Improving Urban Stormwater Quality – From Theory to Implementation

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1 INTRODUCTION

Increasingly over recent years, initiatives to protect the aquatic environment of urban areas have been a focus of many federal, state and local government organisations and community groups. Many of these initiatives have successfully reduced point sources such as sewage discharge and industrial effluent. Urban stormwater and its role in conveying pollutants to our urban waterways is now widely recognised as the next major issue to tackle. However, the sources of urban pollutants are diffuse and inherently more difficult to manage.

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. The treatment of stormwater runoff can no longer be considered in isolation to the broader planning and design of the contributing urban area. Rather, stormwater management needs to be considered at all stages of the urban planning and design process to ensure the site planning, architecture, landscape architecture and engineering infrastructure is all provided in a manner that is sympathetic to the stormwater treatment system.

The concept of Water Sensitive Urban Design (WSUD) is based on formulating development plans that incorporate multiple stormwater management objectives and involve a pro-active process which recognises the opportunities for urban design, landscape architecture and stormwater management infrastructure to be intrinsically linked. At the building design level, innovative means for recycling stormwater for non-potable usage can significantly reduce pressure placed on water resources development and drainage infrastructure by urban development. The concept of WSUD is generic and has now been expanded to apply at a catchment and regional level. The concept provides the basis for a holistic approach to stormwater management using techniques that are capable of delivering a wide range of beneficial outcomes at both the regional and local levels.WSUD is the integration of urban planning and utilisation of best practices to achieve the objectives of sustainable drainage systems for urban areas. Urban planning provides the pro-active element in the process to facilitate the utilisation of stormwater best management techniques. The selection of appropriate Best Management Practices (BMPs) to include within a treatment train involves an assessment made within a variety of disciplines (drainage engineering, landscape architecture, ecology etc) in order to account for site specific characteristic and limitations.

2 MANAGING STORMWATER FOR MULTIPLE OBJECTIVES

As with most multi-objective exercises, the management of urban stormwater will involve the consideration of a range of measures that can appear to be mutually exclusive. For example, the rapid conveyance of stormwater requires hydraulically efficient systems which is contrary to conditions conducive to the effective removal of fine particulates, oil, grit and grease in stormwater. The practicalities of urban stormwater management often require stormwater quantity management issues of flood protection, public safety and drainage economics to be addressed in the first instance before consideration of stormwater quality improvements. Meeting the objectives of stormwater quantity and quality management is however not always mutually exclusive, especially if stormwater management strategies are formulated at the early stages of catchment development as part of the planning phase.

Many water quality management and ecological protection strategies require a combination of water quantity and quality control measures. For example, the protection of ecological health of urban waterways requires both water quantity and quality issues to be addressed with the former often the main causal factor of diminished ecosystem health in urban waterways. The increased magnitudes in stormwater discharges influence the frequency of ecosystem disturbance, which in turn influence the diversity of fauna in the ecosystem. Many measures designed for stormwater quantity control have inherent water quality management functions while others can be retrofitted to serve the dual functions of stormwater quantity and quality management. Similarly, source control for stormwater quality improvement can be utilised for flow reduction and attenuation with beneficial outcomes including the reduction in the frequency of aquatic habitat disturbances and stormwater recycling.

Strategies for the management of non-point source pollutants involve the catchment-wide utilisation of a combination of structural and non-structural measures in series or concurrently as an integrated treatment train approach. Fundamental to the success of this holistic approach to stormwater management is the appropriate prioritisation and positioning of appropriate stormwater management measures. The operation range and target pollutant characteristics for a number of commonly adopted stormwater quality improvement facilities are illustrated in Figure 1.

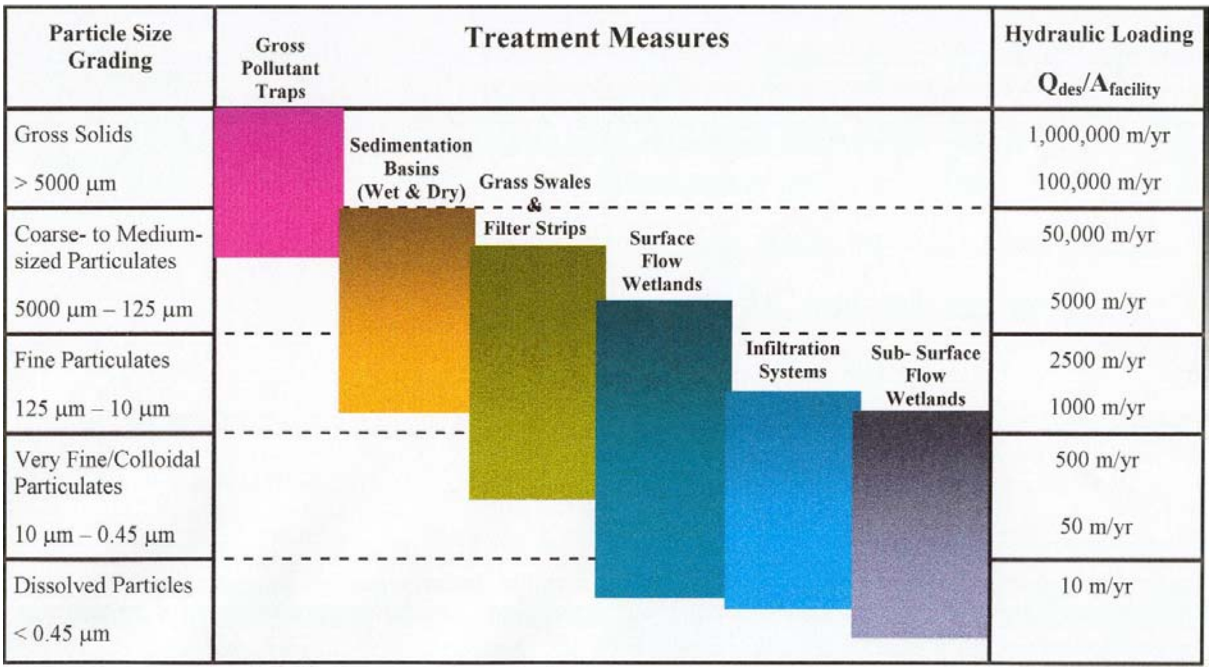

Figure 1 Typical stormwater quality improvement measures, their target pollutant size and hydraulic operating range (Wong et al., 1999)

3 THE CRCCH STORMWATER MANAGEMENT DECISION SUPPORT SYSTEM

The Urban Stormwater Quality Research Program of the Cooperative Research Centre aims to develop a toolkit of models for predicting the performance, and to aid the design, of stormwater management practices. The integration of these models will form a Decision Support System (DSS), which will enable practitioners to develop cost-effective stormwater management strategies, and compare the costs and benefits of different designs. It will also provide a quantitative basis for predicting the performance of stormwater management measures and define their optimal design standards.

The DSS will be developed in modular form, using a Geographic Information System (GIS) platform to link models as required. Consequently, development of the DSS will allow the latest technologies in stormwater quality management to be utilised at a number of levels, from detailed design of individual facilities to the development of catchment stormwater management strategies. Figure 1 illustrates the various components of the DSS.

The DSS will simulate the performance of stormwater management measures on an event or continuous basis, allowing rigorous analysis of the merit of proposed strategies over the short or long-term. Time series of rainfall (from the CRC's Climate Variability Program) will be available as input to the model. Similarly, aquatic ecosystem responses to intermittent and stochastic loading of urban pollutants, derived from research by the CRC for Freshwater Ecology, will also be incorporated into the DSS. To meet industry needs, the DSS will have the capability to operate at a range of temporal and spatial scale, suitable for catchment areas from 100 km^2 to 0.01 km^2.

To underpin the DSS, the CRC is undertaking research to define stormwater pollutant sources, pathways and impacts, and to predict the performance of traditional and innovative stormwater quality improvement facilities to meet user-specified water quality targets.

Integrated management of urban stormwater requires definition of pollutant loads generated in an urban catchment to formulate an integrated water management strategy involving the use of structural and non-structural measures. It also requires an understanding of aquatic ecosystem responses to alteration in hydrology and water quality resulting from catchment urbanisation to set objectives for flow and water quality targets. The CRC research is addressing these needs.

The adoption of WSUD principles in stormwater management and urban design is currently hampered by the lack of quantitative data on the performance and costs of structural and non-structural stormwater quality improvement practices. To ensure the DSS meets the needs of industry, we are researching key knowledge gaps such as processes involved in the removal of stormwater pollutants, the effectiveness of vegetation in the removal and transformation of stormwater pollutants, and effectiveness of infiltration/adsorption systems for stormwater quality improvement. Research will include the development of operation and maintenance practices for these systems.

In addition to these fundamental research activities, the CRC will be monitoring a number of stormwater quality improvement facilities in Brisbane and Melbourne, and assessing the effectiveness of non-structural stormwater management measures.

4 SOME SOURCE CONTROL MEASURES IN WSUD

4.1 Incorporating Stormwater Management Measures into Streetscape

The use of grass swales to promote flow attenuation and water quality improvement has been advocated for many years. Past experiences with grass swale have not been always positive. The main problem stems from inappropriate design with systems that are either too steep (causing localised erosion) or too flat (poor construction leading to localised excessive duration of ponding following a storm event), poor maintenance and a general lack of “ownership” by adjoining property owners. Many of these issues can and have been resolved from learning from these earlier problems. For example, flat terrain may require a system which promotes infiltration and sub-surface drainage as well as flow conveyance through a vegetated channel.

Figure 2 The use of vegetated medium strips for management of car-park stormwater runoff.

Figure 3 Well-planned streetscape can promote local amenity values while having stormwater quality improvement attributes.

Figure 4 Grass swales in place of the conventional kerb and channel system for management of road runoff can promote both water quality improvement and flow attenuation.

The promotion of local ownership has often been overlooked in earlier utilisation of swale system and this is can be addressed through better integration of these system into the streetscape. A number of streetscape design concepts can be utilised to provide enhanced local amenities as well as promote better management of stormwater quantity and quality. Design considerations of local public open space, housing layout, road layout, streetscape, parking space management and reduction of runoff can all contribute to the better management of stormwater runoff for the multiple objectives listed.

Car-parks are high source areas for the full range of pollutant types ranging from gross pollutants to fine particulates and hydrocarbon. There may often be competing requirements in selecting the appropriate measure for the removal of this range of pollutants. Options include the use of non-structural measures for the management of gross pollutants (ie. street sweeping) and a grassed swale for the removal of sediment and associated contaminants (Figure 2).

Residential streetscape design, such as that illustrated in Figure 3, can often significantly enhance the amenity (and thus value) of the local area while having stormwater quality improvement attributes. The use of grassed swale (as illustrated in Figure 4) in place of the conventional kerb and channel stormwater drainage system can effectively improve road runoff quality and flow attenuation.

Infiltration systems are also much advocated as stormwater quantity management, include the adoption of aquifer storage and recharge technologies for stormwater recycling. These systems essentially reduces the equivalent impervious areas of a catchment by allow runoff from these surfaces to be discharged into the surrounding soils (as was the case prior to urbanisation). Infiltration systems have not enjoyed wide-acceptance, mainly as a result of poor maintenance practices (clogging being the most common reason for poor performances) and inadequate pre-treatment of stormwater runoff.

Figure 5 Construction of a Bioretention System in the median strip of a divided street in the Lynbrook Estate for both water quality improvement and flow attenuation.

The use of vegetated infiltration systems, referred to in Germany as biofilters was though to overcome some of the problems associated with clogging with the use of the roots of vegetation to maintain the porosity of the infiltration media. An extension of this concept is the bioretention system which was recently adopted in the Lynbrook Estate, a medium density residential development in the outer suburbs of Melbourne (Figure 5).

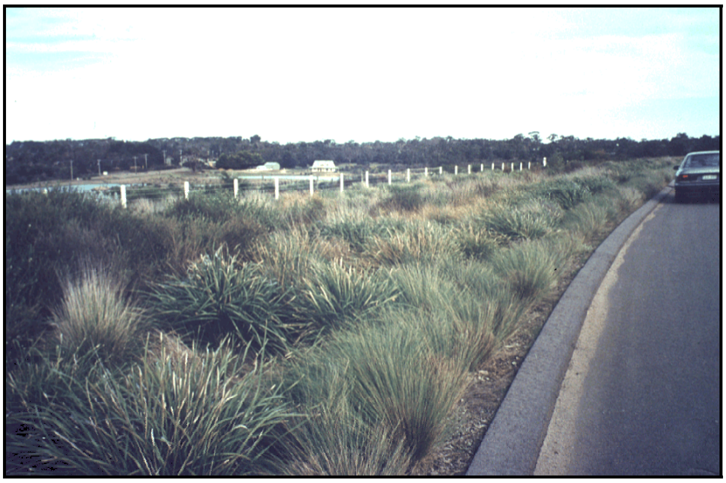

Figure 6 Ephemeral wetland system for treatment of road runoff

4.2 Retrofitting urban stormwater infrastructure

Consideration of treatment methods based on retrofitting existing stormwater drainage infrastructure is of particular relevance and requires matching the capabilities and site requirements of stormwater management techniques to the conditions of the site. Replacement of underground stormwater pipes with more ecologically sensitive systems is not often practical or technically feasible. Retrofitting opportunities in the past have therefore been confined to the application of methods for removal of gross pollutant.

Recent developments in wetland technology have suggested that small constructed wetland systems could be retrofitted into existing underground stormwater pipe systems in built-up urban areas. This follows observation of the performance of small constructed linear wetland systems built along roads for treatment of road runoff (Figures 6 and 7).

Pilot field experiments to quantify the role of vegetation in wetland systems undertaken by the CRC for Catchment Hydrology this summer (Figures 8 and 9) was able to confirm the scalability of current knowledge on the performance of constructed stormwater wetlands for application small confined areas. The CRCCH is now examining how the concept of wetland systems as source control can be incorporated into a densely built-up urban landscape.

Figure 7 Linear wetland systems have been shown to be capable of effective improvement of urban stormwater quality

5 CONCLUSION

Urban stormwater runoff and its environmental impact on urban aquatic ecosystems is a catchment-wide issue and requires a holistic approach in formulating strategies for its management. Measures adopted to improve the quality of stormwater can make an invaluable contribution to the management of non-point source pollutants which may ultimately facilitate the management of stormwater as a resource. There are clearly evolving technologies for effective water quality improvement targeting a wide range of pollutant types.

Figure 8 Experimental channels established for investigation of the role of wetland macrophytes in suspended solids removal and scalability of wetland systems.

There are many best management practices available to us for implementing WSUD. Many of them are not well tested in the field, owing to the lack of demonstration projects and this has hampered further progress and understanding of their long-term operation in actual field conditions. The main impediments to their implementations are mainly related to existing regulatory framework for urban design. As asserted by Wong and Eadie (2000), state and local government planning authorities will need to make a firm commitment to take WSUD beyond just a policy or strategic intent

Figure 9 Dosing of experimental channels with pre-determined particle size tracer

and make it a condition of development by making the necessary amendments to their regulatory planning instruments and relevant urban planning and design guidelines.

To ensure long term sustainability of WSUD elements, communities will need to be empowered with a sense of ownership of the local stormwater assets. This will enable the assets to be cared for and managed in the hands of the community and thus reduce the reliance on recurrent funding from state or local government sources for their maintenance. This will only be achieved through designing urban stormwater systems to be features within the urban landscape and by promoting the inherent values of stormwater (ecological, aesthetic, recreation, education).

There remains a need for further research and development to improve methods of stormwater management under the guiding principles of WSUD. Improving the level of understanding of the processes by which individual stormwater management methods contribute towards the achievement of the multiple objectives of stormwater management is essential for the full value of WSUD to be realized. In addition, there also exists a need to provide robust, but flexible, decision support tools to improve the process by which urban stormwater management systems are developed and implemented.

6 REFERENCES

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