STORMWATER TREATMENT TECHNOLOGIES

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Summary

Rapid urbanization has contributed to considerable increases in urban runoff and pollution, a deterioration of the water quality of urban waterways and significant threats to its ecosystem. The traditional approach of managing only for the flow conveyance of stormwater is no longer sustainable. Stormwater runoff is the most neglected resource and, given that it contributes significantly to diffuse pollution of our waterways, it needs to be managed in more sustainable way to capture its benefits and at the same time to reduce the adverse impacts on waterways and receiving waters. A cultural change is occurring in urban stormwater management practice. Environmental aspects are becoming a major focus, with potentially profound effects on the traditional approach to stormwater management. Water Sensitive Urban Design (WSUD) is increasingly becoming the contemporary approach to manage stormwater and water resources in urban areas in an environmentally sustainable manner. In Australia, WSUD is gaining prominence as a way to minimise the impact of urban development on waterways and bays. WSUD incorporates a holistic management strategy that attempts to integrate aspects of urban planning, design, landscape architecture and stormwater management to achieve the goals of sustainable development. This integrated approach regards stormwater as a resource rather than a waste and considers all aspects of run-off within a development, including implementation of water quality/quantity controls, maximizing water reuse/conservation whilst preserving the amenity and environmental values within the catchment. This chapter discusses the stormwater treatment technologies that incorporate WSUD and the best management practices for protection of urban waterways.

1. Introduction

The rapid growth and expansion of urban centers has meant that stormwater discharge represents a significant component of catchment runoff and severely impacts on flooding, water quality and ecology of waterways. The traditional approach to manage stormwater only for the flow conveyance is not sustainable. This approach is no longer acceptable and there is shift towards more sustainable ways of managing urban waterways.

Environmental Value	**Issue**	**Significance**	**Objectives**
Non Water quality dependent			
Drainage and Flood Management	Hydraulic	Flow attenuation/ detention– protection of downstream ecology and flooding	Provides dual benefit of flood control and maintain flow regimes to sustain healthy aquatic ecosystems
Water Quality dependent			
Aquatic Ecosystem	Environment	Pollution control in respect to protection of downstream waters	Protection of aquatic ecosystems
Recreation and Aesthetic use	Amenity	Recreation (boating, fishing) values;	Protection of recreation water quality and preservation of amenity and aesthetic values
Primary Industry water supply	Economic	Water supply (irrigation) use values;	Protection of Primary industry water supply (irrigation, stock, water supply, aquaculture)

Cultural and Spiritual	Cultural	Cultural, spiritual and heritage values	Protect known sites of cultural and spiritual significance

Table 1. Environmental and use values for urban waterways

The framework for sustainable water management is based on defining key environmental and use values, water quality guidelines and water quality objectives that needs to be developed to protect the urban waterways. In Australia, ANZECC Guidelines for Fresh & Marine Water Quality (ANZECC, 2000) make explicit the water environmental and use values to be protected. In the case of modified or restored waterways, it is explicit of the major threats to these values, and focuses on a risk based management approach. Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits (ANZECC, 2000). A set of environmental and use values typical for urban environment are presented in Table 1.

A water quality guideline is a numerical concentration limit or narrative statement recommended to support and maintains a designated water use (ANZECC, 2000). ANZECC (2000) defines water quality guidelines that specify limits for chemical and physical parameters in water and sediment, as well as biological indicators for each of the environmental values listed. These guidelines are used as a general tool for assessing water quality and are the key to determining Water Quality Objectives (WQOs) that protect and support the designated environmental values and against which performance can be measured. The National Water Quality Management Strategy has produced Guidelines for Urban Stormwater Management (NWQMS, 2000) and these guidelines provide the broad framework and the overall context for stormwater management in Australia.

The current trend for stormwater management is to provide a system based approach to protect key environmental values of waterways whilst meeting WQOs for urban waterways. This has led to Water Sensitive Urban Design (WSUD), a system based approach to stormwater management that incorporates a holistic management strategy that takes into account and closely interlinks urban planning, design, landscape architecture and stormwater management whilst maximizing reuse of stormwater. Managing urban run-off in a sustainable manner not only resolves problems associated with stormwater, but enhances the social and environmental amenity of the urban landscape. Reducing peak flows and maintaining a more natural stormwater system can also potentially reduce capital and maintenance costs of drainage infrastructure.

2. Stormwater Pollution

Issue	**Potential Negative Impact**	**Likely Source**

Litter & debris	• Reduces aesthetic appeal of waterways • Can kill some marine aquatic life (eg fish, turtles, sea birds). • Decay of some gross pollutants can decrease dissolved oxygen levels.	• Littering e.g. bottles, plastic wrapping and caps, cigarette butts ▪ Shopping centres, stores, malls, pedestrian access ways, ▪ Carparks ▪ Leaf-fall from trees ▪ Lawn mowing ▪ Schools ▪ Waste collection • Fast food outlets & restaurants
Turbidity in waterways	• Smothering of plants and animals that live on the bottom of receiving waters, ponds, lakes and streams • Reduced aesthetic value (water looks “muddy") • Reduced aquatic plant growth • clogging of fish gills . • Hinders the ability of aquatic. predators (eg certain fish species) to see their prey.	*Coarse sediments (> 0.5 mm)* ▪ Land-disturbing construction ▪ Erosion ▪ Sand used in spill clean up ▪ Sand blasting, concrete sawing ▪ Deposition from motor vehicles & car parks *Fine Sediments* • Industrial areas, Scrap yards • Car parks, Streets and highways • Construction sites • Atmospheric deposition
Nutrient enrichment	• Nitrogen & phosphorus stimulates the growth of algae and aquatic plants • Decay of algae and plant matter reduces dissolved oxygen levels • Excessive growth of algae and aquatic plants reduces waterway aesthetic values	• Washing cars with detergent containing phosphorus. • Excessive use of fertilisers, which is washed off lawns • Decay of plant material • Leaky or overflowing sewerage systems
Petrol, oils and. Grease	• Reduces aesthetic appeal of Waterways • Can harm some aquatic life • Decay of some hydrocarbons can decrease dissolved oxygen levels	• Leaks from vehicles, roads • Car washing or maintenance • Illegal dumping of industrial waste or food oils. • Car parks • Food waste storage areas • Heavy equipment & machinery • Fast food outlets and restaurants
Pesticides and herbicides	• Harms aquatic plants and animals	• Pesticides and herbicides (weed killers) used on gardens and nature strips and washed off during rain
Trace metal pollution (heavy metals)	• Stress on aquatic plants and animals. • Contamination of the food chain with trace metals	• Runoff from roadways or car parks. • Deterioration of building surfaces (eg. rusting galvanised iron roofs) • By product of burning fossil fuels • Swimming pool water

Bacteria and other pathogens	• Makes contact with water unsafe for humans • Causes disease in aquatic organisms • Contaminates shellfish.	• Animal (dog and cat) faeces • Food wastes disposed improperly • Leaky or overflowing sewerage systems
Vegetation washed into waterways	• Oxygen dissolved in the water is used up when plant matter decays. Fish and other water life need this oxygen to live.	• Leaf drop from gardens and street trees, particularly when they fall onto paved surfaces • Hosing or sweeping lawn clipping and leaves into gutters • Mulch washed or blown from gardens
Loss of aquatic habitats and/or riparian vegetation	• Weed infestation of urban bushland • Nutrients in stormwater and the transport of weeds propagated from urban areas by stormwater • Reduced fish population • Water pollution due to loss of filter. strips adjacent to creeks • Increased water temperature	• Riparian vegetation cleared • Changed flow characteristics resulting from change of land use • Bank erosion • Unrestricted access • Creeks "channelised" or"piped"
High Runoff from urban areas	• Increased pollutant loads • Erosion of creek banks roads • Changed pattern of water levels in wetlands, affecting aquatic flora and fauna • Increased frequency of disturbance to aquatic ecosystems, reducing the diversity of aquatic life	• Increased impervious surfaces (eg. roofs, paved areas, footpaths) directly connected to the stormwater system

Table 2: Common Pollutants, their likely sources in urban stormwater and potential impacts on urban waterways

Pollutants typically found in urban stormwater runoff originate from either point or non-point sources. Point sources are specific identifiable locations where stormwater pollution are generated or occur, and include illegal discharges of trade wastes and sewer overflows. Non-point sources or diffuse sources, by its nature are comparatively difficult to identify and control and include litter, sediments, nutrients, oils & grease from road surfaces, toxic material, bacteria and organic material. Without appropriate stormwater treatment devices, the resulting impacts on receiving waters can be devastating, not only for aquatic ecosystems but also to community values such as aesthetics, recreation, economics and health of receiving water bodies. Table 2 summaries common pollutants in urban stormwater, their likely sources and potential negative impacts on the environment based on the ecological, social and administrative concerns.

	Contaminant/ Pollutants

Land Uses	Litter	Sediment	Nutrients	Oil and Grease	Toxic Material	Bacteria	Organic Material
Residential	■	■	■	■		■	■
Industrial/ Commercial	■	■		■	■	■	
Open Space	■		■			■	■
Roads	■	■		■	■		
Sewer overflows/ Septic tanks			■	■	■	■	■
Construction activities	■	■		■			
Land fill	■	■	■		■	■	■
Underground storage tanks				■	■		

Note:

■	-denotes likely contaminants produced from the specified land use activities

Table 3: Relation of land-use to contaminants/pollutants generated

Table 3 provides a summary of the main land use activities and the likely pollutants that have negative impacts on the environment.

This information can be used to establish targeted strategies to reduce the pollutant loads on the environment, by matching the catchment characteristics and the contaminants, to a suite of treatment strategies can then be tailored to control/trap the specific contaminant. Treatment measures are discussed further in section 4.

3. Water Sensitive Urban Design (WSUD)

Environmental aspects are becoming a major focus in urban stormwater management with potentially profound effects on the traditional approach to drainage. Water Sensitive Urban Design (WSUD) is increasingly becoming the contemporary approach to manage stormwater and water resources in urban areas in an environmentally sustainable manner.

In Australia, WSUD is gaining prominence as a way to minimise the impact of urban development on waterways and bays.

WSUD incorporates a holistic management strategy that attempts to integrate aspects of urban planning, design, landscape architecture and stormwater management to achieve the goals of sustainable development.

This integrated approach regards stormwater as a resource rather than a waste and considers all aspects of run-off within a land development, including implementation of water quality/quantity controls, maximizing water reuse/conservation whilst preserving the amenity and environmental values within the catchment, (Figure 1).

Figure 1 WSUD conceptual model

WSUD offers an alternative to the traditional approach to stormwater management based on consideration of flow conveyance alone. WSUD aims to minimise the impact of urbanization on the natural water cycle, and its principles can be applied to the design of a single building or to a whole subdivision. It seeks to minimise the extent of impervious surfaces and mitigate changes to the natural water balance, through on-site or local reuse of the water as well as through temporary storage. By integrating major and minor drainage flow paths in the landscape and adopting a range of water sensitive design treatment measures, the size of the structural stormwater systems that is required may be reduced. These measures include detention and retention basins to lower peak flows, and grassed swales and vegetation to facilitate water infiltration and pollutant filtration. A multi-purpose corridor, typically a roadway and associated footpaths, easements and buffers, is an important design element in many integrated stormwater management systems, into which many WSUD treatment measures can be incorporated and which may also serve as water features, habitat protection and recreation.

Managing urban run-off in a water sensitive manner not only resolves problems associated with stormwater, it enhances the social and environmental amenity of the urban landscape. Reducing peak flows and maintaining a more natural stormwater system can also potentially reduce capital and maintenance costs of drainage infrastructure. Further by enhancing the social and environmental amenity of the urban landscape, the land and property values within the landscape increase in value making WSUD infrastructure viable and relatively more affordable.

CSIRO (1999) lists five key objectives of WSUD for application to urban stormwater planning and design. They are:-

- Protect natural systems; protect and enhance natural water systems within urban developments

- Integrate stormwater treatment into the landscape; use stormwater in the landscape by incorporating multiple use corridors that maximize the visual and recreational amenity of developments
- Protect water quality; protect the water quality draining from urban development
- Reduce run-off and peak flows; reduce peak flows from urban development by local detention measures and minimising impervious areas
- Add value while minimising development costs; minimise the drainage infrastructure cost of development

These principles collectively call for a more considered approach to the integration of land and water planning at all levels of the urban development process (ie. planning, concept design and detailed design).

3.1 WSUD Model

The WSUD concept (ARQ, 2006) involves the integration of Best Planning Practices (BPPs) (see 3.2.1) and Best Management Practices (BMPs) (see next 3.2.2) to yield appropriate designs for a particular site. A schematic model based on this concept is shown in Figure 2.

Figure 2 Integration of BPP's and BMP's to achieve a WSUD

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Biographical Sketches

Mr Gurmeet Singh is a Drainage engineer, Blacktown City Council, Sydney, Australia. He has post-graduate engineering qualifications (Master's in Civil/Environmental Engineering) with extensive experience working in local government, Sydney, Australia in the area of stormwater management. He has experience in planning, design and construction of stormwater treatment systems, in particular Water Sensitive Urban Design. He has presented several papers in international and national workshops and conferences in the area of stormwater management, WSUD and has affiliations with Institution of Engineers, Australia and Water Sensitive Urban Design for Sydney Region, Cooperative program, Sydney Metro Catchment Management Authority (CMA).

Dr Jaya Kandasamy is Senior Lecturer in the Faculty of Engineering and IT, University of Technology, Sydney, Australia. He obtained his PhD from University of Auckland., New Zealand where is also obtained his Bachelor in Civil Engineering and Masters in Civil Engineering. He has worked in the New South Wales Government as a Senior Engineer for 15 years and has wide industry knowledge.

Dr Saravanamthu Vigneswaran has been working on water and wastewater treatment and reuse related research since 1976. During the last twenty years, he has made significant contributions in physico-chemical water treatment related processes such as filtration, flocculation, membrane-filtration and adsorption. His research activities both on new processes development and mathematical modeling are well documented in reputed international journals such as Water Research, American Institute of Chemical Engineers Journal, Chemical Engineering Science, Journal of American Society of Civil Engineers, and Journal of Membrane Science. He has also been involved in a number of consulting activities in this field in Australia, Indonesia, France, Korea, and Thailand through various national and international agencies. He has authored two books in this field at the invitation of CRC press, USA, and has published more than 230 papers in journals and conference's proceedings. Currently a Professor of the Environmental Engineering Group at the University of Technology, Sydney, he was the founding Head of and the founding Co-ordinator of the University Key Research Strength Program in Water and Waste Management. He is coordinating the Urban Water Cycle and Water and Environmental Management of the newly established Research Institutes on Water and Environmental Resources Management and Nano-scale Technology respectively.

Professor Ravi Naidu joined the University of South Australia in January 2003 as Professor and inaugural Director of the Centre for Environmental Risk Assessment and Remediation. Currently he is the CEO of the Coopertaive Research Centre for Contamination Assessment and remediation of the Environment. Ravi has been involved with contaminants research for over 20 years and has gained advanced leadership and management experience in environmental sustainability throughout this period. Professor Naidu has co-authored 300 technical publications and co-edited 8 books in the field of soil and environmental sciences. He is also Fellow of Soil Science Society of America, Agronomy Society of America and New Zealand Soil Science Society. He is the Chair of the Standards Australia Technical Committee on Sampling and Analyses of Contaminated Soils, Chair of the Committee on Bioavailability and Risk Assessment, Chair of the of the International Union of Soil Sciences' Commission for Soil Degradation Control, Remediation and Reclamation, Member of the Executive Committee, Environmental Geochemistry of Tropical Soils, and sitting member of the Victorian EPA Contaminated Sites Auditor panel.

Dr Rupak Aryal completed PhD in environmental chemistry under the supervision of Prof. Hiroaki Furumai, Department of Urban Engineering, University of Tokyo, Tokyo in September 2003. He continued a postdoctoral research fellow at the University of Tokyo on research of storm water quality and quantity. He currently is as a research fellow at the School of Civil and Environmental Engineering, UTS.