as supply-side management, utilisation of nontraditional water resources, and the concept of fit-for-purpose and decentralisation, which appears in much of the literature discussing urban water and sustainability (see Table 1, Newman and Mouritz 1996, Varis and Somlyody 1997, Niemczynowicz 1992, 1999, Mitchell and others 2002). Niemczynowicz (1999) observed that urban water management was also becoming integrated with land use policy, town and landscape planning, the development approvals process, building construction, economics, regulation and legislation, education and social acceptance, and community involvement.

In the author's view, the principles of IUWM can be summarised as follows.

1. Consider all parts of the water cycle, natural and constructed, surface and subsurface, recognising them as an integrated system.
2. Consider all requirements for water, both anthropogenic and ecological.
3. Consider the local context, accounting for environmental, social, cultural, and economic perspectives.
4. Include all stakeholders in planning and decision-making processes.
5. Strive for sustainability, aiming to balance environmental, social, and economic needs in the short, medium, and long term.

The key to IUWM is that individual processes should be planned and managed in such a way that the collective impact be minimised, and the collective system efficiency be maximised, as much as practically possible. The most important benefit of an integrated approach to urban water systems is the potential to increase the range of opportunities available in order to be able to develop more sustainable systems. The primary aim of IUWM is to enable multifunctionality of urban water services to optimise the outcomes achieved by the system. The dimensions of this multifunctionality include (Mouritz 1996, Aspegren and others 1997, Butler and Maksimovic 1999, Lawrence and others 1999, Heaney and others 2000) affordability, amenity, including recreation, community satisfaction, ecosystem protection, energy usage and greenhouse gas emissions, equity, groundwater management, maintenance of biodiversity, pollution prevention and control, public health protection and sanitation, sharing of water

Table 1. Characteristics of "old" and "emerging" paradigms of urban water systems (Source: Pinkham 1999)

The old paradigm	The emerging paradigm
Human waste is a nuisance. It should be disposed of after treatment.	Human waste is a resource. It should be captured and processed effectively, used to nourish land and crops.
Stormwater is a nuisance. Convey stormwater away from urban area as rapidly as possible.	Stormwater is a resource. Harvest stormwater as a water supply, and infiltrate or retain it to support aquifers, waterways, and vegetation.
Demand is a matter of quantity. Amount of water required or produced by different end-users is the only parameter relevant to infrastructure choices. Treat all supply side water to potable quality, and collect all wast water for treatment.	Demand is multifaceted. Infrastructure choice should match the varying characteristics of water required or produced for different end-users in terms of quantity, quality, level of reliability, etc.
One use (throughput). Water follows one-way path from supply, to a single use, to treatment and disposal to the environment.	Reuse and reclamation, Water can be used multiple times, by cascading from higher to lower quality needs, and reclamation treatment for return to the supply side of infrastructure.
Grey infrastructure. Infrastructure is made of concrete, metal, or plastic.	Green infrastructure. Infrastructure includes not only pipes and treatment plants, made of concrete, metal, and plastic, but also soils and vegetation.
Bigger/centralised is better for collection system and treatment plants.	Small/decentralised is possible, often desirable for collection system and treatment plants.
Limit complexity and employ standard solutions. Small number of technologies by urban water professionals defines water infrastructure.	Allow diverse solutions. Decision makers are multidisciplinary. Allow new management strategies and technologies.
Integration by accident. Water supply, wastewater and stormwater may be managed by the same agency as matter of historical happenstance. Physically, however, three systems are separated.	Physical and institutional integration by design. Linkages must be made between water supply, wastewater, and stormwater, which requires highly coordinated management.
Collaboration = public relations. Approach other agencies and public when approval or pre-chosen solution is required.	Collaboration = engagement. Enlist other agencies and public in search for effective solutions.

resources with other users, including the environment, stormwater flow management, including flood protection, stormwater quality management, waste minimisation including solid waste recycling and management and water supply. (Note that ecosystem protection includes the maintenance of the natural surface and groundwater balance within urban areas and the protection of supply catchments and receiving waters.)

There is a broad range of tools that are employed within IUWM, including, but not limited to water conservation and efficiency; water sensitive planning and design, including urban layout and landscaping; utilisation of nonconventional water sources including roof runoff, stormwater, greywater and wastewater; the application of fit-for-purpose principles; stormwater and wastewater source control and pollution prevention; stormwater flow and quality management; the use of mixtures of soft (ecological) and hard (infrastructure) technologies; and nonstructural tools such as education, pricing incentives, regulations, and restriction regimes.

The case studies reviewed in this article each employ a mix of these tools, depending on the projects' objects and site characteristics, providing practical demonstrations of how the application of IUWM produces urban water systems that depart from traditional practice in Australia. For example, beyond the mandatory installation of a 6/3-L dual-flush toilet, traditional practice would not have resulted in any water usage efficiency measures being included within the developments (which occurred in half of the case study sites;

Table 2, and traditional practice certainly would not result in the utilisation of roof runoff, stormwater, greywater, or wastewater as a second source of supply water, thereby reducing the volumes of potable water piped to the site and the volumes of stormwater and/or wastewater leaving the site.

The first principle of IUWM, listed above, is based on the recognition of the connectivity of water resources, both natural and man-made, which contribute to interdependencies of actions of individual users or developers (Marsalek and others 2001), with these interdependencies being particularly strong in urban areas, providing an impetus for their management through integrated urban water management. Changes to a system will have downstream or upstream impacts that will affect cost, sustainability, or opportunities. Therefore, proposed changes to a particular aspect of the urban water system should include a comprehensive view of the other items and consider the influence on them.

The translation of the concept of IUWM into the practice of urban water system planners and designers has varied internationally. In relation to urban drainage, Chocat and others (2001) termed this as the creation of "national drainage schools of thought", observing that there are quite different approaches being developed, especially in Australia, Germany, France, Japan, the United Kingdom, Denmark, and the United States. Chocat and others (2001) went on to state that they considered that the international exchange of ideas is less influential than in other fields, because the problems encountered are different in each country. It is the author's opinion that this lack of international exchange of ideas goes well beyond the field of urban drainage and applies to IUWM more broadly.

The application of the principles of IUWM in Australia has largely been limited to the technical dimension of urban water service provision, with a predominance of the use of demonstration sites as a means to trial new technologies and methods for design and decision making. For this reason, a critical review of recent experience in implementing these demonstration sites is necessary to determine the successes and weakness of response of the Australian water industries to the paradigm shift to IUWM.

Reviewing Current Australian Practice

The review focuses on the practice and implementation of IUWM, rather than the specific structural technologies and non-structural techniques utilised, and focuses on the total water cycle integration aspects of IUWM, as opposed to the institutional and sociopolitical aspects. Rauch and others (2005) stated that IUWM is being pursued at two conceptual levels, one being the technical infrastructure level and the other being the sociopolitical level. To date, virtually all Australian IUWM practice has occurred within the technical realm, leading to this bias within the review. Total water cycle integration is defined as the collective consideration of the water supply, stormwater, wastewater, and groundwater components of urban water service provision.

Development projects that are either built or likely to be built, where an integrated approach to water servicing has been taken, have been considered, with selection criteria for case studies begin the following:

- Demonstration of a total water cycle integration approach. Therefore, this would be not just an example of best practice water supply, stormwater or wastewater management individually but also best practice in at least two of these three realms. Best management practices can be structural or nonstructural, although more than one single technology or technique must be utilised.
- Representative of the spectrum of climate zones, size of development, resultant land use type, greenfield, infill and redevelopment that occur in Australia.
- Larger than a single land block scale development.
- Sufficiently documented and information available to enable comprehensive review.

Fifteen case studies were reviewed, spanning from neighbourhood to regional scale urban developments, representing a diversity of Australian climate zones, development types, and land use. The case study sites were a mixture of planned developments, currently undergoing construction or fully operational. The majority of information contained in the review is drawn from that available in the public realm, although some additional information is drawn from informal discussions with several individuals either directly involved in, or linked to, the case study sites.

Each case study was assessed in relation to the following; the type of development in terms of descriptors such as land use, size, location, climate zone, greenfield or retrofit, and number of dwellings; the driver for the development adopting an IUWM approach; the features of IUWM that were implemented, both structural and nonstructural; the total water cycle and contaminant flux benefits of the IUWM system; the other benefits of the IUWM system (in accordance with the multifunctionality dimensions listed above); and the reported learnings, positive and negative, including operation and maintenance implications.

Capital, operating, and maintenance costs are not considered in this review, because this is an area fraught with difficulty; clear identification of the boundaries of the water system included in the costing, the method used to calculate the costs, and the underlying assumptions must be clearly stated before any reasonable understanding of the cost implications of IUWM can be gained. Also, in many case studies, a conventional water-servicing approach was not feasible; therefore, the notion of cost advantages or penalties relative to conventional practice is not applicable in these situations.

A summary of the selected case studies is provided in Table 2 and locations are illustrated in Figure 1. Summary details of the sites and their IUWM features are provided in Tables 3 and 4, whereas fuller descriptions and an extensive list of references for all sites is available from Mitchell (2004). The following sections of this article draw on this case study review, first commenting directly on the findings in relation to the above criteria, next a brief critique of the role of these project in progressing IUWM practice, and then there is a more general discussion about IUWM in Australia. As can be seen in Table 3, where possible, the total water cycle implications of the approach taken in each case study are reported. Unfortunately, these implications have not always been assessed and/or made available in the public realm. In addition, only occasionally was there mention of (or research into) the changes in the flux of nutrients and other water contaminants. In general terms, the reported social, environmental, and economic benefits and dis-benefits of the water servicing approach of each of the case study sites are discussed where the availability of information allows.

Development Characteristics

It can be seen in Table 2 that the majority of sites were neighbourhood scale, although the more recent case study sites (classed as "In Development" in Table 2) are predominantly larger subdivisional and regional scale developments, This can be interpreted as both an endorsement of the IUWM paradigm, because larger scale systems involve more risk and require the support of a greater number of stakeholders and the wider community and also due to the perception that larger systems are more effective from a treatment technology sizing and operational perspective. It is likely to be an economically sound trend, because research is suggesting that the optimum scale of integrated water recycling systems is in the range of 1000 to 10,000 connections (N. Booker, personal communication, Fane and others 2002).

The majority of case studies are located in the temperate zone (Table 1), based on the Köppen climate classification system (as applied by Australian Bureau of Metrology, www.bom.gov.au). The review did not identify any barriers to implementation unique to subtropical regions, so this bias towards implementation in temperate zones is most likely due to the geographic spread of population within Australia and regional drivers for innovation. Therefore, the principles of IUWM are equally applicable in any climate zone. There is a longer history of implementation in the states of NSW and South Australia. More recently, the South-East Queensland region has taken significant steps towards the uptake of IUWM within standard practice. This has been led by Brisbane City Council and, more recently, Gold Coast City Council with the Pimpama Coomera Water Futures Project (Gold Coast Water 2003), resulting in a small number of case studies falling in the subtropical zones of Australia, with several other sites undergoing feasibilities studies at the time of the review.

The adoption of IUWM occurred in both state capital cites and regional centres. For example, Fig Tree Place is in Newcastle, and the Thurgoona Campus of Charles Sturt University is located on the fringe of the regional centre of Albury-Wodonga, whereas a further two of the five case studies that are in the development phase are located in regional centres (Sharland Park and Pimpama Coomera). Somewhat surprisingly, no documented case of an implemented IUWM system was found in Western Australia (although excellent examples of water sensitive stormwater management were found, but these did not fit the review criteria). This is despite much of the conceptual thinking underpinning the adoption of IUWM and in particular water sensitive urban design, deriving from the work of a number of key individuals in Western Australia (i.e., Mouritz and Newman 1997).

It can be seen in Table 2 that the adoption of the IUWM approach has occurred in both greenfield and redevelopment situations, with the majority of the operational sites having been redeveloped within existing urban areas, albeit at predominantly neighbourhood scale. Homebush Bay, the site of the "Green Games" (2000 Sydney Olympics) is the only large-scale redevelopment site example currently operating in Australia. Retrofit programs have been used in water conservation, increasing the uptake of efficient fixtures such as shower roses and taps, efficient appliances such as washing machines, and the installation of rainwater tanks and greywater systems within existing properties.

Table 2. Summary of the case study sites features

		Operational										In development				
		Homebush Bay	Rouse Hill	Kogarah Town Square	Figtree Place	Charles Sturt University Thurgoona Campuss	Inkerman D'Lux	Reservior Civic Centre	Carindale Pines	New Haven	Christle Walk	Sharland Park	Mawson Lakes	Aurora	Pimpama Coomera	Manly West ESRD
Spatial scale	Neighbourhood			✔	✔		✔	✔	✔	✔	✔					✔
	Subdivision	✔				✔						✔	✔	✔		
	Urban region		✔												✔	
Climate zone	Temperate	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔		
	Subtropical								✔						✔	✔
Urban type	Capital city	✔	✔	✔			✔	✔	✔	✔	✔		✔	✔		✔
	Regional centre				✔	✔						✔			✔	
Development type	Greenfield		✔			✔			✔	✔			✔	✔	✔	✔
	Redevelopment	✔		✔	✔		✔	✔			✔	✔				
Land use	Residential	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔
	Industrial												✔		✔	
	Commercial	✔		✔			✔						✔		✔	
	Other	✔				✔		✔								
Residential density	Low		✔						✔			✔	✔	✔		
	Medium	✔		✔	✔		✔				✔			✔		
State	New South Wales	✔	✔	✔	✔	✔										
	Victoria						✔	✔				✔		✔		
	Queensland								✔						✔	✔
	South Australia									✔	✔		✔			
Project drivers	Reducing environmental impacts	✔	✔	✔		✔	✔	✔	✔	✔	✔		✔	✔	✔	
	Water resource management	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
	Social			✔	✔		✔			✔	✔			✔	✔	✔
	Economic			✔					✔	✔	✔				✔	✔
Water features	Non structural tools					✔		✔				✔			*	
	Water efficiency	✔		✔		✔		✔	✔		✔			✔	*	
	Potable supply substitution	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	*	✔
	Stormwater quality management	✔	✔	✔	✔	✔	✔		✔	✔		✔	✔	✔	*	✔

Table 2. Continued

	Stormwater flow/flood management	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	*	
	Rainwater/stormwater utilization	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	*	✓
	Greywater/wastewater utilization	✓	✓			✓	✓			✓	✓		✓	✓	*	✓
	Urban form, layout, and design			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	*	
	Organisational arrangements	✓		✓						✓	✓				*	
	Operational and maintenance regimes	✓		✓	✓	✓	✓			✓	✓			✓	*	
Non water features	Solar and or wind energy	✓		✓		✓	✓	✓	✓	✓	✓			✓		
	Energy conservation &/or passive solar design	✓		✓		✓	✓		✓	✓	✓		✓	✓	✓	✓
	Materials selection					✓	✓	✓	✓		✓			✓		✓

However, no retrofit examples fitted the review criteria, and therefore none have been included. Anderson and Iyaduri (2003) provide a clearly articulated integrated approach to the modification of an existing system and benefits that could be reaped, albeit through desktop analysis at this stage.

Commercial and industrial land uses were represented, as well as other land uses including civic, sporting, and educational facilities, although residential land use was the dominant one within the sites reviewed (all but the Reservoir Civic Centre included residential allotments). Within the residential sector, both low-density detached dwellings and medium-density apartment developments had adopted IUWM. There does not appear to be a relationship between development spatial scale and housing density, although a trend towards providing a mixture of housing types within developments was occurring, in line with more general development trends.

Drivers for Adopting IUWM

The dominant reported drivers for the adoption of IUWM was the reduction in environmental impacts of urban development, particularly on water resources. In addition, all but three sites incorporated energy and material selection aspects into their development (these exceptions being Rouse Hill, Figtree Place, and Sharland Park; Table 2). Several sites had social and/or economic primary drivers in addition to the environmental driver. The exceptions to these comments are Fig Tree Place, whose major driver was the provision of affordable housing on an environmentally constrained site, and Rouse Hill, whose exclusive driver was the reduction of environmental impacts (nutrients due to the discharge of wastewater).

It is important to note that a number of the case study sites would have been difficult to service through conventional means because of environmental or infrastructure constraints. Thus, an innovative approach was necessary to enable the development to proceed rather than a true alternative to conventional practice. Rouse Hill, Aurora, and Manly West ESRD (Environmentally Sustainable Residential Development) are all prime examples of this. Often they also have had "champions" driving the process and keeping it on track.

IUWM Features Implemented

A broad spread of IUWM features have been utilised within the sites. Half of the sites employed water-efficient practices (Table 2) (the use of a compulsory low-flush toilet is now mandatory and so it was discounted). This is a somewhat surprisingly low propor-

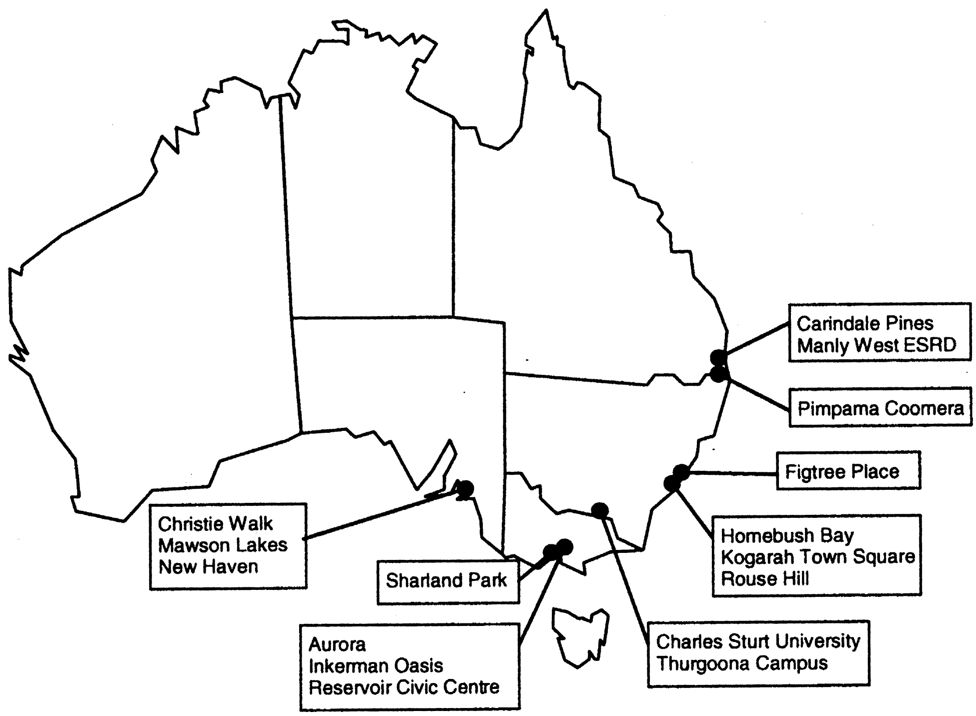

Figure 1. Locations of the case study sites within Australia.

tion given the current emphasis placed on water efficiency within the Australian water industry. Its lack of inclusion in the operational sites can in part be explained by the lesser emphasis on water efficiency during the early 1990s when many of these projects were first conceived. However, this explanation does not apply to Inkerman D'Lux and Sharland Park, with these sites reporting the use of water-efficient fixtures and the promotion of water-efficient appliances and landscaping, despite being planned and/or constructed more recently.

There is a gradual movement towards the utilisation of distributed and at-source approaches to IUWM, as opposed to bottom-of-catchment approaches. For example, older sites often incorporated features such as a few large wetlands for managing stormwater quality or sole adoption of large-scale "dual-reticulation" of nonpotable water (dual reticulation is a term commonly used in Australia to describe the installation of a secondary water supply reticulation system alongside a potable water supply reticulation system, hence it being called "dual"). However, more recently, more localised alternatives are being implemented such as combinations of grass swales, bioretention systems and smaller distributed wetlands, and smaller scale potable substitution approaches such as rainwater tanks and greywater systems. There is some way to go, however, before there is wide-scale incorporation of source control and prevention at source (i.e., the use of alternative household chemicals). The use of nonstructural tools in several of the sites tend to be supplementary measures supporting the structural measures rather than being integral to system design in their own right.

It is important to bear in mind that most of the operational case study sites were first conceived some 5 to 10 years ago. Therefore, the level of innovation incorporated into the water system and the degree to which they "pushed the envelope" should be judged against the state of IUWM knowledge and understanding at the time that planning and design decisions were being made. Subdivisional and regional developments, because of the nature of staging land releases, take a long time, and by the completion of the development, the water-servicing approach may no longer be leading edge, even if it was fairly ambitious when first proposed.

Little mention was made of biosolids management, with focus on recycling the aqueous portion of wastewater, rather than the solids portion. Likewise, few case studies considered the mitigation of the flux of contaminant loads within the urban water cycle due to the water-servicing approach adopted or proposed, other than through stormwater quality management measures. This is, belived by the author to be due to the separation of technical expertise and responsibility for biosolids management from water

Table 3. Description of case study sites that where operational at the time of the review

Site details	**Christie Walk, Adelaide, South Australia** Commenced in 1998, first occupants in 2001, final stage commenced in 2004. Mixed density community housing comprising of 14 households and community facility on a 0.2-ha site.
IUWM features	Water efficiency including low flow shower heads, flow restrictors, low water usage plants, subsurface irrigation systems, and a communal laundry. Wastewater treatment and use for irrigation. Stormwater used for toilet flushing & irrigation, Rooftop garden and landscaping.
Total water cycle benefits	Final values not yet available. Estimated sizable reduction in potable water supplied to the site and a reduction in stormwater, wastewater, and the associated contaminant loads leaving the site.
Site details	**New Haven Village, Adelaide, South Australia** Commenced in 1992 and completed in the late 1990s. Medium density residential with 65 households on a 2-ha site.
IUWM features	On-site stormwater and wastewater treatment and use. Grinder pump sewers. Source control of stormwater.
Total water cycle benefits	A 30% reduction in potable water usage and near elimination of stormwater and wastewater discharge. Contaminant loads associated stormwater and wastewater treated and assimilated within the site.
Site details	**Carindale Pines, Brisbane, Queensland** Site works completed in 2001, construction of houses occurring. Low density residential land use with 31 households in a 1%-ha site.
IUWM features	Rainwater tanks. Water efficiency. Landscaping and urban form. Stormwater quality and flow management.
Total water cycle benefits	Greater than 80% reduction in potable water usage, with an estimated 70% to 80% of residential demands meet by rainwater tanks. Internal water usage efficiency reduces wastewater loads. Reduced stormwater flows and improved stormwater quality.
Site details	**Rouse Hill, Sydney, New South Wales** Commenced in 2001, expected completion in 2010–2015 comprising low density residential development. The scheme has the capacity to supply 35,000 homes, although at present around 12,000 homes are connected with some 3000 more infill connection currently under development.
IUWM features	Dual reticulation of treated wastewater for toilet flushing, garden watering, and car washing. Stormwater flow & quality management. Rainwater tank and washing machine rebates available.
Total water cycle benefits	Estimated 20% reduction in the use of potable water. Reduced release of stormwater and treated wastewater into the Hawkesbury/Nepean River system and minimal observed nutrient impact on the Hawkesbury/Nepean River system
Site details	**Homebush Bay, Sydney, New South Wales** Completed in 2000 with 2400 medium density residential households, industry, commercial and sporting facilities on a 90-ha site.

(Continued)

Table 3. Continued

IUWM features	Dual-reticulated supply, with mix of stormwater and wastewater in the nonpotable system. Water efficiency. Stormwater quality and flow management.
Total water cycle benefits	50% reduction in potable water demand. 850 mL/y reduction in wastewater discharge. Reduction in total flow of stormwater leaving the site as well as reduction in peak flows and flood damage potential. 70–90% reduction in suspended solids and nitrogen in the stormwater runoff.
Site details	**Kogarah Town Square, Sydney, New South Wales** Commenced in 1997 with medium density residential, commercial, retail, and municipal land uses. The development comprises 194 residential apartments, 224 parking spaces, 2500 m^2 of commercial space, and 2500 m^2 of retail outlets, 240 m^2 of civil exhibition space, and the Town Square.
IUWM features	Rainwater use for toilet flushing, car washing, and water feature, while stormwater use for irrigation of open space within the site. Water efficiency measures include water-efficient toilets, showerheads, and appliances and flow restrictors and aerating taps. Landscaping integrated into stormwater quality and flow management approach.
Total water cycle benefits	Reduced potable water use by 42% through a combination of water efficiency, rainwater, and stormwater use. Reduced volume of rainwater and stormwater leaving the site by 85%. Reduced volume of wastewater leaving the site by 4500 kL. Reduced concentration and load of stormwater contaminants leaving the site.
Site details	Fig Tree Place, Newcastle, New South Wales Completed and occupied since 1998. Medium density residential with 27 households on a 0.6-ha redevelopment site.
IUWM features	Rainwater tanks supply residential hot water and toilet flushing. Aquifer recharge and recovery with ground water used for irrigation and bus washing at the adjacent bus station. Stormwater quality and flow management.
Total water cycle benefits	Estimated 60% reduction in potable water. 100% reduction in stormwater flows and associated contaminants. Wastewater discharge reductions due to indoor water usage efficiency.
Site details	**Charles Sturt University Thurgoona Campus, Albury, New South Wales** Construction began in 1996 and was completed in 1999. University campus and student accommodation in an 87-ha site.
IUWM features	Use of rainwater for building temperature control and clothes washing, stormwater for landscape irrigation, and greywater for subsurface irrigation and clothes washing. Water-efficient usage including water-efficient taps and shower heads and low water use landscaping. Stormwater flow and quality management. Composting toilets. Landscaping and plant selection.

(Continued)

Table 3. Continued

Total water cycle benefits	Minimal potable water usage. No blackwater generated and all greywater handled within the site. Minimal stormwater flows from the site, with the system designed to discharge stormwater in a 1 in 20-year event and above.
Site details	**Inkerman D'Lux, Melbourne, Victoria.** Initiated in 1996 and occupied in 2003. Medium density residential and retail with 236 apartments on a 1.2-ha site.
IUWM features	Combined treated greywater and stormwater use for toilet flushing and subsurface landscape and garden irrigation. Stormwater flow and quality management. Landscaping and roof gardens.
Total water cycle benefits	Estimated up to 40% reduction in potable water usage. Reduced wastewater and Stormwater flowing from the development. Reduction in contaminants associated with Stormwater and wastewater. Reduced landscape and garden fertiliser usage.
Site details	**Reservoir Civic Centre, Melbourne, Victoria.** Redevelopment—completed in 2003. Darebin City Councils civic centre providing council and community facilities.
IUWM features	Water efficiency with low flow taps, toilets, and showers, waterless urinals, efficient dishwashers. Rainwater used for toilet flushing and Stormwater used for garden bed irrigation. Real-time reporting of water use and rainwater tank storage.
Total water cycle benefits	Estimated potable water saving of 1200 to 1400 kL/y. Reduction in Stormwater leaving the site, estimated to be up to 600 kL/y. Reduced wastewater leaving the site, on the order of several hundred kL/y.

supply and stormwater and to a lesser extent wastewater management that occurs within the Australian water industry, as is the case in many countries around the world (Grigg 1986, van Rooy and others 1993).

The degree of integration between water supply, stormwater, and wastewater components of the case study sites varies from highly integrated to minimally integrated. For example, Rouse Hill includes water supply, stormwater, and wastewater management features, but these features are not well integrated with one another, largely due to the initial emphasis on nutrient reduction to the Hawkesbury-Nepean river system, rather than water cycle management. Even within stormwater management, Lloyd (2001) commented that often the water sensitive stormwater management technologies are not well integrated into the landscape to form a treatment train, but instead act in isolation from one another.

Total Water Cycle and Contaminant Flux Benefits

The reported total water cycle and contaminant flux-benefits of the sites are presented in Tables 3 and 4. These values are largely based on estimates, because even for the operational sites there was a lack of monitoring and postimplementation performance analysis to determine the extent to which the sites achieved their original water-servicing project goals. There are several notable exceptions, where the sites have been well monitored and assessed, including Fig Tree Place, Kogarah Town Square, and Reservoir Civic Centre.

Estimated potable water usage reductions range from rather modest (20% for Rouse Hill) through to aiming for near self-sufficiency (Manly West ESRD). Reductions in stormwater volumes leaving the site range from minor (Rouse Hill) to near elimination (New Haven, Fig Tree Place, Charles Sturt University).

Table 4. Description of case study sites that were in development at the time of the review

Site details	**Mawson Lakes, Adelaide, South Australia** Commenced in 1997, expected completion in 2010. Nonpotable system operational early 2004. Low density residential and industrial and commercial land use with 4000 households on a 620-ha site.
IUWM features	Aquifer storage and recovery used to provide a seasonal balancing store. Dual reticulation of nonpotable treated wastewater used for toilet flushing, garden watering, car washing and other outside uses (expect swimming pools and other body contact activities). Stormwater quality management.
Total water cycle benefits	Aim to reduce usage of potable water by 70%.
Site details	**Aurora, Melbourne, Victoria** Planned commencing occupation in ~2005. Mixed density residential with 8455 households on a 668-ha site.
IUWM features	Rainwater tanks for hot-water use. Dual-reticulation of nonpotable water for toilet flushing, gardening watering, and the irrigation of open spaces. Stormwater flow and quality management.
Total water cycle benefits	Estimated reduction of up to 69% in potable water. Reduced Stormwater flow from the site. 100% reduction in wastewater flows from site. Estimated reduction of 24 tonnes of nitrogen and 8 tonnes of phosphorus leaving site.
Site details	**Sharland Park, Geelong, Victoria** Site works completed in 2003 and land blocks sold. Low density residential and open space with 36 households.
IUWM features	Plant selection and landscaping. Stormwater flow and quality management. Stormwater use for open space irrigation.
Total water cycle benefits	Reduced potable water usage. Reduced Stormwater peak and total volume of flow. Improved Stormwater quality leaving the site.
Site details	**Pimpama Coomera, Queensland** Proposed regional development, master planning process complete early 2004. Regional growth from a population of 5000 to 150,000 in an area of ~6,000 ha.
IUWM features	Wastewater recycling for outdoor use and fire fighting. Innovative sewer design. Water efficiency. Rainwater tanks.
Total water cycle benefits	Reduced potable water usage. Reduced the volume of wastewater and associated loads of contaminants released into the environment. Reduced stormwater volumes and improved quality.
Site details	**Manly West ESRD, Brisbane, Queensland** Proposed project. 20 houses in a 1.9-ha site.
IUWM features	Aims for self-sufficiency in water supply and wastewater management. Rainwater used for kitchen, bathroom, and laundry end uses. Separation of greywater and blackwater. Treated wastewater for subsurface irrigation and treated greywater for toilet flushing. Nutrient adsorption. Stormwater flow and quality management. Composting of biosolids and other site organic waste.

Table 4. Continued

Total water cycle benefits	Estimated 90% reduction in potable water usage. Estimated 100% reduction in wastewater leaving the site. Reduction in stormwater flows from the site. Significantly reduce the load of contaminants leaving the site.

Wastewater flows entering the centralised sewer system from the site have been modestly reduced through water usage efficiency in some cases (Carindale Pines, Fig Tree Place), Whereas, in others wastewater reuse significantly reduced the occurrence of wastewater discharges (New Haven, Charles Sturt University, Aurora, Reservoir Civic Centre, Manly West ESRD). In one case the centralised sewer system is still used to handle the biosolids generated by the site's wastewater treatment plant (Christie Walk). In comparison to the reporting of water cycle benefits, very few sites reported their estimated or monitored contaminant flux benefits. Those that did calculate these benefits are Homebush Bay, Inkerman D'Lux (Table 3), and Aurora (Table 4).

Other Reported Benefits

Because of the cost and/or environmental impacts associated with servicing the sites using conventional practices, the adoption of IUWM enabled three of the sites (Rouse Hill, Aurora, and Manly West ESDR) to be developed.

Positive community acceptance and resident pride in their water recycling and potable water savings has been reported in association with several sites (Rouse Hill, Homebush Bay, New Haven, Sharland Park). Several sites also report residents appreciating the lower water bills (Fig Tree Place, New Haven) and the amenity the IUWM approach has provided (Fig Tree Place).

However, Marks and others (2002) found that there were varying levels of residential occupant awareness about the nonstandard nature of their water service in the New Haven and Mawson Lakes sites. Ensuring that adequate levels of occupant awareness are maintained requires more effort than when a conventional water-servicing approach is adopted. Mechanisms to maintain continuing occupant awareness should be incorporated during the planning and design process, and responsibility should be assigned during commissioning and operation.

These findings should be viewed in light of broader social research, which has found that the nonconventional nature of the water servicing acts as neither an attractor nor detractor for a potential residential house purchaser (N, Roseath, personal communication). Other factors, such as location, are significantly more influential in the purchasing decision.

Other Lessons from Adopting an IUWM Approach

Many of the parties involved in the IUWM case studies found breaking new ground time consuming, often slowing the development process. Most of the participants are taking an integrated approach to water servicing for the first time and are learning as they go. The current lack of analysis tools and procedural frameworks has meant that, in some cases, different groups in different parts of the country have broken the same "new ground." Other reported difficulties included the lack of adequate guidelines, standards, and regulations, the lack of understanding about appropriate risk management regimes, and the lack of appropriate financial and economic frameworks.

Many of the sites reported problems during the design, construction, and commissioning of the IUWM system. These include odour problems with the dry composting toilets (Charles Sturt University) and construction scheduling problems (Inkerman D'Lux), but mostly problems related to maintaining design integrity throughout the whole process. One site recommended that the development principles be clearly explained to all consultants, construction contractors, and subcontractors during the tendering process to minimise the risk of miscommunication and compromise about the project's IUWM goals (C. Hoyle, personal communication). Another stressed the need to be thorough in all planning and documentation activities, not taking anything for granted (Salan undated).

Despite the difficulties associated with breaking new ground, most sites reported satisfaction in the degree of innovation that was achieved, considering they had successfully demonstrated that IUWM could be applied in practice. In the occasional case, the developer also stated the approach to be commercially viable (e.g., Kogarah Town Square, Carindale Pines), although this was not always the case (e.g., Mawson Lakes, Aurora).

The information associated with the majority of sites made mention of operation and maintenance regimes, although not in sufficient detail to provide insight into lessons learnt in this area. A few case studies appear to have employed nonstandard organisational arrangements for the delivery and operation of the water services although, again, little detail was available.

Twelve of the sites had some form of direct involvement of one or more public organisations. Public organisations have often been involved in the developments in order to provide demonstration projects, with the intention of stimulating private developers to adopt a more integrated approach to water servicing (as well as other sustainability aspects such as energy and social equity).

A number of the developments set up public/private partnerships, formed between a public organisations such as a city council or water authority and a private development consortium (e.g., Inkerman D'Lux, Kogarah Town Square, Rouse Hill). This type of arrangement has generally been successful, enabling the drawing of skills and experience from both public and private organisations. Such arrangements are also a good mechanism to avoid the often-adversarial relationship between a private developer and the various public authorities that are involved in the approval process. This can be a significant benefit, because the nonconventional nature of the water servicing approach often increases the complexity of the approval process and therefore the time and effort invested by a developer and, to a lesser extent, the approval authorities.

The above comment on the value of public/private partnerships in providing solutions supports Niemczyowicz's (1996) view that '-the failure or success of novel systems is less dependent on the form and origin of construction but very much dependent on the commitment of all involved actors. Technical problems can be solved provided that an appropriate supportive infrastructure is created." On a similar note, Mouritz (2000) stated that "if you put a good design team that is willing to work together, it can be done and done well. The interesting thing is that it is often the institutional setting that creates the problems." Thus, the development of public/private partnerships could be considered an important mechanism to minimise the problems created by the institutional setting.

Less formal partnerships or alliances have also been employed to provide a greater pool of skills, as have the accessing of grant money from state and federal government sources. However, words of caution were given by Salan (undated), commenting that increasing the number of groups involved increases the amount of negotiation required and that grants increase the amount of administration. Also, several of the public parties who entered a public/private partnership found that, due to private organisations having greater experience in development, the public organisation can be disadvantaged in negotiations.

Critique of the Role of IUWM Demonstration Projects

In 1999, Niemczynowicz stated that the general application of an IUWM approach "in a pure form is, as yet, mostly in our minds. It has not yet formulated as a consistent methodology." The somewhat haphazard experiences reported in the case studies certainly support the view that this formulation had not occurred during the 1990s and early 2000s, when these IUWM projects where conceived and implemented. The limited knowledge transfer from site to site significantly reduced the extent to which the case studies provided a progressive learning experience for those directly involved and the broader water industry.

In support of both the implementation of both IUWM projects and their role in learning, Mouritz (2000) referred to case study sites such as those reviewed here as learning by doing. He went on to state that demonstration sites are the most appropriate way to learn our way forward, considering that the Australian industry needed more of them, but perhaps more importantly there was a need for them to be documented so that what is learnt is translated into wider practice. Unfortunately, the extent of information available on the IUWM sites varies greatly, from extensively documented in one case (Fig Tree Place) through to poorly documented in the case of a number of examples of IUWM that were insufficiently documented to be included in this review. The documentation that is available often lacks a comprehensive critique of the development, although there are several exceptions, with excellent examples such as those provided for Inkerman D'Lux (Melbourne Water undated) and Kogarah Town Square (Salan undated). In order to allow people to build on the experience of others and enable knowledge gaps to be filled, improved dissemination of knowledge gained and lessons learnt, including pitfalls to be avoided and process followed, is required.

Monitoring is generally limited to that required for system operation, usually dictated by regulation and licensing requirements. There is a lack of systematic performance monitoring, and in the few cases where this has occurred, it is associated with research projects that, by their very nature, have a relatively short life span compared to the operational life of the development and its infrastructure. Long-term performance monitoring is resource intensive, but essential to determine the efficacy of nonconventional systems and their components and to refine their design.

There is also a lack of postimplementation assessment, with much of the documentation ceasing to be updated once the site is commissioned, which is consistent with experience overseas. For example, Marsalek and others (2001) stated that "post-audit is rarely practiced or reported." The authors went on to state "yet it appears inevitable that future progress will depend on learning more about the results of water management schemes and practicing adaptive water management," emphasising the importance of postimplementation assessments in the progressive learning process.

There are a few notable exceptions to the above, including that of Sydney Water Corporation conducting a postimplementation review of the Rouse Hill Project Area water-servicing system. One constraint in this regard appears to be the propensity to report exclusively on success stories, with a lack of interest within the development industry in reporting the less than successful projects or aspects of the IUWM system within a project. Also, many organisations, particularly larger ones, find it a challenge to capture the knowledge of individuals and translate it into more widely held "corporate knowledge." Documenting the process followed can also be challenging because it is often iterative and involves many players, although this is the area in which many major development barriers are encountered.

General Discussion About IUWM in Australia

It has been stated that infrastructure cost savings will only be realised if water authorities downsize or defer augmentation of centralised infrastructure to account for lower system burden achieved by implementing IUWM approaches (Coombes and Kuczera 2002). At the present time, water authorities are not sufficiently confident of the resultant long-term changes in system performance and operation and maintenance costs. They are also aware of the experiences of other utilities, such as energy, who have not been able to realise the projected reductions in end use. As a consequence, they are reticent to diverge very far from traditional infrastructure planning practice, being risk adverse and conscious of the difficulties of enlarging buried infrastructure, such as pipes, once they are constructed. Further research into the changes in system behaviour, and therefore, the changes in design, operation, and maintenance requirements, is required to change this situation. This will require greater activity in systems performance monitoring and analysis as well as tracking, reporting on operational and maintenance regimes (including costs), and broad dissemination of the findings.

Care must be taken not to just shifting the environmental, social, and/or economic dis-benefits of urban water servicing in either time or space. That is, the dis-benefits should not be simply shifted to a new location, such as from a local surface water body to a distant groundwater system, or delayed in time, such as from an immediate negative impact to a slow-building but long-term impact. The lack of a commonly agreed, robust assessment tool or framework that could be used to evaluate the merits of proposed alternative water servicing options, against environmental, social, and economic criteria, considering short, medium, and longer term time, horizons is a key issue in this regard. Such a tool would enable issues such as an apportioning of developer charges and incentives, management of risk (financial, public health, environmental, political), end user and community acceptance, and operational roles and responsibilities to be assessed in an agreed manner between developers and approval agencies.

There is certainly much research required in the area of risk, of which there are many dimensions (for example, public health, financial, political, environmental, and technical). However, more broadly, there is a need for risk assessment frameworks that are designed for use within an IUWM assessment framework. Work in this area has begun by a number of groups, but it is a large area, and requires sizeable resources to be addressed fully. Research into risk should also be linked to demonstration project monitoring programs, providing quantification of risk whenever practicable. It should also take a balanced view of the risks in the existing conventional system and the potential benefits of alternate systems.

Conclusion

The last decade has been a period of substantial change in the urban water industry, in Australia and internationally. A new paradigm of IUWM has emerged and appears to have taken root. As Niemczynowicz (1999) stated, "we are beginning to talk not only about some new isolated technologies but instead about new *total system solutions*." The paradigm of IUWM and total water cycle solutions has evolved alongside the planning and implementation of the "demonstration sites" that have formed the basis of this article.

The review of the case studies has found that it certainly is possible to successfully implement IUWM approaches, in a manner that is both technically sound and acceptable to stakeholders. The reported total water cycle benefits ranged from modest through to significant reductions in the impact of the development on the water cycle. Public organisation involvement in the planning and implementation of the IUWM case studies has been very strong, either in an active role, driving or being party to the development, or in more of a support role. Partnerships or alliances were often formed to deliver the case study projects, and are important to the IUWM process. Project champions also have often emerged, providing the required drive to travel the still less known path of IUWML.

It was observed, though, that there is still room for greater integration of the water supply, stormwater, and wastewater components of the urban water cycle. Other areas in which current practice can be improved include information dissemination and sharing of learnings, enhancing the skills of a greater number of staff in both public and private organisations, and assessing the performance of the IUWM systems and their component technologies.

Efforts should be invested in performance monitoring and postimplementation assessments of demonstration projects, particularly in the area of the total water cycle outcomes and the degree to which the original project goals and objectives were delivered. The outcomes of these assessments, along with the results of performance monitoring, should be widely disseminated to allow others to learn from the demonstration projects, enable more informed risk assessments of proposed IUWM options, and continue to move forward in the quest towards more sustainable urban water systems.

The creation and maintenance of sustainable urban water services require technologies, actions, and behaviours of many actors to produce the desired outcomes. IUWM solutions will take many forms, tailored to the specific characteristics and requirements of diverse locations that make up Australian cities and towns. There is much to be done before these cities and towns tread more lightly in terms of water service provision but, given the significant advances made in the practice of IUWM in the last 10 years, and the momentum for change within the water industry and the broader community, the water industry appears to be heading along the right path. Many steps along this path are available, including water recycling, water efficiency programs, and water-sensitive stormwater management, and progressively these individual IUWM tools are being combined to create the integrated total system solutions that urban communities require.

Acknowledgments

This article is the result of a project funded by CSIRO Water for a Healthy Country and the Australian Water Conservation and Reuse Research Program.

Literature Cited

Anderson, J., and R. Iyaduri. 2003. Integrated urban water planning: Big picture planning is good for the wallet and the environment. *Water Science and Technology* 47:19–23.

Aspegren, H., B.-G. Hellstrom, and G. Olsson. 1997. The urban water system— a future Swedish perspective. *Water Science and Technology* 35:33–43.

Bertrand-Krajewski, J.-L., S. Barraud, and B. Chocat. 2000. Need for improved methodologies and measurements for sustainable management of urban water systems. *Environmental Impact Assessment Review* 20:323–331.

Butler, D., and C. Maksimovic. 1999. Urban water management—challenges for the third millenium. *Progress in Environmental Science* 1:213–235.

Chocat, B., P. Krebs, J. Marsalek, W. Rauch, and W. Schilling. 2001. Urban drainage redefined: From stormwater removal to integrated management. *Water Science and Technology* 43:61–68.

Coombes, P. J., and G. Kuczera. 2002. Integrated urban water cycle management: Moving towards system understanding. *in* Proceedings of the 2nd National Conference on Water Sensitive Urban Design, Engineers Australia, 2–4 September 2002. Brisbane, Australia.

Fane, S. A., N. J. Ashbolt, and S. B. White. 2002. Decentralized urban water reuse: The implications of system scale for cost and pathogen risk. *Water Science and Technology* 46:281–288.

Gold Coast Water. 2003. Pimpama Coomera Water Futures Master Plan Options Summary Report. Gold Coast Water, 32 pp. Available at http://www.goldcoast.qld.gov.au/attachment/goldcoastwater/PC_SummaryExecReport.pdf.

Grigg, N. S. 1986. Urban water infrastructure. John Wiley and Sons, New York 328 pp.

Grigg, N. S. 1999. A systemic approach to sustain and civilise urban water systems. *in* Proceedings of the EPA Conference on Futures of Urban Water Systems, 29 August 1999, Austin, Texas.

Harremoes, P. 1997. Integrated water and waste management. *Water Science and Technology* 35:11–20.

Heaney, J. P., L. Wright, and D. Sample. 2000. Sustainable urban water management. Pages 75–120 *in* R. Field, J. P. Heaney, R. Pitt (eds.), Innovative urban wet-weather flow management systems. Technomic Publishing Company, USA.

Lawrence, A.I., J. B. Bills, J. Marsalek, B. Urbonas, and B. C. Phillips. 1999. Total urban water cycle based management. Pages 1142–1149 *In*: Proceedings of the 8th International Conference Urban Storm Drainage, 30 August–3 September 1999. Sydney, Australia.

Leitmann, J. 1999. Sustaining cities: environmental planning and management in urban design. McGraw-Hill, USA 412 pp.

Lloyd, S. D. 2001. Water sensitive urban design in the Australian context; Synthesis of a conference held 30–31 August, Melbourne, Australia, CRC for Catchment Hydrology, Report 01/7, 26 pp.

Marks, J., N. Cromar, F. Howard, D. Oemcke, and M. Zadoroznyj. 2002. Community experience and perceptions of water reuse. *in* CD proceedings of Environ 2002 IWA World Water Congress, 7–12 April 2002. Melbourne, Australia.

Marsalek, D. J., M. Q. Rochfort, and P. D. Savic. 2001. Chapter 2: Urban water as a part of integrated catchment management. Pages 37–83 *in* C. Maksimovic, J. A. Tejada-Guibert (eds.), Frontiers in urban water management deadlock hope. IWA Publishing, London.

Melbourne Water. (undated) "Site 1—Inkerman Oasis, St Kilda," 8 pp. Available at http://www.melbournewater. com. au/content/library/wsud/case_studies/inkerman_oasis. pdf.

Mitchell, V. G., R. G. Mein, and T. A. McMahon. 2002. Utilising stormwater and wastewater resources in urban areas. *Australian Journal of Water Resources* 6:31–43.

Mitchell, V. G., T. A. McMahon, and R. G. Mein. 2003. Components of the total water balance of an urban catchment. *Environmental Management* 32:735–746.

Mitchell, V. G. 2004, Integrated urban water management: A review to current Australian practice. 58 pp. Available at http://www.clw.csiro.au/priorities/urban/awcrrp/stage1-files/AWCRRP_9_Final_27Apr2004.pdf.

Mouritz, M. J. 1996. Sustainable urban water Systems: Policy and professional praxis. Unpublished PhD thesis, Institute for Science and Technology Policy, School of Social Science. Murdoch University, Perth.

Mouritz, M. 2000. Water sensitive urban design—where to now? in Proceedings of the Water Sensitive Urban Design Workshop, Aug 30–31 2000. Melbourne, Australia.

Mouritz, M., and P. Newman. 1997. Sustainable urban water systems: Issues and opportunities. Urban Water Research Association of Australia. Research Report No 116.

Newman, J., and M. Mouritz. 1996. Principles and planning opportunities for community scale systems of water and waste management. *Desalination* 106:339–354.

Niemczynowicz, J. 1992. Water management and urban development: A call for realistic alternatives for the future. *Impact of Science on Society* 42:133–147.

Niemczynowicz, J. 1996. Challenges and interactions in water future. *Environmental Research Forum* 3–4:1–10.

Niemczynowicz, J. 1999. Urban hydrology and water management—Present and future challenges. *Urban Water* 1:1–14.

Pinkham, R. 1999. 21st century water systems: Scenarios, visions and drivers, 20 pp. Available at http://www.rmi.org/images/other/Water/W99-21 21CentWaterSys.pdf.

Rauch, W., K. Seggelke, R. Brown, and P. Krebs. 2005. Integrated approaches in urban storm drainage: Where do we stand? *Environmental Management* 35:1–14.

Salan, R. undated. Case study 8—Kogarah Municipal Council, Kogarah Town Square—A sustainable development. ESD information guide, 10 pp. Available at www.lgov.org.au/docs/Policy/Environment/ESD/ESDsite/CaseStudy8.pdf.

van Rooy, P. T. J. C., D. L. Anderson, and P. J. T. Verstraelen. 1993. Integrated water management considers whole water system. *Water Environment & Technology* 5:38–40.

Varis, O., and L. Somlyody. 1997. Global urbanization and urban water: can sustainability be afforded? *Water Science and Technology* 35:21–32.

Vlachos, P. E., and P. B. Braga. 2001. Chapter 1: The challenge of urban water management. Pages 1–34 *in* C. Maksimovic, J. A. Tejada-Guibert (eds.), Frontiers in urban water management, deadlock or hope. IWA Publishing, London.