# A CHANGING PARADIGM IN AUSTRALIAN URBAN STORMWATER MANAGEMENT

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## ABSTRACT

Contemporary urban stormwater management is aimed at reducing the impacts of urbanisation on the natural water cycle. Management objectives go beyond the traditional concept of efficient and rapid conveyance of urban stormwater runoff and now include the protection of aquatic ecosystem health of receiving waters, promotion of stormwater as a resource and integration of stormwater management facilities into the urban landscape. By necessity, urban stormwater management now needs to be broadly based, requiring multi-disciplinary inputs. In Australian practice, the adoption of an integrated approach to urban design that implicitly integrates urban stormwater management practices has been slow and sporadic. However, the past three years have seen increased efforts to forge a stronger link between research institutions, state and local government departments and the land development industry. This represents a significant paradigm shift in stormwater management practice in Australia.

Research organisations are now placing a higher emphasis on effective engagement and partnership with the industry. Recent land development projects have adopted a Water Sensitive Urban Design philosophy, a reflection of the changing paradigm towards an integrated urban water cycle management approach to ecologically sustainable urban design. In most states of Australia, current institutional arrangements are such that the responsibility for urban water resources management are fragmented and make integrated water management difficult. Efforts are made to overcome this impediment to provide the necessary administrative and regulatory framework to support industry adoption of best practice environmental management of urban stormwater. This paper describes the current status of Australian practice in urban stormwater management and outlines some of the initiatives taken to complete the paradigm shift to an ecologically sustainable urban stormwater management.

## KEYWORDS

**Stormwater management, urban planning and design, retrofitting, wetlands, bio-filtration, modelling.**

# 1. INTRODUCTION

Urban stormwater and its role in conveying pollutants to our streams is now widely recognised as a significant environmental threat to ecologically sustainable development. However, the sources of urban pollutants are diffuse and inherently 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. To achieve ecologically sustainable development, 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.

Research into the source, characteristics, pathways and impacts of urban stormwater pollutants and development of appropriate stormwater quality improvement practices are important elements underpinning effective stormwater management. Research outputs in the past have not necessarily resulted in beneficial outcomes, often owing to inadequate industry partnership and engagement in supporting the adoption of recommendations derived from research findings.

The land development industry has, over the last decade, incorporated ponds and wetlands in urban design with a strong "natural environment" theme in their development plan. These features were not often directly linked to stormwater management considerations and have in the past led to a number of these urban wetlands and ponds becoming a long term liability to the community. Many of the problems encountered can be minimised or avoided by good multi-disciplinary design principles. Furthermore, conventional development layouts and construction practices have limited the opportunities for any genuine attempt at integrating contemporary best practices in urban stormwater management into land development.

In most states of Australia, institutional arrangements are such that the responsibility for urban water resources management are fragmented, making integration of stormwater management initiatives difficult, particularly when municipal boundaries do not match catchment boundaries.

The last three years have seen increased efforts to forge a stronger link between research institutions, state and local government departments and the land development industry. This represents a significant paradigm shift in stormwater management practice in Australia. This paper describes the various projects in which the Cooperative Research Centre for Catchment Hydrology (CRCCH) are participating to facilitate the paradigm shift to ecologically sustainable urban stormwater management practices in Australia.

# 2. RESEARCH COMMUNICATION AND ADOPTION

Successful approaches to urban stormwater management require catchment-wide integration of urban drainage infrastructure planning and design, with elements of urban hydrology, ecologically sustainable land development, landuse planning, urban landscape architecture and asset life-cycle economics. The removal of non-point source pollutants involves 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. This has been the focus of research efforts of the CRCCH.

In conjunction with planning the CRCCH urban stormwater quality research activities was the development of the Communication and Adoption Plan to facilitate effective technology transfer and adoption of research findings. In the process of industry consultation, it was apparent that a different research ethos needs to be adopted. The traditional approach to technology transfer in the form of publications in journals and conferences will need to be complemented by a more pro-active plan of engaging the industry. It was also necessary for researchers to "put their best science forward" to accommodate an immediate need for technical guidance in stormwater management.

## 2.1 THE ADOPTION ENVIRONMENT

To address the environmental imbalance being caused by conventional urban development practices, a philosophical change is required in the way urban areas are planned and designed. A more holistic and multi-disciplined approach is required to ensure planning and design decisions are made with a full and complete understanding of the environmental, social and economic consequences of those decisions. The change that is required will need the full cooperation and commitment of all those associated with the regulation, planning, design and development of urban areas. This includes state and local government policy and planning personnel, planning and design professionals and the land development industry.

Current institutional arrangements are such that the responsibility for urban water resources management, including urban stormwater and protection of the receiving waters (eg. bays and estuaries), are separated within or between local and state departments. This fragmentation makes integrated water management difficult. For example, regional catchment management and drainage authorities implement stormwater management initiatives at a strategic level by constructing regional stormwater management facilities and serving as referral authorities in catchment development applications. State and local governments are responsible for identification of land release and redevelopment projects. In addition to this, local government is generally responsible for approving development applications and usually specifies the development standards to be met. Standards for stormwater management infrastructure adopted by local governments are based on rigid engineering conventions and do not allow for an integrated approach to urban water cycle management. Often local government officers feel they lack the expertise to assess alternative designs and are reluctant to accept the inherent risk involved in approving alternative approaches.

## 2.2 COMMUNICATION AND ADOPTION STRATEGY

Partnership with industry, the model of the Australian Government's Cooperative Research Centres initiative, provides the framework for effective communication and adoption of research findings. The construction of demonstration sites, access to pilot scale research sites, industry cash and in-kind funding, and policy support in the implementation of recommendations derived from research projects are all important ingredients of a successful research program. The communication and adoption strategy of the urban stormwater quality research program of the CRCCH includes the following initiatives:-

***Industry Partners***

- involvement of industry partners in the identification of knowledge gaps and industry needs, and subsequent research project development and planning;
- involvement of industry partners in the research steering committee, and in some cases piloting of outputs and recommendations derived from the research activity;
- input by research team into the planning, design and provision of continuing technical advise in structural and non-structural stormwater management projects of its industry partners;
- provision of technical support to industry partners' initiative in amending policies and regulations.

***Industry at large***

- a program of technical seminar, shortcourses and field trips to demonstration sites;
- assistance to local and state governments in their development of the necessary state and local government policies on stormwater management and water sensitive urban design to encourage/support best practices in urban stormwater management
- development of technical guidelines and design tools to (i) assist the industry in accommodating new state and local government policy on stormwater management, and (ii) assist local and state government in regulating their new policies.

# 3. WATER SENSITIVE URBAN DESIGN

The concept of Water Sensitive Urban Design (WSUD) is based on formulating development plans that incorporate multiple stormwater management objectives and involves a pro-active process which recognises the opportunities for urban design, landscape architecture and stormwater management infrastructure to be intrinsically linked. WSUD espoused the need to integrate stormwater management into the planning and design of urban areas. It presents a range of alternative planning and design practices aimed at changing the conventional layout and design of urban areas to achieve the multiple objectives of stormwater management outlined above. 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.

The concept of WSUD is generic and applies across the entire spatial scale of urban catchment management, from a catchment-wide regional level to the precinct level to the local, on-site level. The concept is not new and has been referred to by other names such as "Low Impact Urban Design". In Australia, the uptake of WSUD in the industry has been slow, impeded by inadequate technical underpinning of many of the BMPs recommended, insufficient data on life-cycle costs, limited Australian experience and a largely fragmented institutional framework which is not conducive to integrated urban catchment management.

Many research organisations in Australia, including the CRCCH, are now undertaking projects to provide the technical underpinning of WSUD principles. The CRCCH undertook to communicate and demonstrate the application of many of its research outputs through a combination of field tours, short-courses, a national industry seminar series, an industry report and video. The following sections highlight some of these initiatives.

## 3.1 CONSTRUCTED STORMWATER WETLANDS

At the regional level, the use of constructed stormwater wetlands in the urban landscape has become common practice as an effective means of stormwater quality improvement in addition to their other environmental and landscape/passive recreational values. The effectiveness of constructed wetlands in water quality improvement is well documented in the wastewater industry. The extension of this technology to stormwater management brings with it unique challenges stemming from the stochastic nature of the hydraulic and pollutant loading on a stormwater wetland compared to wastewater treatment systems. The proper design of these systems is not a straightforward task owing to its multi-disciplinary nature, the general lack of practical experience in their management and operation in Australia and performance data on which design guidelines can be formulated.

Many pitfalls confront designers as they attempt to reconcile the interaction between the wetland hydrology and hydrodynamic behaviour with the various physical, chemical and biological treatment processes. Many of these pitfalls are borne out of misconception and inappropriate utilisation of available design guidelines, through a general lack of appreciation of the inherent assumptions in these guidelines. A review of past practices in the utilisation of constructed and natural wetlands for stormwater pollution control found design guidelines to be ad-hoc. Most design parameters were based on adaptation of experiences from treatment of wastewater. It was not clear in most cases how some of the differences in the hydrologic and pollutant loading characteristics between stormwater and wastewater have been accommodated in practice.

Research undertaken at the CRCCH has provided a sounder basis for sizing constructed wetlands for stormwater management and for its integration into landscape design. Key outcomes from research work undertaken to date include:-

- the compartmentalisation of constructed stormwater wetlands to enable different processes to be promoted and to provide for the by-pass of high flows (Wong et al., 1998);
- the particle size distribution on suspended sediments conveyed by urban stormwater in Australian catchments appears to be finer than that for overseas catchments (Figure 1, adapted from Lloyd *et al*., 1998);
- the development 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 (Figures 2 and 3; Wong *et al*, 1998);
- the development of technical guidelines which enable landscape designer to achieve a balance between meeting their aesthetic objectives with those of stormwater quality improvement, ie.
  - quantifying the relative significance of vegetation coverage on the performance of stormwater

wetlands, (Wong *et al*., 2000);

– to establish a quantitative measure of hydrodynamic conditions (ie. hydraulic efficiency) in constructed wetlands and ponds and to relate wetland and pond shapes to hydraulic efficiency (Figure 4; Persson *et al*., 1999)

The influence of meteorological factors, particularly the sequence of storm events and inter-event dry period, on the stochastic nature of stormwater runoff results in a much higher level of dynamism in the operation of stormwater wetlands. The designer needs to consider and provide for the operation of the wetland system across the full range of flows encountered, including the management of flood events through flow attenuation and the provision of flow by-pass of high discharges. High discharges not by-passed may either re-suspend and remobilised deposited material or damage the biological integrity of the system (Figure 5).

The provision of an inlet zone, characterised by a deep pond with fringing vegetation, for sedimentation of coarse to medium sized sediment and a by-pass flow path for high flows are now standard design features in constructed stormwater wetlands in Australia (Figure 6).

*Figure 1 Comparison of Particle Size Distributions of Suspended Solids in Urban Stormwater (adapted from Lloyd et al., 1998)*

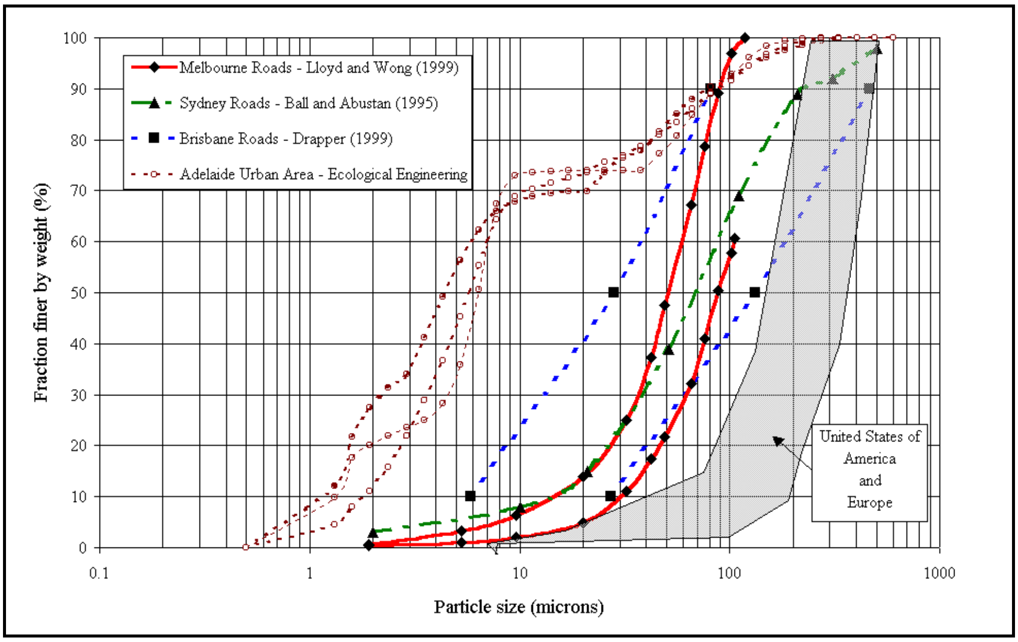


*Figure 2 Hydrologic Effectiveness Curves for Constructed Stormwater Wetlands in Melbourne; Hydrologic Effectiveness – the percentage of mean annual runoff treated by the constructed wetland (Wong et al., 1998)*

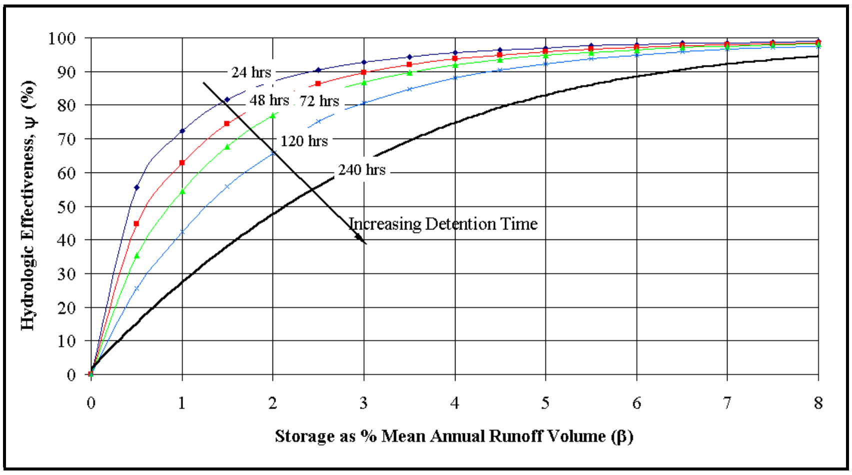



*Figure 3 Hydrologic Effectiveness for Constructed Wetlands designed for 72 hour extended detention period for typical urban catchments(35% imperviousness) in Australian Cities (Wong et al. 1998)*

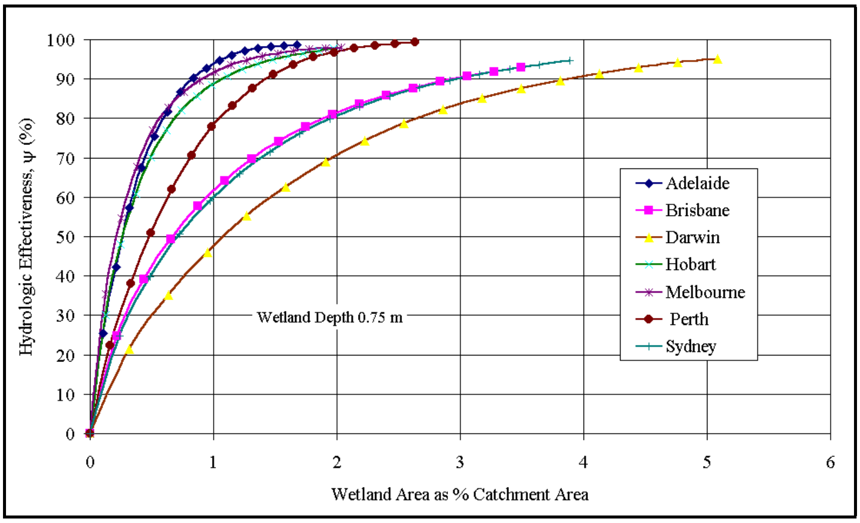



*Figure 4 Hydraulic Efficiency – A measure of Flow Hydrodynamic Conditions in Constructed Wetlands and Ponds; Range is from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment (adapted from Persson et al., 1999)*

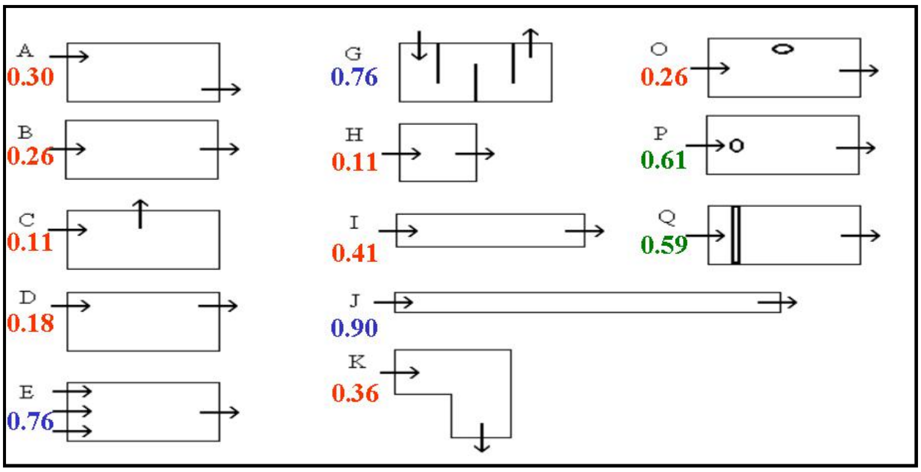


*Figure 5 Constructed wetland in Melbourne without provision of a high flow by-pass and an inlet sedimentation zone : (Left) wetland fully established in 1997; (Right) wetland in 1999 – silted with sediment and a significant majority of vegetation scoured out by flood events.*

*Figure 6 Constructed Stormwater Wetland built in 2000 at Hampton Park, Victoria, Australia (macrophyte zones will require at least two years to fully established)*

## 3.2 RETROFITTING EXISTING FLOOD MITIGATION INFRASTRUCTURE

Changes in catchment hydrology as a result of urbanisation can result in a number of important changes in stream channels which have ecological significance. They include:

- increased frequency of high water velocities;
- increased frequency of disturbance to the substratum;
- increased sediment supply and transport rates;
- long term changes to substratum particle size range due to the removal of the more easily eroded and supply limited materials;
- increased rates of bed erosion and knickpoint (bed erosion heads) retreat.

These changes generally result in a reduction in in-stream physical diversity and, as a result, reduction in aquatic ecosystem health. A number of studies, (eg. Miller, 1984, Schueler, 1995, Wong *et al*., 1999) have reported significant changes and decreases to the diversity and abundance of macroinvertebrate communities under these conditions. It was apparent from these studies that deterioration of aquatic ecosystem in urban waterways could be attributed to two possible factors, ie. the frequent disturbance of aquatic habitats and degraded water quality. The former is directly the consequence of a hydraulically efficient stormwater conveyance system associated with traditional stormwater drainage infrastructure.

Site conditions determine which of the two factors is the dominant factor affecting aquatic ecosystem health, but clearly both factors will need to be addressed in rehabilitating urban waterways. In addition to recommending initiatives to improve the quality of stormwater discharging to urban waterways, recommendations were made by the CRCCH to reduce the frequent disturbances of aquatic habitats in Australian practice by seeking to attenuate post-development peak discharges corresponding to the 1.5 year ARI event to pre-development levels.

### 3.2.1 DISTRIBUTED STORAGES

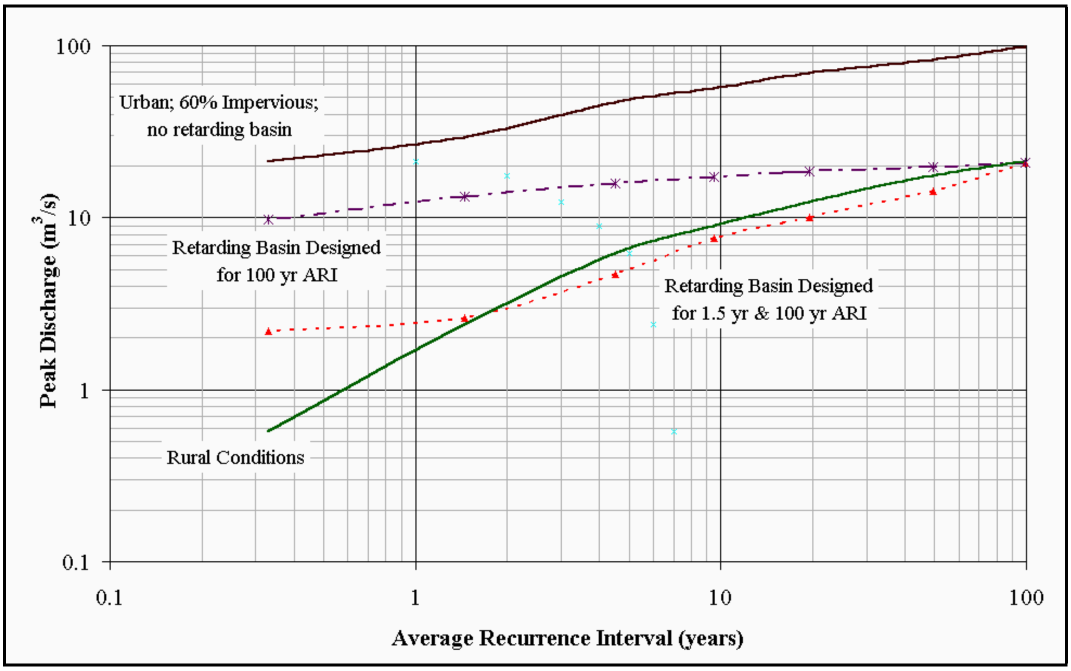
In a built-up catchment, opportunities for source control can be limited and often, the stormwater drainage system has already undergone significant modification (eg. underground pipes, excavated and lined channels) to increase their hydraulic efficiencies. An alternative means of compensating for the improved hydraulic efficiency is the construction of small distributed storages throughout the catchment. These can be in the form of recreational lakes or wetlands. The sites of these storages are generally small and would not have the capacity to effectively attenuate large flood events. They have, as a consequence, been often disregarded in the past when formulating a stormwater drainage strategy based on traditional flood mitigation objectives. Apart from the well recognised benefits in water pollution control, associated with lakes and wetlands, these storages serve to attenuate runoff generated from the local area and they can be sized such that discharges corresponding to frequent events can be attenuated to pre-development levels. This would relieve the stress imposed on downstream aquatic habitats and is often a necessary first step towards the re-establishment of urban waterway ecosystem.

### 3.2.2 RETARDING BASINS

At a larger scale, regional retarding basins have traditionally been utilised to control peak discharges generated from an urban catchment. Current design objectives of these basins have focused on reducing the peak urban discharge for events of high average recurrence intervals (eg. 50 years or 100 years ARI) to pre-development conditions. These objectives have no benefits to habitat protection. It is only in recent times that many of these flow detention systems have been designed or retrofitted for stormwater quantity and quality management. Opportunities for retrofitting existing retarding basins to provide water quality enhancement functions include the development of wetland systems within the storage area of these basins.

Designing retarding basins to meet more than one discharge criterion can provide beneficial outcomes for ecological management without compromising drainage and flood protection requirements. Figure 7 compares two peak discharge frequency curve; one resulting from a retarding basin designed to match the pre-urbanisation 100 year ARI peak discharge and the other for a retarding basin designed to match both the 1.5 year ARI and 100 year ARI pre-urbanisation peak discharges.

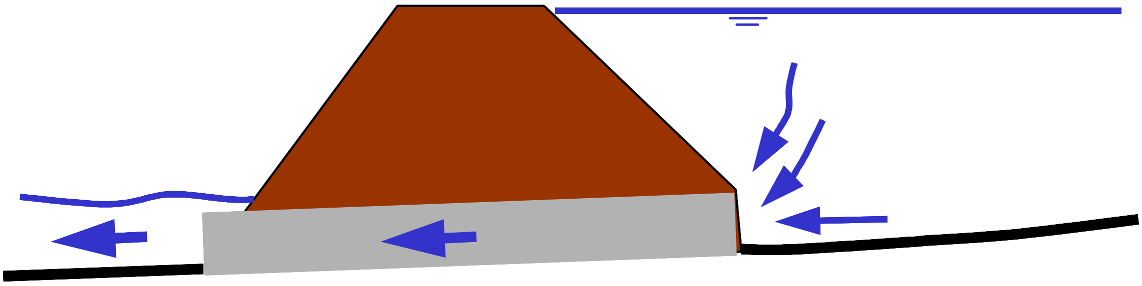
*Figure 7 Effect of Retarding Basin on Stormwater Peak Flow Frequency Curves (Wong and Somes, 1997)*



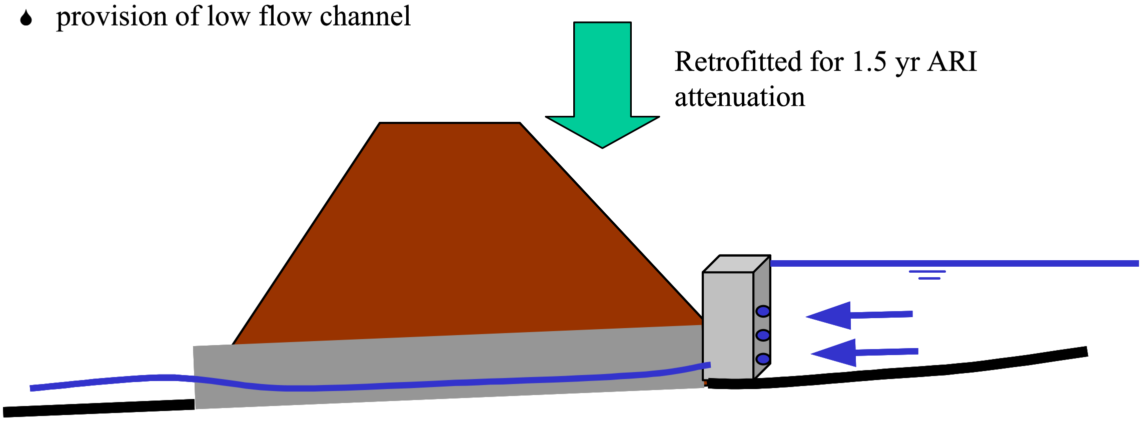

The plot clearly shows that retarding basins can be designed to match a range of peak discharges expected under rural conditions. In this case, the flood frequency curve under urbanised conditions (with a multiple design discharge criteria retarding basin) is almost similar to the rural condition curve for events larger than the 1.5 year ARI event.

As discussed by Wong and Somes (1997), two groups of outlet pipes for the retarding basin can be used to match to the two discharge criteria. The first group of outlet pipes is selected to attenuate the 1.5 year ARI urban discharge back to the discharge expected for rural conditions. The second set of outlet pipes is located at a higher elevation and will only be utilised for events larger than the 1.5 year ARI event. This second group of pipes is selected to attenuate the 100 year ARI urban discharge back to the rural condition discharge. The additional discharge criterion can result in increased storage requirements and inundation frequency of the basin. The significance of these increases will vary considerably depending on site specific topography. The case study undertaken by Wong *et al*. (1999) suggests an increase in storage requirement of approximately 10%. Figure 8 illustrates a possible set-up associated with the retrofitting of an existing retarding basin outlet for 1.5 year ARI attenuation.

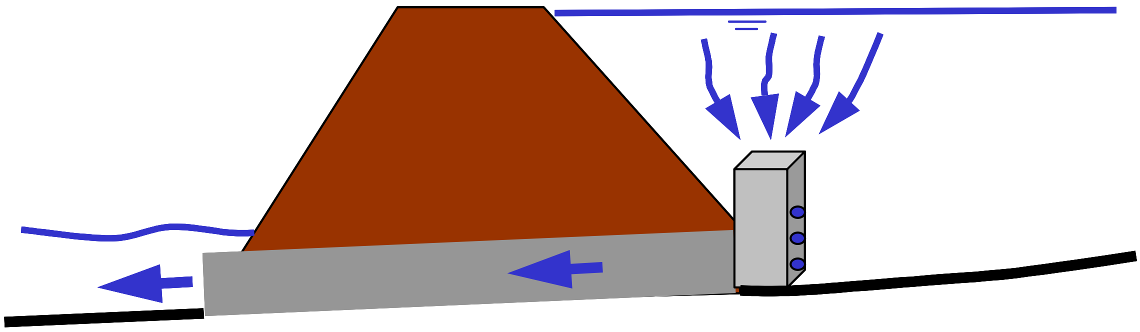
*Figure 8 Illustration of a possible means of retrofitting a conventional retarding basin outlet for 1.5 year ARI attenuation*



- outlet pipe located at one invert level and sized to provide required 100 year ARI peak discharge attenuation
- outlet operates under outlet control
- provision of low flow channel




- Install inlet pit with smaller orifices on the wall of the pit
- outlet operates under orifice flow up to 1.5 year ARI event



- above the 1.5 year ARI event, overflow of the inlet pit allows the full 100 year ARI capacity of the outlet pipe to be utilised

A number of projects associated with the retrofitting of the retarding basin outlet structure have incorporated a constructed wetland within the retarding basin for water quality improvement as illustrated in Figure 9. Downstream waterway remodelling following retarding basin retrofits follows, with the establishment of a low flow natural channel with densely vegetated benches up to the 1.5 year ARI level.

*Figure 9 Conventional retarding basins (left) could be retrofitted (right) to provide a range of multiple functions without affecting its functionality as a flood mitigation facility*

### 3.2.3 STREETSCAPE AND SOURCE CONTROL

Recent developments in wetland technology have indicated 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 (Figure 10). Pilot field experiments to quantify the role of vegetation in wetland systems undertaken by the CRCCH (Wong *et al*, 2000) were 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 including incorporation into building forecourts (Figure 10).

*Figure 10 Constructed wetland systems can be used as source control measures along roads (left) and as part of an building forecourt (right).*

Grass swales are not uncommon in Australian regional urban townships and alongside country roads. 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 ponding for excessive duration following a storm event), poor maintenance and a general lack of "ownership" by adjoining property owners. Many of these issues have been resolved and they are becoming increasingly common as a landscaping feature of redeveloped areas in built-up urban catchments as illustrated in Figure 11. Field experiments to define the performance of grass swales in stormwater quality improvement are being undertaken by the CRCCH to better define design specifications for these systems.

*Figure 11 Grass swales are now increasingly being incorporated into residential streetscape as a landscape feature*

## 4. LYNBROOK ESTATE STORMWATER MANAGEMENT SYSTEM

A collaborative approach was adopted between Melbourne Water Corporation, the Urban Land Corporation (land developers), KLM Development Consultants (engineers), Murphy Design Group (landscape architects), and the CRCCH to design and construct a 300-allotment residential estate serviced by non-conventional stormwater management infrastructure. The Lynbrook Estate, located in the outer eastern suburb of Melbourne, has been a remarkable success story, being the first residential estate in Victoria to incorporate WSUD. Features include a series of linked gravel-filled, vegetated drains along wide nature strips (called *bioretention or biofiltration systems*) designed to absorb and filter stormwater, swales and constructed wetlands as illustrated in Figure 12.

The $15 million development has had good sales, even in the recent downturn in the property market. The inclusion of water features, preservation of remnant vegetation and an emphasis on environmental issues tends to make developments more desirable and marketable and consequently the market now perceives Lynbrook as an "upmarket development". Second and subsequent home buyers are now in the majority of consumers and house size has increased accordingly. Sales rates today are in the range of 15 to 20 per month in a depressed market.

The CRCCH and Melbourne Water are using the Lynbrook Estate as a major demonstration of WSUD principles as well as a site for field experiments (see Lloyd *et al*., 2001). Documentation of construction techniques was also a major activity in a research project conducted by the CRCCH to enable future improvements in design and construction specifications. Field experiments on the biofiltration system have demonstrated that the system has led to improved water quality.

The project is providing an opportunity to evaluate costs and benefits and consumer responses to WSUD. Comparison of costs between implementing a WSUD stormwater management scheme and a conventionally designed stormwater drainage system shows only a minor increase of 5% to the cost of the drainage component of the development. Considering the drainage works component represents only 10% of the overall cost, the incorporation of WSUD into the stormwater management system at the Lynbrook Estate increased the total budget by approximately 0.5%. It is expected that in the future cost neutral outcomes will predominantly occur as contractors become more familiar with the construction of WSUD infrastructure and remove the extra costs associated with a 'safety margin' included into their project budget.

*Figure 12 Features of the Lynbrook Estate stormwater management infrastructure (a & b) bio-filtration system constructed on the medium strip of a divided road; (c) outlet pit of the biofiltration system showing the location of the perforated pipe beneath the biofiltration media; (d) a variation of the bio-filtration system is used for smaller undivided roads; (e) biofiltration system discharges into a constructed wetland for further stormwater quality improvement – ornamental lake in the background.*

This project was presented with an Urban Development Institute of Australia's Excellence Award for innovation in land development in 2000. The Lynbrook Estate project has been a fine example of effective collaboration between a research organisation, local government, regional catchment management authority and the land development industry. Melbourne Water Corporation and the Urban Land Corporation were instrumental in ultimately convincing the local government to waive its conventional and rigid stormwater drainage requirements. Melbourne Water Corporation agreed to underwrite the conversion of the stormwater infrastructure back to conventional design should the system proved not to be adequate and the Urban Land Corporation extended the maintenance period from the conventional three month period to a twenty four month period.

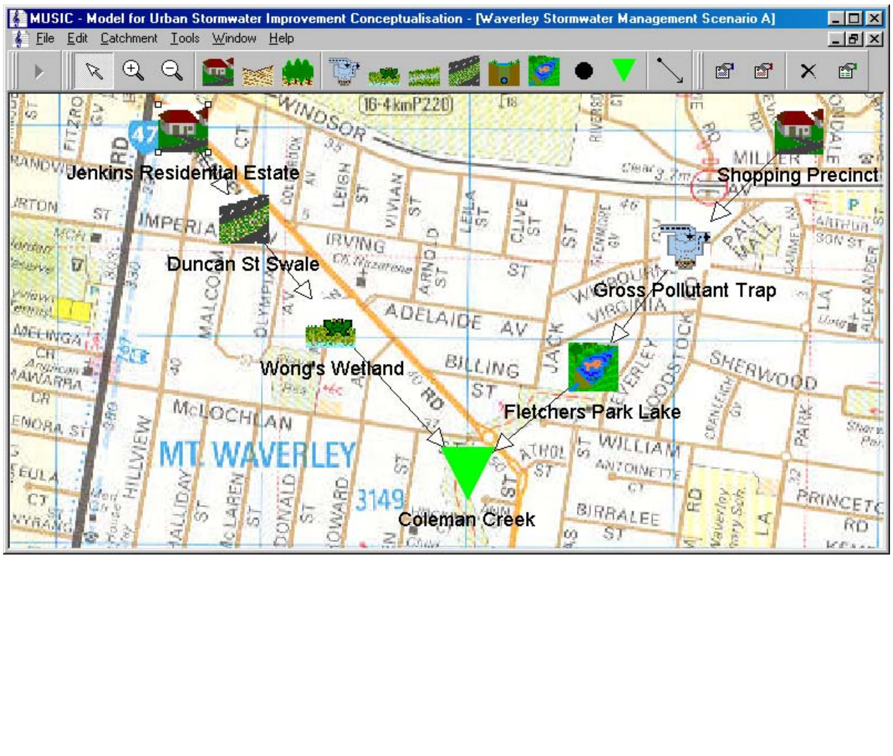
The CRCCH, through its efforts in engaging industry in the communication and adoption of its research findings and recommendation as demonstrated by the Lynbrook project has led to it winning the recent CRC Association Technology Transfer Award.

# 5. MODELLING THE PERFORMANCE OF URBAN STORMWATER MANAGEMENT SYSTEMS

Until recently, there have been a number of significant gaps in prioritisation of urban waterway management activities, and in particular, management of urban stormwater impacts. Inadequate information about the performance of stormwater treatment measures (e.g. wetlands, vegetated swales, or gross pollutant traps) has created uncertainty in the minds of urban catchment managers about their merit. The CRCCH developed a decision-making framework for urban stormwater management, which uses a stochastic watershed modelling approach to predict the generation of stormwater flows and pollutant loads. This system allows urban catchment managers to predict changes to water quality and hydrology resulting from altered land use and to develop best-practice stormwater strategies to avoid or ameliorate these changes (Fletcher *et al*., 2001). The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is designed to simulate stormwater systems in urban catchments and has the capability to operate at a range of temporal and spatial scales, suitable for catchment areas from 100 $km^2$ to 0.01 $km^2$. Modelling time step can range from 6 minutes to 24 hours to match the spatial scale.

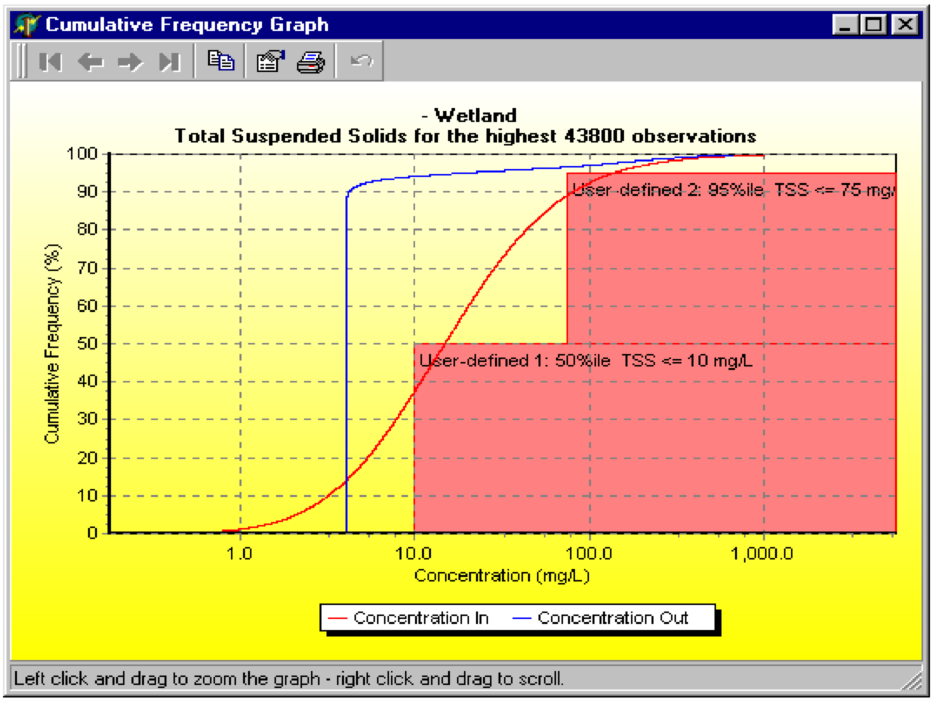
The operation of MUSIC is based on a simple icon-driven interface (Figure 13) and urban catchment managers can layout their proposed stormwater management strategy on a map or plan, creating the 'treatment' train of required stormwater treatment measures. MUSIC will simulate the performance of the proposed strategy on an event or continuous basis using historical and/or stochastically generated data.

*Figure 13: MUSIC interface, showing layout of stormwater treatment strategy, and background map.*



The performance of the stormwater treatment train can be examined using a range of output options, including time-series graphs of flows and pollutant loads/concentrations, statistical summaries of pollutant concentrations and pollutant loads removed, or cumulative probability plots (Figure 14). Water quality standards can be applied to any of these outputs, to allow easy interpretation of performance. The most important feature of MUSIC is that it readily facilitates scenario 'gaming', in which the user can evaluate the short- or long-term performance of alternative strategies.

*Figure 14: Cumulative probability plot output, showing water quality standard (shaded box).*




# 6. GOVERNMENT INITIATIVES

## 6.1 LOCAL GOVERNMENT POLICY

The past three years have seen increased government funding for stormwater management, with the combined Federal and State funding initiatives directed at urban stormwater management of over AUD$100 million. There is currently a Commonwealth Senate Inquiry into Australia's urban water management (ref. www.aph.gov.au/senate_environment) with the following terms of reference:-

- The management of water in Australian cities including an assessment of what constitutes ecologically sustainable water use and the environmental, health and economic implications and imperatives for achieving this;
- The progress and adequacy of Australia's policies to reduce urban water use and improve water quality;
- Environmental performance in urban stormwater management; and
- Potential for Australia to improve water quality and environmental outcomes.

These initiatives have been a significant catalyst for local government to develop and implement strategic plans for improvement of urban stormwater quality.

Many of the state and federal funding for stormwater management have, in the past, been confined to structural works, often with no provision for performance monitoring. In recent times, this imbalance has been addressed with funding now available for development of non-structural initiatives, particularly in the area of local government policy development and implementation.

Brisbane City Council in Queensland has recently rewritten its planning policy to specify WSUD as the preferred option in land development unless WSUD can be discounted on the grounds of safety, on-going maintenance or of being a nuisance. The City of Blacktown in New South Wales has adopted as policy, a set of stormwater quality improvement objectives for new development within its municipality. This change in local government policy is a vital element in creating the right adoption environment for the adoption of innovative stormwater management practices. Implementation of these policies will require standards and approval procedures to be redrafted to include WSUD planning and treatment measures. A key issue will be the skills and capabilities of council planners and engineers for the approval of water sensitive concept designs.

## 6.2 POLICY COMPLIANCE AND LINKAGE TO REGIONAL INITIATIVES

The use of local planning policy is only one aspect of supporting the paradigm shift in urban stormwater management. Fundamental to an effective regulatory framework for WSUD is the linkage between the three levels of WSUD initiatives, ie. the local or on-site, precinct and regional levels. The limitation in using only local planning policy and design standards is that such development standards usually apply to on-site or source control measures and they may not necessarily be the most effective or strategic action from a catchment management perspective. Often, opportunities for on-site works can be limited and compliance criteria that are inflexible or prescriptive can be counter-productive, especially when our scientific understanding of stormwater pollutants and best management practices is rapidly evolving.

The CRCCH is embarking on a project directed at formulating compliance criteria for local government policy on stormwater management that support industry capacity building and innovation. The compliance criteria are to be fundamentally performance-based, but will still need to accommodate the needs of a largely low industry skill-base. The technical guidelines, whilst needing to be simple, must be able to accommodate the range of site characteristics encountered, and identify those characteristics that may limit the range of applicable stormwater quality control measures and/or its operating conditions (and thus design specifications). The compliance criteria must provide for alternative means in which compliance can be demonstrated. For example, in larger development projects, the developer could be expected to have access to higher levels of technical skills and modelling tools to undertake detailed hydrological and water quality control computations in developing a site-based stormwater management plan that will comply with local government policy.

A scheme to allow developers (especially in-fill developers with limited treatment opportunities in built-up catchments) to contribute to regional and precinct WSUD schemes in-lieu of some (but not all) required on-site works would be consistent with the integrated catchment management philosophy in urban stormwater management. Investigation into the feasibility of a scheme for “trading” of stormwater quality improvement credits or ‘off-sets’ for environmental management of urban stormwater is one of many efforts by Victorian local and state government departments to formulate a more integrated regulatory framework for WSUD. The modelling capability of MUSIC will provide the quantitative basis underpinning such a scheme in linking government policy to stormwater quality treatment technology.

# 7. CONCLUSION

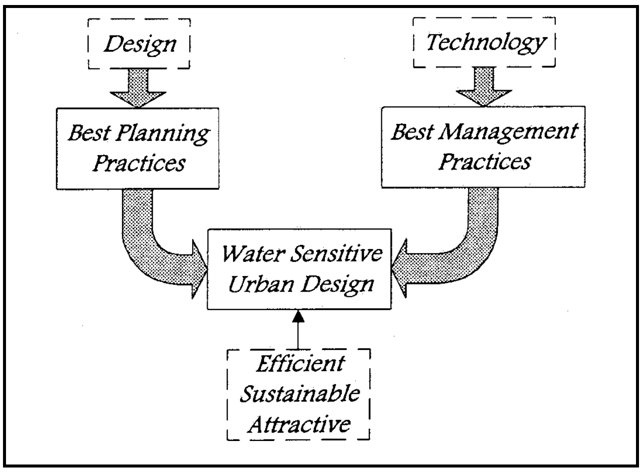
The past few years have seen a significant change in Australian stormwater management practices as a result of a stronger link between research institutions, state and local government departments and the land development industry.

Research organisations are now placing a higher emphasis on effective engagement and partnership with the industry, in addition to its traditional responsibilities in ensuring scientific rigour in their research. Recent land development projects have adopted a Water Sensitive Urban Design philosophy, a reflection of the changing paradigm towards an integrated urban water cycle management approach to ecologically sustainable urban design.

Funding by state and federal governments has provided the catalyst for engaging local government in this paradigm shift in urban stormwater management. There are demonstration sites of innovative stormwater management practices across local/precinct/regional scales which are actively monitored and in some cases used as research sites to further our scientific knowledge of urban stormwater pollution and mitigation measures. There are now significant steps taken to overcome current administrative impediment associated with the fragmented responsibilities for stormwater management across municipal and catchment boundaries to provide the necessary administrative framework to support industry adoption of best environmental management of urban stormwater.

These are all ingredients to a successful integration of non-structural and structural stormwater management practices, so well depicted in the report by Whelan *et al.*(1994) (Figure 15) which sets the agenda for a paradigm shift in stormwater management in Australia in 1994. The next decade will indeed be a very exciting period for stormwater management practices in Australia

*Figure 15 The integration of Best Management Practices and Best Planning Practices – the basis for Water Sensitive Urban Design (Whelan et al.., 1994)*



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