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An Overview of Water Sensitive Urban Design Practices in Australia

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ABSTRACT

Ecologically Sustainable Development in Australia can be described as going beyond the protection of the environment from the impacts of pollution, to protecting and conserving natural resources. In an urban environmental context this means urban development (both greenfield development and urban renewal) that seeks to have no long term effects on various aspects of the environment related to aspects such as greenhouse gas levels, material resources, biodiversity and ambient water environments. Water environments, such as waterways and coastal waters, and water supply catchments are key areas where urban development can have significant impacts. Water Sensitive Urban Design in Australia has evolved from its early association with stormwater management to provide a broader framework for sustainable urban water management. It provides a common and unified method for integrating the interactions between the urban built form (including urban landscapes) and the urban water cycle. This paper presents an overview of current industry practice and research implementation of Water Sensitive Urban Design in Australia.

KEYWORDS

bioretention, constructed wetlands, stormwater quality, urban design

INTRODUCTION

The pursuit of *sustainability* has emerged in recent years as a progression from previous environmental protection endeavors. The ambition of *sustainability* and *sustainable development* is to have lifestyles, and their supporting infrastructure, that can endure indefinitely because they are neither depleting resources nor degrading environmental quality. Land development activities impact on the sustainability of the physical environment, including the health and amenity of water environments.

Water environments, such as waterways and coastal waters, and water supply catchments are key areas where urban development can have significant impacts. In Australia, Ecologically Sustainable Development (ESD) initiatives can be described as going beyond the protection of the environment from the impacts of pollution, to also protecting, conserving and restoring natural resources. Environmental sustainability can be described as a condition where there is a zero net environmental cost associated with development activities. While such ambitions may seem beyond reach, they set a challenge that can reap wide ranging benefits – environmental, social and economic – with each step towards the ultimate goal of sustainability.

Protecting the environment from which, (i) water is diverted for urban consumption, and (ii) treated wastewater and stormwater is discharged to, is the key objective of sustainable water resource management. Managing the impacts of urban development on the water environment must include attention to all three streams of the urban water cycle and necessitates an integrated approach that is now widely acknowledged as achieving water sensitive urban development through Water Sensitive Urban Design.

In Australia, Water Sensitive Urban Design (WSUD) has evolved from its early association with stormwater management to provide a broader framework for sustainable urban water management. It is a framework that provides a common and unified method for integrating the interactions between the urban built form (including urban landscapes) and the urban water cycle. It is increasingly practiced in new urban greenfield development areas and urban renewal developments linked to a broader ESD agenda. Key guiding principles of WSUD include:

1. reducing potable water demand through water efficient appliances and seeking alternative sources of water such as rainwater and (treated) wastewater reuse, guided by the principle of “fit-for-purpose” matching of water quality and end uses.
2. minimising wastewater generation and treatment of wastewater to a standard suitable for effluent re-use opportunities and/or release to receiving waters
3. treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters
4. using stormwater in the urban landscape to maximise the visual and recreational amenity of developments.

INTEGRATED MANAGEMENT OF URBAN WATER STREAMS

Four major inter-related issues are identified as essential elements in advancing the concept of WSUD in Australia. These include (i) Regulatory Framework; (ii) Assessment & Costing; (iii) Technology & Design; and (iv) Community Acceptance and Governance. While there has been advances in research and practice within each of these themes (as briefly presented below), the scope of this paper only allows for a more detailed review of progress made in the ‘technology and design element’ with specific attention to the management of urban stormwater.

Regulatory framework relates to the role of local, regional and state government departments in facilitating the implementation of WSUD in urban development and renewal projects. It is well recognized that the current fragmentation of roles and responsibilities in urban catchment management impedes integrated approaches to urban water cycle management. Over the last five years new research and innovative practices in Australia have revealed what some of the likely and necessary dimensions of a regulatory and administrative framework would be for systematically enabling the implementation of innovative technologies and improved land-use practices. Examples of these include the establishment of practical and equitable performance standards and a simple rating system for demonstrating compliance to these standards as described by Kay *et al.* (2004).

Assessment and costing of WSUD initiatives are linked to issues related to life-cycle costs of these initiatives and the nexus with external benefits. There have been progressive

documentations of performance of various WSUD elements derived from field monitoring and project cost evaluation in Australia.

Community acceptance and governance are considered essential in enabling broad scale political support for WSUD and is fundamental to facilitating enhanced implementation rates, as well as improving industry's technical capacity in complex urban environments (Brown, 2003). There has been a significantly increased focus on the role of communities in both refining the WSUD 'problem' and participating in developing WSUD strategies. 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.

Technology and design of WSUD elements have evolved since 2000 with many projects demonstrating innovation at a range of scales. 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 1 illustrates a recently constructed cluster of apartment buildings in Melbourne that attempts to "close-the-loop" with respect to the indoor water budget. The buildings are "plumbed" differently such that there is a separate collection of the water from the showers, baths and hand basins to a package treatment plant consisting of an aeration balancing tank, a membrane biological reactor (MBR) tanks. Stormwater is collected from roof and adjoining impervious areas and directed to gross pollutant traps and thence to a bioretention basin. Treated stormwater is then directed to the MBR tanks for tertiary treatment. Treated water passes through a ultra-violet disinfection unit and is then reused for toilet flushing and landscape watering. This is the first building-scale water recycling scheme and thus has a high level of conservatism in its design and water quality standards. Monitoring of this system is on-going and it is envisaged that future variations of such system will require less stringent water quality treatment requirements.



Figure 1. Integrating water management systems into residential buildings for greywater and stormwater harvesting, treatment and reuse (D'Lux Apartments, Melbourne)

The most widespread application of WSUD has been in the integrated management of urban stormwater. The integration of WSUD elements have been at a range of scales. This is the focus of this paper with presentation of the current trends in concept and systemic design and how recent research findings are advancing innovation in this regard.

Integrated Management of Urban StormWater

The management of stormwater runoff in conventional urban developments has been driven by an attitude that reflects the view that stormwater runoff has no value as a useful resource, is environmentally benign and adds little to the amenity (aesthetic, recreation, education, etc) of an urban environment. Consequently, conventional urban stormwater management has focused on providing highly efficient drainage systems to rapidly collect and remove stormwater runoff using a combination of underground pipes and linear “engineered” overland flow paths (often located along the back fence line of properties to keep them out of sight). These systems kept stormwater runoff “out of sight” and consequently “out of mind”. The increased rates of stormwater runoff associated with conventional urban development coupled with a dramatic increase in stormwater runoff volume and associated contaminants such as litter, sediments, heavy metals and nutrients has caused significant degradation of the natural environments.

As part of an emerging new paradigm in urban management, the treatment of stormwater runoff is no longer considered in isolation to the broader planning and design of the contributing urban area. Stormwater management is considered at all stages of the urban planning and design process to ensure that site planning, architecture, landscape architecture and engineering infrastructure is provided in a manner that supports the improvement of stormwater quality and the management of stormwater as a valuable resource. Similarly, the stormwater treatment system are adapted to the requirements of each of the other urban infrastructure elements in order for the “whole” package to function as an ecologically, socially, and economically sustainable urban system.

The success of WSUD as an urban planning and design paradigm will rest largely on the ability of the urban design industry to provide engaging and informative landscape design solutions within the public realm. The use of innovative landscape elements that show the connectivity between human activity and the urban water streams are increasingly recognised as having a powerful influence on the consciousness of individuals and recognition of their role and responsibility in the protection and enhancement of our natural water resources. By contrast, there is a distinct lack of visual connectivity between human activity, urban water streams, and receiving natural waterways with the conventional “piped” stormwater system. Thus within the conventional urban setting it is difficult for individuals to see, and indeed understand, the impact of their actions on the sustainability of our natural water resources.

Cooperative collaboration between the urban design professions can achieve “smarter” and more sustainable urban areas where urban landscapes engage, inform, and influence human behavior for the benefit of the natural environment and the improvement of the social fabric. The following sections present the outcome of recent collaborations between the urban design professions in integration of stormwater treatment measures into the built form.

Stormwater Treatment Measures

Two of the most common stormwater treatment technologies that can be readily integrated into urban design are constructed wetlands and bioretention systems.

Constructed Wetlands The use of constructed wetlands for urban stormwater quality improvement is widely adopted in many Australian cities. Research and on-going refinement to practice have provided a sounder basis for sizing constructed wetlands for stormwater management and for its integration into landscape design (Wong and Breen, 2003).

Hydrologic, hydraulic and botanic designs are inter-related and must be integrated for successful long-term outcomes. Current Australian design practices of constructed stormwater wetlands include:-

- the compartmentalisation of constructed stormwater wetlands to enable different processes to be promoted and to provide for the by-pass of high flows;
- testing the particle size distribution on suspended sediments conveyed by urban stormwater in order to determine the required detention time (Australian catchments appear to be finer than that for overseas catchments, Lloyd *et al.*, 1998);
- the use of *hydrologic effectiveness* curves for selecting appropriate extended detention storage volume of constructed wetlands throughout Australia, linking the influence of probabilistic storm intensities, duration and inter-event period on the operation of stormwater wetlands;
- the use of a quantitative measure of hydrodynamic conditions (ie. *hydraulic efficiency*) in constructed wetlands and ponds and to relate wetland and pond shapes, bathymetry, and vegetation layout to hydraulic efficiency;
- the active engagement of landscape designer to achieve a balance between meeting their aesthetic objectives with those of stormwater quality improvement.

Bioretention Systems Recent adaptations of swale systems for stormwater quality treatment are directed at promoting a higher degree of stormwater treatment by facilitating infiltration of stormwater through a prescribed soil media. These systems are referred to as bioretention systems where a trench, filled with a “prescribed” soil of known hydraulic conductivity, is used to filter stormwater.

Vegetation is a crucial component of bioretention systems. Plants roots support a wide range of microbiota (particularly bacteria and fungi) and influence characteristics of the media for several millimeters around the root (the rhizosphere) and they can significantly increase the physical trapping and biological uptake of nutrients and water by plants. Plant growth also plays an important role in maintaining the structure and hydraulic conductivity of the media. Their growth and death cycle results in macro-pore formation and maintenance, an important function in prevention of clogging of the soil media.

Recent research and monitoring of field applications have demonstrated that they present an effective “soft-technology” for removal of urban stormwater pollutants (Davis *et al.*, 2001, Lloyd *et al.*, 2001, Kim *et al.*, 2003). When designed with appropriate soil media and planting, these systems have long-term capacities to assimilate heavy metals washed off urban catchments.

Building, Local and Precinct Scale Constructed Wetlands and Bioretention Systems

Recent research into stormwater treatment technology has been able to confirm the scalability of stormwater treatment technologies such as constructed wetlands and bioretention systems for application in small confined areas. 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. These are described in the sections below and illustrated in Figures 2, 3 and 4.

Building Scale. Harvesting of roof stormwater runoff can be integrated with building design. This runoff could be treated with bioretention or constructed wetland systems laid out in a

roof-garden and delivered to architecturally-designed rainwater tanks that are incorporated into individual apartments for toilet flushing. Contrary to many misconceptions of roof top gardens, the entire roof space does not need to be fitted with stormwater treatment measures. Often, the vegetated treatment areas (eg. bioretention systems and constructed wetlands) need only to take-up 2% to 5% of the roof area to adequately treat stormwater runoff. A schematic of a building project where roof water is to be treated in a roof garden and stored in architecturally designed storage tanks within individual apartments for reuse in the hot water system is shown in Figure 2 (the building is also to be fitted with a greywater recycling system for toilet flushing and garden watering).

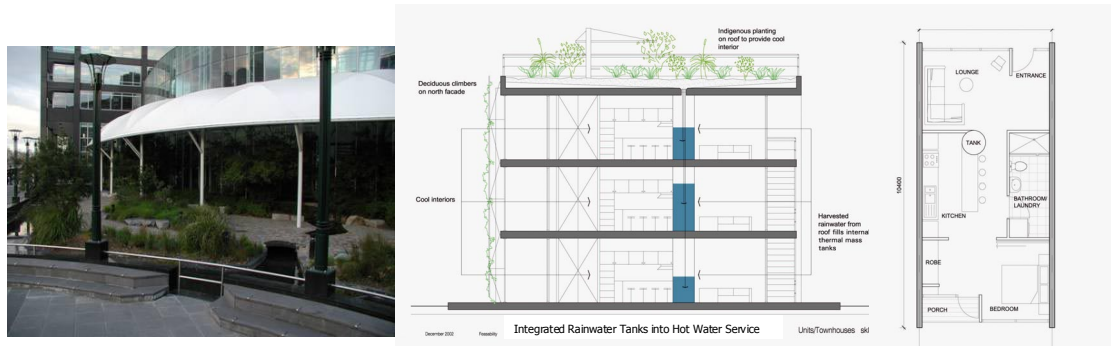


Figure 2. Integrating stormwater management systems into buildings – proposed rainwater harvesting from roof top garden and storage within apartments for hot-water (Landcom, Sydney)

Local Scale. Public building forecourts and local streetscapes represent the connecting pathways between the buildings where we live and work and the areas of sub-regional and regional public open space where we interact and recreate at a local and regional community scale. In terms of stormwater runoff generation, public building forecourts and local streetscapes represent public realm areas located closest to the source of most urban stormwater runoff (i.e. from impervious surfaces associated with buildings and road pavements). Integration of stormwater management functionality within landscape elements associated with public building forecourts and local streetscapes allows for a number of key WSUD best management practices to be satisfied, namely: collection and treatment of stormwater runoff at its source; first use of stormwater runoff for watering the landscape; and visual connectivity between the built form and the urban stormwater stream.

Precinct Scale. Precinct scale public open space areas provide an opportunity to integrate stormwater collection, treatment and storage/re-use facilities within the overall landscape design of these areas. With competing uses for these spaces the scale and landscape form of the stormwater management systems needs to carefully consider the other uses of the park and their potential interaction with the stormwater management systems. Issues of public safety and aesthetic amenity are important design considerations requiring site analysis to determine site usage patterns, journeys, site lines, and existing landscape character in order to ensure an appropriate landscape form.



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



Figure 4. Various scales of stormwater bioretention systems recently constructed in Australia

CONCLUSIONS

The concept of Water Sensitive Urban Design is based on formulating development plans that incorporate an integrated approach to the management of the urban water cycle. In relation to stormwater management, WSUD involves a pro-active process which recognises the opportunities for urban design, landscape architecture and stormwater management infrastructure to be intrinsically linked. WSUD espouses the need to integrate stormwater management into the planning and design of urban areas and applies across the entire spatial scale from a catchment-wide regional level to the precinct level to the local, building level.

Opportunities for the innovative integration of stormwater management functions within contemporary urban landscape designs at a range of scales within the public realm and private buildings were presented in this paper. A shift towards “at source” stormwater management systems will further advance the development of innovative on-site, streetscape and precinct scale landscapes incorporating stormwater management functionality.

The principles of WSUD are equally relevant to achieving sustainable developments in other places with different water infrastructure systems to the Australian context. The challenge ahead is to continue the collaborative approach to urban design and to provide technically robust solutions that excite and engage communities and deliver improved environmental outcomes for today and future generations.

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