BEDP ENVIRONMENT DESIGN GUIDE

Water Sensitive Urban Design – the Journey Thus Far

Tony H F Wong

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Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- The pursuit of 'sustainability' has emerged in recent years as a progression from previous 'environmental protection' endeavours. Ecologically Sustainable Development (ESD) can be described as going beyond the protection of the environment from the impacts of pollution, to protecting and conserving natural resources.
- Since its initial conceptualisation as an urban planning and design framework for more sustainable management of urban water, WSUD has evolved from its early association with stormwater quality management to a broader framework for integrating the holistic management of the three urban water streams with the practice of urban design.
- WSUD brings 'sensitivity to water' into urban design. The words 'water sensitive' define a new paradigm in integrated urban water cycle management that combines the various disciplines of engineering and environmental sciences associated with the provision of water services, including the protection of aquatic environments in urban areas. Community values and aspirations of urban places necessarily govern urban design decisions and therefore water management practices. Collectively WSUD integrates the social and physical sciences.

Basic Strategies

WSUD is centred on integration at a number of levels:

- the integrated management of the three urban water streams of potable water, wastewater and stormwater
- the integration of the scale of urban water management from individual allotments and buildings, to precincts and regions
- the integration of sustainable urban water management into the built form, incorporating building architecture, landscape architecture and public art
- the integration of structural and non-structural sustainable urban water management initiatives.

Cutting EDGe Strategies

- Integrated management of the three urban water streams of potable water, wastewater and stormwater, by accessing alternative sources of water with their uses guided by a 'fit-for-purpose' approach to water sources and associated quality.
- Research studies have been able to demonstrate the scalability of most stormwater treatment technologies. With these systems being scalable according to catchment area (within a hydrologically-similar region), close collaboration with landscape architects and urban designers has made it possible to incorporate many of these technologies into the urban form at a range of spatial scales.
- The success of WSUD is underpinned by the integration of structural and non-structural sustainable urban water management initiatives that include policies for the sustainable operation of structural measures. These include setting design objectives that are consistent with the capability of existing technologies (best practice), and a simplified and transparent assessment of compliance to design objectives.

Synergies and References

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- *BEDP Environment Design Guide*: DES 13: An Introduction to Water Sensitive Design.

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Water Sensitive Urban Design – the Journey Thus Far

Tony H F Wong

This paper presents an overview of the current state of adoption of Water Sensitive Urban Design (WSUD) and future trends in Australian practice. At the inaugural conference on WSUD in Melbourne 2000, several inter-related issues were identified as essential elements in underpinning the effective adoption of WSUD. Since 2000 progress on each of these issues has led to further advancement of WSUD in Australian practice. Successes in implementation are however varied, a reflection of an industry transitioning to a new paradigm.

The technology and design of WSUD elements has evolved since 2000 with many projects demonstrating innovation at a range of scales. Current trends in concept and systemic design, and recent research findings, are rapidly advancing innovation in this regard. Construction and maintenance practices are identified as one of the recurring impediments to the effective implementation of many excellent conceptual designs of WSUD. Institutional reform for integrated urban water cycle management remains elusive. The socio-institutional dimension of WSUD, while instrumental to effective policy development and technology diffusion efforts, still remains a largely underdeveloped area of research.

Keywords

water sensitive urban design, integrated water cycle management, stormwater quality

1.0 Introduction

Urban developments to support a growing community have consequential impacts on the land and water environments. The land development industry captures the very essence of what triple bottom line philosophy represents. Land development companies need to be financially viable and profitable. They are in the business of building communities and influencing the social fabric of society through transport infrastructure, affordable housing, community precincts etc. Land development impacts land and water, and these environmental impacts need to be mitigated and opportunities taken to enhance the environment when undertaking urban renewal projects.

The pursuit of 'sustainability' has emerged in recent years as a progression from previous 'environmental protection' endeavours. Ecologically Sustainable Development (ESD) can be described as going beyond the protection of the environment from the impacts of pollution, to protecting and conserving natural resources. The ambitions of ESD are to consider lifestyles, and their supporting infrastructure, that can endure indefinitely because they are neither depleting resources nor degrading environmental quality. While such ambitions may seem beyond reach, they set a challenge that can reap benefits, environmental, social and economic, with each step towards the ultimate goal of sustainability.

In urban environments there are in effect, three separate water systems, i.e. (1) the potable water supply consisting of a piped system delivering water treated to drinking water standard, from catchments outside of the urban area, (2) the sewerage system, consisting of a piped system collecting and transporting wastewater to treatment plants, and (3) the stormwater drainage system, consisting of various elements, from natural waterways through to constructed channels and underground piped systems mainly transporting stormwater. Water Sensitive Urban Design (WSUD) has evolved from its early association with stormwater management to provide a broader framework for a holistic management of the urban water cycle and its integration into urban design. It should be noted that the original conceptualisation of WSUD (in Perth, Western Australia) was as an alternative planning and design framework for urban development that attempts to break the dependency of urban environments on large water services infrastructure that is not integrated in a manner that manages all water streams as resources, promotes recycling, mitigates the impact of urban stormwater on the urban water environment through the promotion of at-source detention and retention of stormwater using landscaped features. This 'radical' approach did not gain favour in the early 1990s, and it was in the mid to late 1990s that the stormwater management aspect of this framework was further developed (in the eastern states of Australia) in response to a wider international appreciation of the impacts of urban stormwater quality on the ecological health of urban waterways.

At the inaugural conference on WSUD in Melbourne 2000, four major interrelated issues were identified as essential elements in underpinning the effective adoption of WSUD. These were regulatory framework, assessment and costing, technology and design, and community acceptance. This paper provides a brief overview of the ongoing evolution of WSUD, the current state of adoption of WSUD in Australian practice and future trends.

2.0 Water Sensitive Urban Design

The definition of WSUD among practitioners often appears confused, reflecting wide coverage of the applications of the WSUD framework. The inter-government agreement on a National Water Initiative defines WSUD as "*the integration of urban planning with the management, protection and conservation of the urban water cycle, that ensures that urban* *water management is sensitive to natural hydrological and ecological processes*". In a submission to the International Water Association (IWA)/International Association of Hydraulic Engineering and Research (IAHR) Joint Committee on Urban Drainage, Ashley and the author state that the term WSUD "*….comprises two parts – 'Water Sensitive' and 'Urban Design'. Urban Design is a well recognised field associated with the planning and architectural design of urban environments, covering issues that have traditionally appeared outside of the water field but nevertheless interact or have implications to environmental effects on land and water. WSUD brings 'sensitivity to water' into urban design, i.e. it aims to ensure that water is given due prominence within the urban design processes. The words 'Water Sensitive' define a new paradigm in integrated urban water cycle management that integrates the various disciplines of engineering and environmental sciences associated with the provision of water services including the protection of aquatic environments in urban areas. Community values and aspirations of urban places necessarily govern urban design decisions and therefore water management practices. Collectively WSUD integrates the social and physical sciences*" (Wong and Ashley 2006).

The relationships between Ecologically Sustainable Development, Water Sensitive Urban Design and other elements are shown in Figure 1. Whereas ESD pertains to a wide spectrum of matters concerning sustainable development, WSUD pertains more specifically to the interactions between the urban built form (including urban landscapes and buildings) and the integrated management of the urban water cycle as defined by the three urban water streams. Integrated urban water cycle management includes objectives for water conservation, pollution control of wastewater and stormwater, and mitigation of the effect of increased flow as a result of catchment urbanisation.

As shown in Figure 1, there are a number of natural synergies in achieving individual urban water management objectives. For example, the installation of water efficient appliances has the benefit of reducing

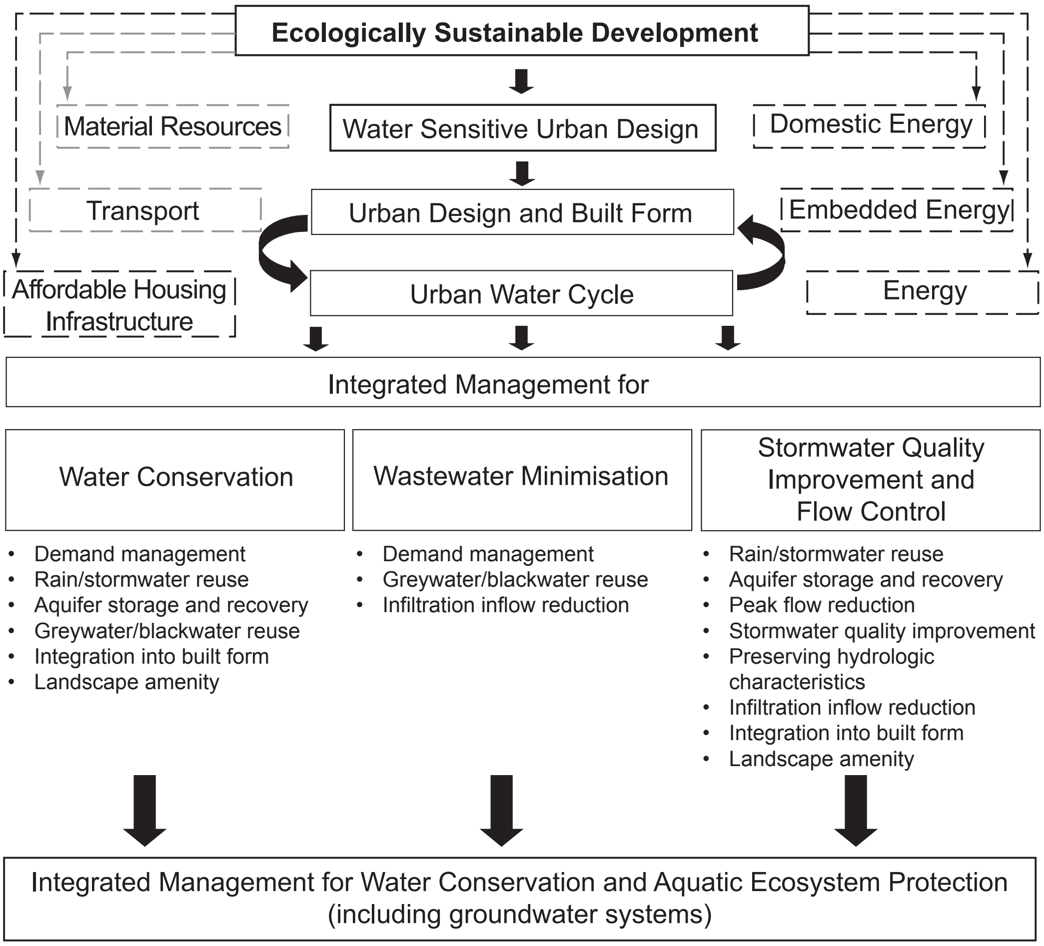


Figure 1. Interactions between ecologically sustainable development, water sensitive urban design and the urban water cycle

(Ecological Engineering, 2003, Australian Runoff Quality, Engineers Australia, 2006) mains potable water usage but also reduces the generation of wastewater. Rainwater or stormwater harvesting has benefits in achieving water conservation and stormwater management. Efforts to reduce the import of water and the export of wastewater and stormwater pollutants will increase the overall sustainability of an urban area. To this end, water reuse and water treatment are essential elements. Within the context of stormwater, the harvesting of stormwater as an alternative water resource is clearly an initiative that would address both the potable water conservation and stormwater quality objectives.

3.0 Integrating Water Management with Urban Planning and Design

Integrating urban water management with urban planning and design has many dimensions including:

- integrated management of the three urban water streams of potable water, wastewater and stormwater
- integration of the scale of urban water management from individual allotments and buildings, to precinct and regions
- integrating sustainable urban water management into the built form incorporating building architecture, landscape architecture and public art
- integration of structural and non-structural sustainable urban water management initiatives, i.e.
  - policies underpinning the sustainable operation of structural measures
  - physical and social sciences
  - setting design objectives that are consistent with the capability of existing technologies (best practice)
  - simplified and transparent assessment of compliance to design objectives

4.0 Integrated Management of the Urban Water Streams

The integrated management of the urban water streams addresses the three key management objectives of mains potable water conservation, minimization of wastewater discharge and stormwater quantity and quality management. This is represented in Figure 2 which shows alternative sources of water with their uses guided by a 'fit-for-purpose' approach to the use of different water sources and associated quality.

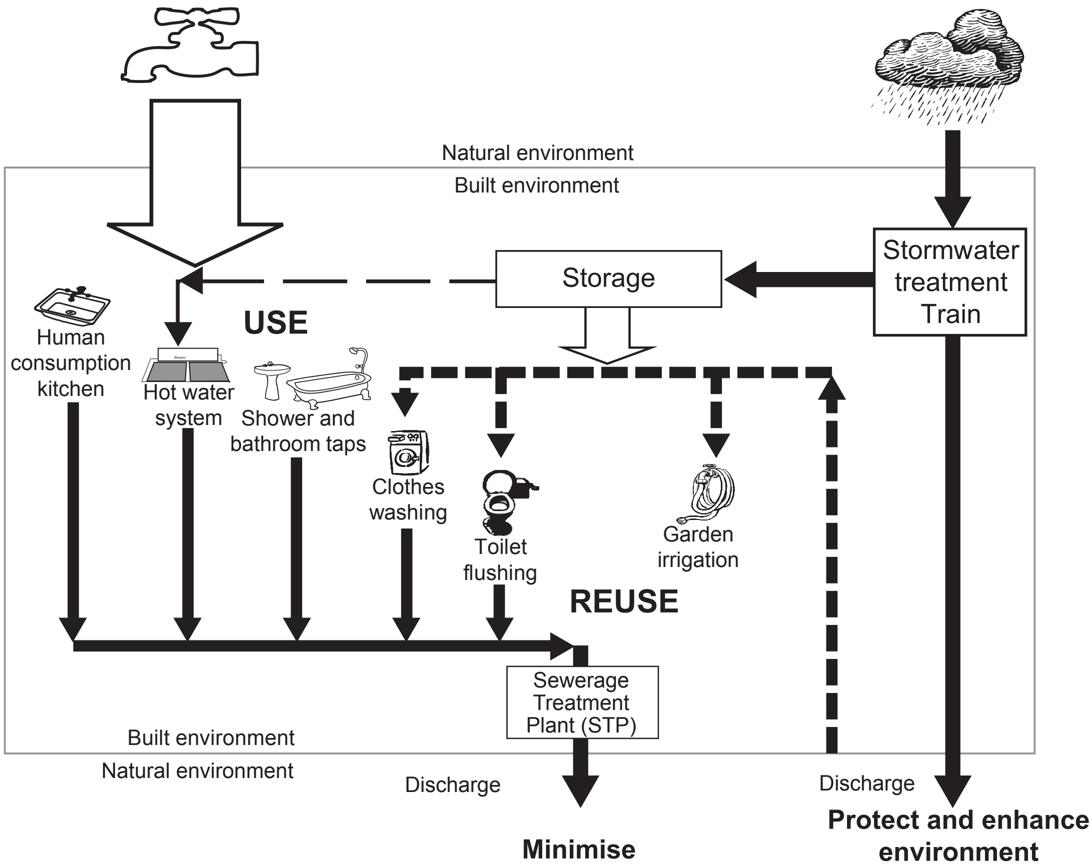


Figure 2. Schematic illustration of alternative sources of water with an emphasis on minimising import of potable (mains) water to, and export of wastewater and stormwater from, the built environment

(adapted from Ecological Engineering, 2005)

The initiatives contained within the built environment 'boundary' in Figure 2 apply across the full range of scales. There have been some significant initiatives in Australia in centralised stormwater harvesting or treated wastewater reuse schemes, most notably the Rouse Hill scheme in Western Sydney, currently supplying treated wastewater to 15,000 households, and planned to ultimately supply an estimated 9 ML/d to approximately 100,000 households.

An integrated urban water management strategy developed by Gold Coast Water (Queensland) for the 7,000 ha Pimpama-Coomera Greenfield development, planned for 130,000 inhabitants, involves the integration of three sources of water supply. Treated wastewater will be reticulated to households for non-potable use, supplemented by harvested roof water for use in bathrooms, laundry and hot water systems. The estimated reduction in mains (potable) water consumption is in excess of 80 per cent. The strategy also includes the incorporation of swales, bio-retention systems and constructed wetlands for the treatment of stormwater prior to its discharge to the receiving waters. Gold Coast Water was awarded the 2006 International Water Association Global Grand Prize for planning.

Aquifer Storage and Recovery (ASR) of treated stormwater is another approach to using alternative sources of water to conserve mains potable water, and is most prominent in Adelaide, South Australia. The treatment of stormwater using constructed wetlands and subsequent aquifer storage of the treated stormwater at the Parafields, managed by the City of Salisbury, is now well-established and has been in operation for over 5 years. The scheme was recently awarded the 2006 International Water Association Global Grand Prize for small projects. The CSIRO has recently commenced a trial at the Greenfields Railway Station site in Adelaide to investigate the feasibility of using aquifer attenuation to enable potable water quality end-uses from stormwater injectant. A preliminary Hazard Assessment Critical Control Point (HACCP) plan has been formulated (Swierc *et al*, 2005) to facilitate the on-going development of ASR technology for the provision of potable water supply. The network of ASR schemes within the City of Salisbury is probably the first large-scale example of the use of urban environments as (non-potable) water supply catchments, an expected recurring theme as we continue to built or retrofit urban environments to become more resilient to climate change.

At a smaller scale, the use of greywater and treated blackwater from sewer mining plants at the multi-unit development level is evolving and is anticipated to gain prominence in urban renewal projects. Probably the most widely publicised apartment project involving the recycling of greywater is the Du'Lux apartment project in the City of Port Phillip, Victoria. Another project is the apartment precinct development by Stockland at the Prince Henry site at Little Bay in Sydney. Sewer mining at Melbourne City Council's Council House 2 project will supply all non-potable requirements for that building. These are discussed further in a later section of the paper.

Rainwater harvesting is a valuable means of alternative non-potable water supply for a variety of domestic and industrial usages. The significance of rainwater harvesting, as a primary source of water for non-potable use, is often understated. Coombes (2006) showed the significant difference in yield from roof areas compared to the yield of a traditional water supply catchment, with the latter being influenced by catchment antecedent soil moisture conditions. A logical expansion of exploiting the break in water supply dependency to catchment antecedent conditions is the notion of urban environments as water supply catchments. A good example of this is the Porters Creek Wetland stormwater harvesting scheme in NSW, which was recently awarded a $2.6M grant under the Australian Government Water Smart Australia programme. The Porters Creek Wetland is a sensitive natural wetland of significance. Located in the Wyong municipality, its catchment is subjected to development pressures for residential and commercial use, with the region experiencing growth at over 2 per cent per annum. The Warnevale Employment Zone is located within the Porters Creek wetland catchment. The protection of this and other sensitive natural wetlands required WSUD solutions that preserve the natural supporting hydrology of the wetlands (Wong and Breen, 2006). The Gosford-Wyong region is also experiencing significant water shortages. The combination of development pressures in the catchment, the need to protect the Porters Creek Wetland from the impact of urban development, and current water shortages provided a very strong business case for a catchment-wide stormwater harvesting scheme concurrent with development in the catchment. Stormwater is treated at source and an appropriate amount (i.e. that required to preserve the natural supporting hydrology in terms of magnitude and seasonal pattern) discharged into the Porters Creek Wetland, while excess flow is diverted into a regional pipeline and conveyed to the Wyong River to supplement environmental flow thus allowing more water to be extracted from the river for water supply to the Gosford-Wyong region.

Local and state governments across Australia have supported mains (potable) water conservation initiatives in various forms in response to the current water shortage conditions in many capital cities. These initiatives include prescriptive requirements of rainwater tanks, while others have focused on achieving outcomes of water conservation while allowing opportunities for innovative solution sets involving demand management and alternative sources of water to be developed. Appropriate solutions towards achieving water conservation objectives may not always include stormwater harvesting (e.g. wastewater reuse) and there is a danger that current focus on water conservation and security of water supply can lead to solutions which overlook the 'other' aspect of sustainable urban water management related to mitigating the impacts of urbanisation on the receiving water environment through poor water quality and flow management. An example of this is the recent white paper of the Victorian Government *Securing Our Water Future Together*, which provided the strategic framework for water conservation and reuse of wastewater and stormwater but overlooked the 'discharge' and environmental protection aspects of the urban water cycle. Reference is made to ensuring that environmental flows are protected but urban stormwater quality control does not feature in any substantial way in the policy framework for sustainable urban water management. Similarly the main emphasis of the inter-government agreement of a national water initiative is predominantly one of water reform to support the security of water supply with little reference to the issues of protecting the natural environment from impacts of urban developments.

5.0 Integration of Spatial Scale

Best practice in sustainable water management encompasses elements at the site, precinct and regional levels, which can be combined to provide a strategic framework for integrated catchment management. Many of the concepts and types of treatment measures adopted in formulating integrated urban water management plans are applicable at all three scales, as illustrated in Table 1.

Many of the WSUD elements for stormwater quality management presented in Table 1 share a common design and operation approach and philosophy, with their differences merely in their spatial scale. For example, good site planning practice applies across the three spatial scales in terms of allotment layout, street layout and regional planning of roads and public open space and multiple use corridors. Similarly, rain gardens and bio-retention systems used at the allotment scale for treatment of roof and pavement runoff operate in a similar way to street-scale bio-retention systems, and urban forest parks and bio-retention basins, in treating catchment runoff from a larger, precinct-scale catchment. Research studies have been able to show that for a given region the ratio between the required size of these systems, and the stormwater runoff contributing area to ensure effective treatment to meet the best practice objectives, are essentially the same. Thus these systems can generally be scalable according to catchment area (within a hydrologically-similar region). Through close collaboration with landscape architects and urban designers, it has been possible to incorporate many of these technologies into the urban form at a range of spatial scales. The range of scales of constructed wetlands and bio-retention systems that have been typically implemented in recent projects is shown in Figures 3 and 4. It is anticipated that many of these elements will become mainstream features for stormwater quality management, particularly in Victoria where recent amendments to the state planning provisions have made stormwater quality treatment to best practice objectives mandatory.

Assessment and costing of WSUD elements are linked to issues related to their life-cycle costs and the nexus with external benefits. There has been progressive documentation of performance of various WSUD elements derived from field monitoring, project cost evaluation and documentation. While some municipalities are attempting to monitor the performance of local WSUD elements, these are activities that are best undertaken by research organisations with funding and infrastructure support from state and local government agencies. With an increase in WSUD projects there is a growing collection of capital costs and maintenance costs of WSUD projects. Maintenance costs are highly variable both from project to project and with the passage of time. Maintenance cost data remains difficult to obtain although there are sufficient collected to enable a first attempt at developing empirical relationships of capital and maintenance cost for a number of stormwater treatment measures (Taylor and Wong, 2002; Taylor, 2005).

Local	Precinct	Regional
Planning		
• Allotment density and layout	• Local street layout	• Major road layout • Public open space and multi-use corridor
Water Conservation		
• Rainwater tank	• Stormwater storages/pond • Aquifer storage and recovery	• Stormwater storages/pond • Aquifer storage and recovery
Stormwater Quality		
• On-site retention (infiltration) • Porous pavement • Sand filters • Bio-retention planters • Rain garden • Vegetated buffer	• Precinct-wide infiltration basins • Porous pavement • Sand filters • Bio-retention swales • Bio-retention basin • Vegetated swales • Urban forest • Constructed wetlands	• Riparian buffer • Natural channels • Urban Forest • Constructed wetlands
Stormwater Detention		
• On-site detention	• Retarding basins • Ponds	• Retarding basins • Lakes

Table 1. Inter-relationship between site-precinct-regional WSUD initiatives

Hampton Park Wetland, Vic (Melbourne Water)

All Nations Park Wetland, Northcote, Vic (City of Darebin)

NAB Wetland, Melbourne Docklands, Vic (Lend Lease)

Figure 3. Various scales of stormwater treatment wetlands recently constructed in Australian projects

Construction and maintenance practices are identified as one of the recurring impediments to the effective implementation of many excellent conceptual developments of WSUD. Construction staging of WSUD needs to be better planned and implemented to ensure that the intent of the concept and design is preserved during construction. Many constructed projects to date have had teething problems caused by a combination of poor engineering design and construction practices, as illustrated in Figure 5. Additional funds had to be committed to rectify these problems, thus biasing the capital and maintenance costs. To date, the industry remains very cautious about embracing WSUD, with the perception that these good ideas are 'experimental' from an implementation/construction standpoint.

5.1 Integration into the Built Form

New initiatives involving collaboration with building architects have extended the application of WSUD into a new dimension related to their integration into the building form. Figure 6 illustrates a proposed new building that attempts to 'close-the-loop' in terms of the household water budget. The plumbing within the building is to be configured differently to provide a separate collection of water from showers, bath and hand basin and deliver greywater to a package treatment plant in the basement of the building. Treated greywater is then pumped to a header tank in the roof of the building and gravity fed to toilets. In addition, roof runoff could be treated with bio-retention systems laid out in a roof-garden and delivered to architecturally-designed rainwater tanks that are incorporated into the building design and directed to the hot-water service. Stormwater runoff from ground-level paved areas could be directed to stormwater quality treatment measures that are incorporated into the building forecourt and adjoining streets.

Elements of this conceptual design are evident in a number of projects in Melbourne and Sydney. The Du'Lux apartment building in St Kilda, Melbourne, features the recycling of greywater and stormwater. Stockland's flagship mixed-used apartment project at the Prince Henry development at Little Bay, Sydney consists of many innovative environmental initiatives, including a greywater recycling system. Melbourne City Council has constructed Council House 2, a 6 Green Star rated building where sewer mining will deliver an alternative non-potable water supply for cooling, plant watering and toilet flushing needs within the building, as well as supplying other Council buildings in its general vicinity.

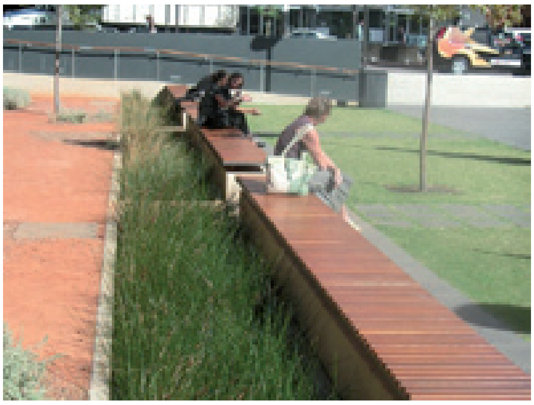
The role and inter-linkage of public art to urban design is currently not well understood and practiced. They are often separate commissions which do not adequately tell the story of water and its intrinsic values as a precious resource. It is envisaged that early collaboration with a water artist by the WSUD practitioner will result in much better integration of these disciplines.

5.2 Integration of Structural and Non-Structural Initiatives

Urban development is largely a private domain enterprise with government providing the framework within which land development is to take place. The most significant non-structural initiative is that of government policies on ESD, and in the case of urban water management, on WSUD. It is well recognised that fragmentation of roles and responsibilities in urban catchment management and provision of water services impedes integrated approaches to urban water cycle management.

Reference to WSUD as a framework for sustainable urban water management now features in various state and federal government policies, and is notable in the inter-governmental agreement on a National Water


Victoria Harbour, Melbourne Docklands, Vic (Lend Lease)


Adelaide Museum, SA (Adelaide Museum)


Baltusrol Estate, Moorabbin, Vic (Australand)


Cremorne Street, Richmond, VIc (City of Yarra)


Victoria Park, Zetland, NSW (Landcom)


Baltusrol Estate, Moorabbin, Vic (Australand)


Batman Ave Tree Planters, Melbourne Docklands, Vic (VicUrban)


Hoyland St Bioretention Basin, Bracken Ridge, Qld (Brisbane City Council)

Figure 4. Various scales of stormwater bio-retention systems recently constructed in Australian projects.

Figure 5. Construction damage is shown with clogging of the bio-retention system surface and loss of vegetation, Victoria Park, South Sydney, NSW.

Initiative (Clause 92), the recent amendment to the Victorian Planning Provision and various other state planning blueprints. Amendments to the planning provision for residential subdivision (Clause 56) in Victoria have result in mandatory water quality targets. In addition to this, references to potable water conservation and wastewater minimisation have been made, albeit not in any quantitative manner. It should be noted that reference to stormwater quality objectives have been made since 1999 but not stipulated as mandatory. The six years leading to this amendment may be seen as a period of industry engagement and demonstration to refine the practical implementation of such legislation in Victoria. This was facilitated by the number of demonstration projects, capacity building of local government and the industry on WSUD, and the development of tools for demonstrating compliance to the stated water management objectives. It is envisaged that a similar process may precede the implementation of quantitative water conservation and wastewater minimisation objectives.

A comparable approach adopted in NSW is the Building Sustainability Index (BASIX). While covering issues much wider than water management, BASIX sets a target for reduction in potable water consumption in new residential dwellings that can be achieved through a combination of water saving initiatives and alternative sources of non-potable water. The NSW Department of Planning intends to include a module for stormwater quality management in BASIX.

In order to ensure a level of transparency and consistency in industry participation towards sustainable urban water management, it is desirable that management objectives are defined by quantitative measures of performance and that attaining these objectives can be readily demonstrated. The BASIX on-line tool is a good example of how compliance with stated objectives can be readily demonstrated. From a stormwater quality objectives perspective, the development of the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) by the Cooperative Research Centre for Catchment Hydrology (Wong *et al*, 2002) has been instrumental in advancing government policies on urban stormwater quality in Victoria, New South Wales, Queensland, Tasmania and now in parts of Western Australia.

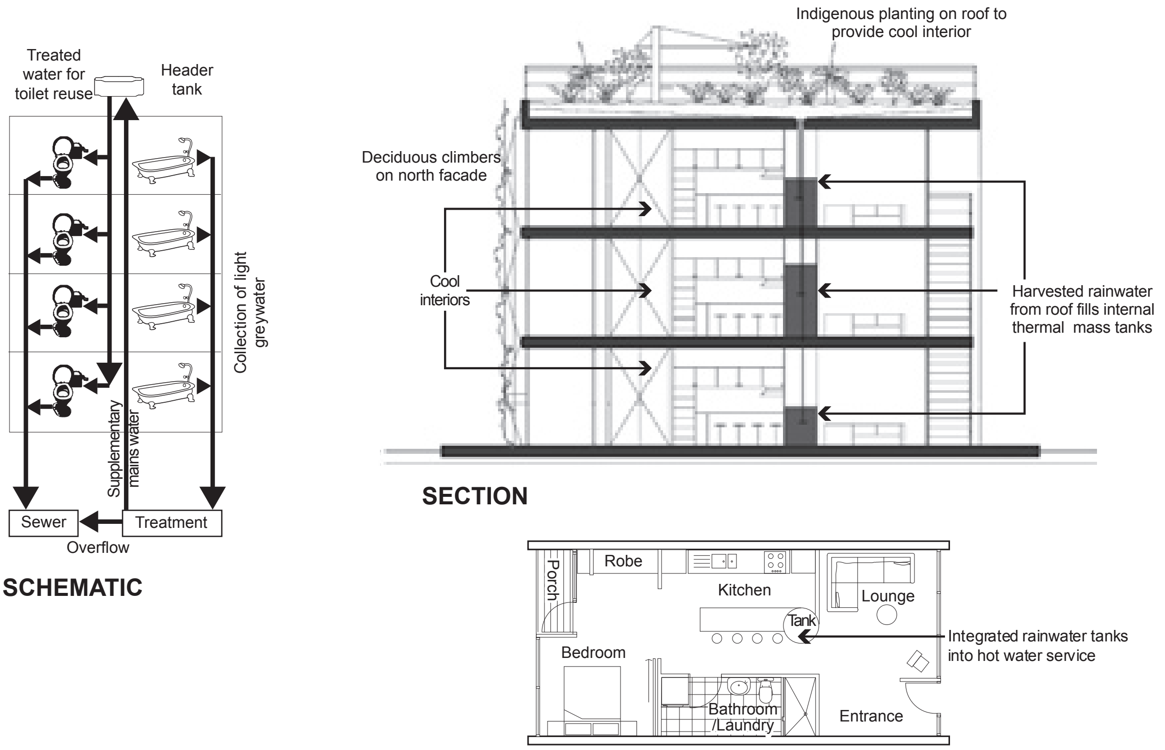


Figure 6. Integrating water management systems into buildings

Performance measures or design objectives of integrated urban water management strategies can be expected to evolve and to be adaptive, as knowledge in sustainable urban water management itself is still an evolving field of multi-disciplinary sciences. Percentage reduction in per capita potable water usage and wastewater generated that is discharged to the receiving water environment can be specified as integrated water management objectives. Wastewater minimisation is linked to demand management and reuse of treated wastewater and is closely associated with the objectives of water conservation. Its key sustainability indicator and target are thus also closely aligned. In terms of stormwater quality, there is on-going debate about whether the design objectives should be based on meeting probabilistic pollutant concentration levels or mean annual load reductions from that typically generated from urban environments (in the absence of any intervention measures). Research studies by Walsh *et al* (2004) have indicated that impact on stream health occurs with effective imperviousness as low as 5 per cent and they advocate that stormwater management in urban catchments '*must retain water for infiltration, evapotranspiration and reuse for all rain events up to the size of events that would have produced overland flow from the development in its pre-development state*'. This requirement is not dissimilar to that identified by Wong and Breen (2006) for natural wetland systems and will involve a significant component of stormwater harvesting and reuse since the capacity for infiltration and evapotranspiration is often diminished as a catchment is developed.

Community acceptance and enabling broad scale political support for WSUD is fundamental for enhanced implementation rates and improving industry's technical capacity and ingenuity in complex urban environments. There has been a significant increase in the focus on the role of communities in both refining the WSUD 'problem' and participating in developing WSUD strategies. Public art highlights communities' relationship with water and the general 'intrinsic values of water' and helps bring community awareness and participation in decision making on urban water management. Some recent projects have focused on profiling community attitudes and receptivity to water reuse and pollution prevention activities to inform local WSUD policy development. Other projects have focused on implementing community participatory action models, including scenario workshops for jointly envisaging sustainable water futures, and different types of community-based deliberative forums designed to deliver jointly developed strategies and local WSUD plans.

Institutional reform for integrated urban water cycle management remains elusive. Like most reform agendas this is an area that requires consideration of options that are not immediately intuitive, technically or otherwise. The socio-institutional dimension of WSUD, while instrumental to effective policy development and technology diffusion efforts, still remains a largely underdeveloped area of research. Brown and Clarke (2007) recently undertook a historical socio-technical transition analysis of the drivers that underpinned the development of WSUD across Melbourne. Melbourne was selected as a case study because it is often informally identified as a leading city, both nationally and internationally, in the fields of urban stormwater management and WSUD. Additionally, this work has drawn on contemporary social science thinking in relation to technology diffusion in a range of other fields.

The outcomes of this research revealed that the development of WSUD across Melbourne has been the result of a complex and sophisticated interplay between key champions, or change agents, and important local context variables. In particular, the champions represent a small and informally connected group of individuals across government, academia and the development industry that has pursued change from a best practice management ideology that was consistently underpinned by local science and technology development. However, the existence of champions alone was insufficient to explain the development of WSUD as there were a number of instrumental context variables that represent a mixture of 'historical accidents' and advocacy outcomes. Over the last 20 years these included the social rise of environmentalism, strategic external funding points, and the establishment of a number of industry-focused cooperative research centres to bring researchers and industry practitioners together. These associations and networks led to the formalising of stormwater quality objectives, market receptivity with large developers and the development of strategic capacity building tools such as MUSIC.

What was demonstrated as being critical to fostering this interplay between the local context and champions was the role of bridging organisations in the form of the inter-governmental stormwater committee, the Cooperative Research Centres for Catchment Hydrology (CRCCH) and Freshwater Ecology (CRCFE), and the Clearwater Capacity building program. These organisations hosted multiple stakeholder groups, were founded on trusted local science and were dedicated to strategic industry adoption. It is hoped that the research findings will help provide a preliminary institutional template for continued diffusion of WSUD, both as a philosophical approach to sustainable urban water management and in practice.

6.0 Conclusions

Since the initial conceptualisation as an urban planning and design framework for more sustainable management of urban water, WSUD has evolved from its early association with stormwater quality management to a broader framework for integrating the holistic management of the three urban water streams with the practice of urban design. This new paradigm is centred on integration at a number of levels:

- the integrated management of the three urban water streams of potable water, wastewater and stormwater
- integration of the scale of urban water management from individual allotments and buildings, to precincts and regions

- integration of sustainable urban water management into the built form, incorporating building architecture, landscape architecture and public art, and integration of structural and
- the non-structural sustainable urban water management initiatives.

While there have been a number of successful projects involving one or more elements of WSUD, the overall successes in implementation are however varied; a reflection of an industry transitioning into a new paradigm. Construction and maintenance practices are identified as one of the recurring impediments to the effective implementation of many excellent conceptual designs of WSUD. Institutional reform for integrated urban water cycle management remains elusive. In spite of these impediments, the transition to WSUD in stormwater quality management over the last 10 to 15 years has been quite remarkable, especially when we consider that in this short timeframe we have seen the philosophy, technology and language of WSUD developed to industry standards and referenced in policies across all levels of government in Australia. The socio-institutional dimension of WSUD, while instrumental to effective policy development and technology diffusion efforts, still remains a largely underdeveloped area of research. However, recent studies may provide an initial institutional template for supporting diffusion of WSUD, both as a philosophical approach to sustainable urban water management and in practice.

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Biography

Dr Tony Wong is formerly a founding partner of the consulting firm Ecological Engineering which is now EDAW. He is also CEO of the Facility for Advancing Water Bio-filtration at Monash University. Tony has over 25 years of experience in the fields of water resources engineering and management, advancing ESD, particularly in integrated urban water cycle management and WSUD. His expertise has been gained through consulting, research, and academia. Tony provides strategic advice to governments, and the land development industry, on sustainable urban water management and has led the development of many state and corporate policies on WSUD.