



Department of Water  
Government of Western Australia



# Stormwater Management Manual for Western Australia

A component of integrated  
water cycle management

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## Decision Process for Stormwater Management in WA

Publication date: May 2005

### Instructions

To ensure that you have the latest version of each chapter of the *Stormwater Management Manual for Western Australia* (Department of Water 2004–2007), please go to the Department's website <http://stormwater.water.wa.gov.au>, under the Management Manual heading.

Alternatively, you can go direct to the Management Manual page <http://portal.water.wa.gov.au/portal/page/portal/WaterManagement/Stormwater/StormwaterMgtManual>.

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## Decision Process for Stormwater Management in WA (Department of Environment and Swan River Trust, 2005)

### Preamble

The *Decision Process for Stormwater Management in WA* provides a decision framework for the planning and design of stormwater management systems. The methodology outlined in the decision process will result in minimising potential changes in the volume of surface water flows and peak flows which, if not managed, would lead to adverse impacts on water regime, water quality, habitat diversity and biodiversity in receiving water bodies<sup>1</sup> resulting from land development (i.e. residential, rural-residential, commercial and industrial). The process also addresses the management of flood events for the protection of properties. The decision process sits within the objectives, principles and delivery approach outlined in the *Stormwater Management Manual for Western Australia* (DoE, 2004). This includes: minimising risk to public health and amenity; implementing systems that are economically viable in the long term; and ensuring that social, aesthetic and cultural values are maintained.

A significant stormwater management measure is to minimise the ‘effective imperviousness’ of a development area. Effective imperviousness is defined as the combined effect of the proportion of constructed impervious surfaces in the catchment, and the ‘connectivity’ of these impervious surfaces to receiving water bodies. The purpose of minimising effective imperviousness is to reduce the transportation of pollutants to receiving water bodies and to retain the post development hydrology as close as possible to the pre-development hydrology. This is achieved by ‘disconnecting’ constructed impervious areas from receiving water bodies and by reducing the amount of constructed impervious areas.

To retain the pre-development hydrology of a site, the order of management priorities is: the magnitude of peak flows; the volume of catchment run-off; and the seasonality of catchment run-off.

Rainfall, for the majority of events occurring each year, should be retained<sup>2</sup> or detained<sup>3</sup> on-site (i.e. as high in the catchment and as close to the source as possible, subject to adequate site conditions). Runoff from constructed impervious areas (e.g. roofs and paved areas) should be retained or detained through the use of soakwells, pervious paving, vegetated swales or gardens. For detention systems, the peak 1 year Average Recurrence Interval (ARI<sup>4</sup>) discharge from constructed impervious areas should be attenuated to the pre-development discharge rate. Events larger than 1 year ARI can overflow ‘off-site’.

For larger rainfall events (i.e. greater than 1 year ARI events), runoff from constructed impervious areas should be retained or detained to the required design storm event in landscaped retention or detention areas in public open space or linear multiple use corridors. Any overflow of runoff towards waterways and wetlands should be by overland flow paths across vegetated surfaces. Further detention may be required to ensure that the pre-development hydrologic regime of the receiving water bodies is largely unaltered, particularly in relation to peak flow rates and, where practical, discharge volume.

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<sup>1</sup> Water bodies are defined as waterways, wetlands, coastal marine areas and groundwater aquifers.

<sup>2</sup> Retention is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation. Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design ARI event.

<sup>3</sup> Detention is defined as the process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design ARI event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.

<sup>4</sup> ARI is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For further information, refer to *Australian Rainfall & Runoff* (IEA, 2001) and the Bureau of Meteorology website via <[www.bom.gov.au/hydro/has/ari\\_aep.shtml](http://www.bom.gov.au/hydro/has/ari_aep.shtml)>.

Urban pollutants, whether in particulate or soluble forms, are conveyed by stormwater almost every time a storm event occurs. Studies in urban areas have shown that there is no general trend of increased concentrations of contaminants such as nutrients and metals with increasing storm sizes. Figure 1 shows that most hydraulic structures can be expected to treat over 99% of the expected annual runoff volume when designed for a 1 year ARI peak discharge. Unlike flood mitigation measures, stormwater quality treatment devices do not need to be designed for rainfall events of high ARI to achieve high hydrologic effectiveness (i.e. the percentage of mean annual runoff volume subjected to treatment) and therefore a high level of beneficial environmental outcomes.

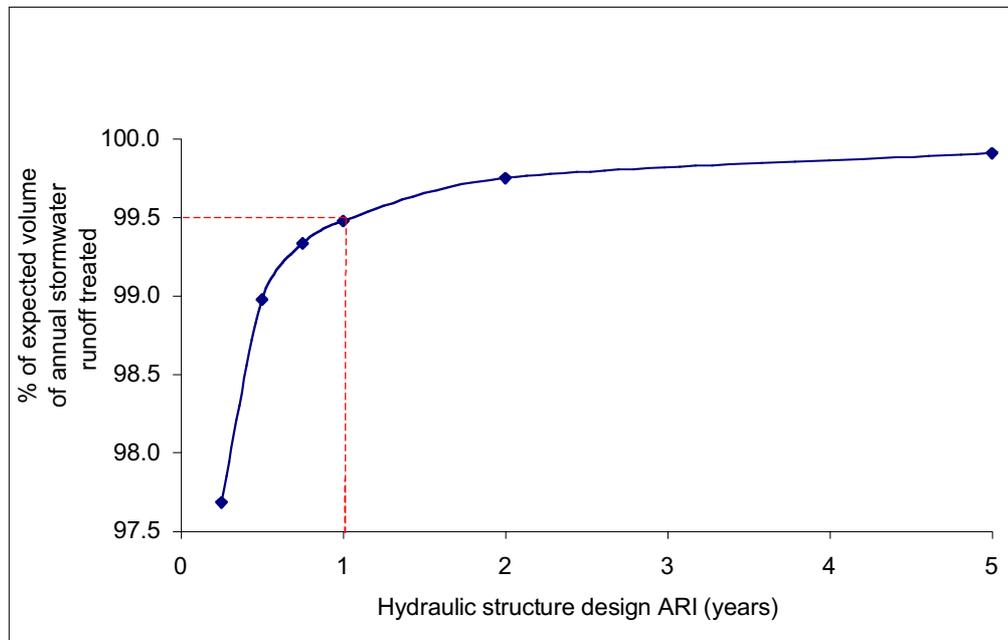


Figure 1. Treatment efficiency of stormwater hydraulic structures for Perth, Western Australia (adapted from Wong, 1999)

Stormwater management systems should be based on adequate field investigations and the conditions of the site. Prior to design, developers should consult with the Department of Environment, local government authority and other relevant stakeholders. For further information, refer to the *Decision Process for Stormwater Management in WA* flow chart.

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# Decision Process for Stormwater Management in WA (DoE and SRT, 2005)

1. Stormwater management systems shall be designed in accordance with the objectives, principles and delivery approach outlined in the *Stormwater Management Manual for Western Australia* (DoE, 2004). This includes: minimising risk to public health and amenity; protecting the built environment from flooding and waterlogging; implementing systems that are economically viable in the long term; and ensuring that social, aesthetic and cultural values are maintained.
2. Prior to design, developers shall consult with the Department of Environment (DoE), local government authorities and other relevant stakeholders. Maintenance requirements should be considered at this stage.
3. Adequate field investigations shall be undertaken to determine the appropriate hydrologic regime for the site and potential site constraints, such as contaminated sites, acid sulfate soils or highly elevated nutrient levels in groundwater. Baseline and/or ongoing monitoring of groundwater and surface water quality and quantity may be required.
4. Stormwater management systems may be subject to additional design and performance criteria if they have the potential to impact on sensitive receiving environments. Sensitive receiving environments include (but are not limited to) conservation areas or reserves, wetlands and waterways with conservation values, Waterways Management Areas, the Swan River Trust Management Area, Environmental Protection Policy areas, and some areas of native vegetation. Sensitive native vegetation includes (but is not limited to) Declared Rare Flora, Priority Species, Threatened Ecological Communities, Threatened Fauna Habitat and vegetation identified in *Bush Forever* (WAPC, 2000), including vegetation located east of the Southern River Vegetation Complex on the Swan Coastal Plain.

## Water quantity management

1. Is the proposal completely or partly within a known contaminated site (i.e. a contaminated site listed on the contaminated sites register, or identified through adequate field investigations) or high acid sulfate soil risk area?
2. Does the soil or groundwater contain *highly elevated* nutrient levels? A definition for highly elevated nutrient levels has not been provided, as nutrient breakthrough is highly variable and is dependent on the soil type (e.g. organic, clay and iron oxyhydroxide content) and local wetting and drying cycles.

### Avoid mobilisation or disturbance of the in-situ contaminants

If yes to question 1 - seek further advice from the DoE.

If yes to question 2 - consult with the DoE about best management practices to minimise nutrient leaching through the soil profile (i.e. structural and non-structural controls suitable to the site conditions).

Yes (to either question)

No (most situations)

1. Maintain the pre-development hydrologic regime and meet the ecological water requirements of the receiving environment.
2. Hydraulic requirements shall be determined by ecosystem requirements and the hydrologic form of the local and downstream environment. Physical survey measurements and a biological survey should be undertaken.
3. Hydrologic and hydraulic analyses, modelling and design shall incorporate the recommendations and methodology of *Australian Rainfall and Runoff, A Guide to Flood Estimation* (IEA, 2001).
4. The effective imperviousness of a development shall be minimised. The process for achieving this is outlined below:

### Less than and up to 1 year ARI events

Generally, rainfall from 1 year average recurrence interval (ARI) events should be retained or detained on-site (i.e. as high in the catchment and as close to the source as possible), unless it can be clearly demonstrated that achievement of this objective is impractical due to site conditions.

Generally, for detention systems, preserve the pre-development 1 year ARI peak discharge rate. Use best management practices (structural and non-structural) to treat water quality.

### Greater than 1 year and up to 100 year ARI events

Mitigate runoff from constructed impervious areas for greater than 1 year ARI events, in landscaped retention or detention areas in public open space or linear multiple use corridors. Any overflow of runoff towards waterways and wetlands shall be by overland flow paths across vegetated surfaces.

Design for greater than 1 year and less than 10 year ARI events

Design for 10 year to 100 year ARI events

Minor system conveyance (i.e. swales and pipes).

Major system conveyance (i.e. via overland flow).

## Water quality management

1. On-site field investigations are required to determine the appropriate water quality management measures for the site, including consideration of potential pathways of nutrients towards receiving water bodies. Receiving water bodies are defined as waterways, wetlands, coastal marine areas and groundwater aquifers.
2. The components of the water quality treatment train must be designed so that their combined effect meets the water quality management objectives as specified in the relevant regional water quality management targets (e.g. local government stormwater management plans, the Regional Natural Resource Management Strategy, *Swan-Canning Cleanup Program Action Plan* (SRT, 1999) and the *Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992* (EPA, 1992)). The requirements for demonstration of compliance shall depend upon the scale of the proposed land development. Demonstration of compliance may be achieved by the use of appropriate assessment methods, to the satisfaction of DoE.

## Protect waterways and wetlands

1. Retain and restore waterways and wetlands. For waterways, the approach should be consistent with the *River Restoration Manual* (WRC, 1999-2003), *Draft Waterways WA - A Policy for Statewide Management of Waterways in Western Australia* (WRC, 2000), *Foreshore Policy 1 - Identifying the Foreshore Area* (WRC, 2002) and, in the Swan and Canning Catchments, the *Environmental Protection (Swan and Canning Rivers) Policy 1998* (EPA, 1998). For wetlands, the approach should be consistent with the *Environmental Protection of Wetlands Position Statement No. 4* (EPA, 2004) and the *Wetlands Conservation Policy for WA* (Government of WA, 1997). On the Swan Coastal Plain, the approach to managing wetlands should also be consistent with the *Environmental Protection (Swan Coastal Plain Lakes) Policy, 1992* (EPA, 1992) and the *Position Statement: Wetlands* (WRC, 2001).
2. There shall be no new constructed stormwater infrastructure within Conservation category wetlands and their buffers, or other conservation value wetlands and their buffers, or within a waterway foreshore area (e.g. no pipes or constructed channels within these wetlands and their buffers, or within waterway foreshore areas), unless authorised by the DoE or the Environmental Protection Authority. For Resource Enhancement and Multiple Use category wetlands, stormwater management shall be consistent with the objectives outlined in the *Position Statement: Wetlands* (WRC, 2001).
3. The creation of artificial lakes or permanent open water bodies generally will not be supported when they involve the artificial exposure of groundwater (e.g. through excavation, or lined lakes that require groundwater to maintain water levels in summer) or the modification of a wetland type (e.g. converting a dampland into a lake). Where water conservation (e.g. summer water supply) and environmental and health concerns (e.g. hydrology, water quality, mosquitoes, midges, algal blooms, acid sulfate soils and iron monosulfide minerals) can be adequately demonstrated to be addressed through design and maintenance, consideration may be given to the creation of artificial lakes/ponds. Seasonal wet infiltration areas or approved constructed waterways (i.e. ephemeral 'Living Streams') are preferred options.

## Management of groundwater levels

1. Any proposals to control the seasonal or long-term maximum groundwater levels through a Controlled Groundwater Level (CGL) approach shall demonstrate through adequate field investigations, to the satisfaction of the Department of Environment, that local and regional environmental impacts are adequately managed.
2. The CGL may be defined as the controlled (i.e. modified) groundwater level (measured in metres Australian Height Datum) at which the DoE will permit drainage inverts to be set. The CGL must be based on local and regional environmental water requirements, determined in accordance with the *Environmental Water Provisions Policy for Western Australia* (WRC, 2000) and the *Urban Development and Determination of Ecological Water Requirements of Groundwater Dependent Ecosystems* (DoE, in preparation).
3. Where appropriate, field investigations must be undertaken to identify acid sulfate soils (ASS). Any reduction in groundwater level should not expose ASS to the air, as this may cause groundwater contamination. Refer to the ASS Guideline Series, including *Identification and Investigation of Acid Sulfate Soils* (DoE, 2004). If field investigations identify ASS, seek further advice from DoE.

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Stormwater  
Management  
Manual for  
Western Australia

1  
Introduction



Department of  
Environment

*Cover photograph: Vegetated and grassed swale, Ascot Waters, Ascot*

# Stormwater Management Manual for Western Australia

## 1 Introduction

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Consultation and guidance from the Stormwater Working Team



February 2004

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## Reference details

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### **We welcome your feedback**

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# Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the *State Water Strategy* (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Catchment Management Branch of the Department of Environment.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

This chapter outlines the purpose of the Stormwater Management Manual for Western Australia. Stormwater is water flowing over ground surfaces in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ/ANZECC, 2000). Normal rainfall events on natural or undeveloped catchments are generally totally infiltrated or absorbed into the ground, with some excess slowly forming overland runoff to streams or watercourses. In catchments with built environments such as urban, rural residential, commercial and/or industrial development, rainfall rapidly collects on impervious surfaces. The impervious surfaces of the built environment, including streets, parking areas, paved areas and rooftops, prevent absorption of water into the ground. Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available. The quality and quantity of stormwater shed by a built area is dependent on the climate, geology, topography, land use, degree of imperviousness and stormwater management practices. Stormwater Management incorporates the efforts to address the negative effects of inadequate and/or inappropriate stormwater management on the environment and the community. It aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, valuing stormwater as a resource, protecting ecosystems and providing livable and attractive communities.

The manual's purpose is to provide a consistent approach while considering a variety of stormwater management options that may be suitable to a range of built environments across Western Australia. It has been developed for engineers, planners, scientists and managers throughout local government, the development industry, environmental and planning consultants, state government agencies and water resource suppliers and managers. Sections of the manual are also relevant to individual landowners and community groups. Information in the manual is generic and needs to be adapted to suit particular sites and circumstances. It is recommended that you use this guide after identifying and giving careful consideration to any individual circumstances that apply to the catchment, redevelopment or development area. Stormwater management techniques should not be implemented in isolation, but as part of an overall management plan.

# 1 What is stormwater?

**Stormwater is water flowing over ground surfaces in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ/ ANZECC, 2000).**

Normal rainfall events on natural or undeveloped catchments are generally totally infiltrated or absorbed into the ground, with some excess slowly forming overland runoff to streams or watercourses. The impervious surfaces of the built environment, urban, rural residential, commercial and/or industrial development prevent absorption of water into the ground. In these catchments, surfaces such as roads, parking areas, paved areas and rooftops mean that rainfall rapidly collects on impervious surfaces and is unable to replenish the superficial groundwater aquifer to the degree of the undeveloped catchment. Undeveloped catchments can absorb and infiltrate up to 90% of precipitation, whereas in built environments the amount of infiltration can be as little as 10% of precipitation (ECITALC, 2002).

Rainwater has the potential to recharge the superficial aquifer either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater which supports consumptive use and groundwater dependent ecosystems.

Groundwater is very close to the surface over much of the Perth metropolitan area and in other areas of Western Australia. To enable development and prevent seasonal inundation when groundwater levels peak in winter, drains have been traditionally installed to intercept and manage the seasonal peak groundwater levels. In these areas, stormwater and groundwater management are inseparable and need to be managed concurrently.

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. The quality and quantity of stormwater shed by a built area is dependent on the climate, geology, topography, land use, degree of imperviousness and stormwater management practices. In most established urban areas, stormwater enters the waterways without treatment, however, in some cases the polluted stormwater may be treated through structural measures such as swales, traps and basins. If stormwater is not infiltrated close to where it falls, there is the potential to collect contaminants and litter from hard surfaces such as roads, roofs, pathways and buildings before it enters waterways.

These contaminants and the increased flows that may occur can impact the receiving environment if not adequately managed, causing erosion, nutrient enrichment, pollutant contamination and changes to watercourses. Communities may also be affected with nuisance algal blooms, increased mosquitoes and midge populations and a reduction in aesthetic values. The degree of stormwater pollution will depend on the nature of the catchment and the stormwater management measures that have been implemented. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

Traditionally, stormwater was generally piped and channelled into retention basins, watercourses or drains that discharge into natural waterways, wetlands, beaches or bushland. It was believed that all rainfall events posed a flooding risk due to the degree of imperviousness of the built environment. However, normal rainfall events can be adequately dealt with on site in most areas, through infiltration or water capture and reuse. Only high intensity rainfall events need to be managed primarily for water quantity.

Stormwater Management addresses the negative effects of inadequate and/or inappropriate stormwater management practices on the environment and the communities. It aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, valuing stormwater as a resource, protecting ecosystems and providing healthy attractive communities.

## 2 What is the purpose of this manual?

The manual's purpose is to provide a consistent approach to a variety of stormwater management options that may be suitable to a range of built environments throughout Western Australia. The overarching stormwater management objective embraces the principle of sustainability, to achieve a balance of economic, social and environmental outcomes through policy, planning and development.

The manual is directed at the management of stormwater in new developments and redevelopment projects, as well as the retrofitting of existing drainage systems.

The following information is included:

- reasons why we need to manage stormwater
- performance objectives for managing stormwater
- preparing and implementing Stormwater Management Plans
- maximising the adoption of source controls
- non-structural and structural management tools available
- retrofitting existing urban and built areas, in addition to management of new development areas
- capture and reuse of stormwater
- engaging the community for optimal results, and
- performance monitoring and evaluation.

The *Manual for Managing Urban Stormwater Quality in WA* (Water and Rivers Commission, 1998) was intended to be regularly reviewed and updated as research and experience continued. This manual represents the first revision of that document. It considers the:

- Experience and knowledge gained in respect to the management systems implemented in WA and their maintenance requirements since the 1998 Manual.
- A change in emphasis from end of pipe solutions to source control, including pollution prevention, planning mechanisms, regulation and education.
- The release of *A State Water Strategy for Western Australia – securing our water* (Government of Western Australia, 2003) and an increasing need to optimise integration of issues of water supply, sewerage and stormwater, including maximising opportunities for capture and reuse of stormwater.
- The release of the *State Water Quality Management Strategy* (Government of Western Australia, 2001) in association with the *National Water Quality Management Strategy – No. 10 Australian Guidelines for Urban Stormwater Management* (ARMCANZ/ANZECC, 2000).
- The release of the draft *Australian Runoff Quality Guidelines* (2003) by the Institution of Engineers Australia.
- An increasing emphasis, in Australia and overseas, to address the health of aquatic ecosystems (USEPA, 2002; ARMCANZ/ ANZECC, 2000), including streams, rivers and wetlands. Improved environmental performance is needed to ensure that the environmental values and beneficial uses of receiving waters are sustained or enhanced.

- Research findings by the Cooperative Research Centres for Catchment Hydrology (Wong *et al*, 2000) and Freshwater Ecology (Chiew *et al*, 1997) and CSIRO (Victorian Stormwater Committee, 1999).
- The need for current information on ‘at source’ non-structural controls, retrofitting to improve the effectiveness of existing drainage infrastructure, information data sheets on new products that have become available since 1998, and guidelines on the monitoring of the performance of stormwater management systems.

The strategy outlined in this manual is in accordance with current best practice in stormwater management and with ‘whole of catchment’ and ‘total water cycle management’ approaches (refer to Chapter 2).

### 3 Who is this manual for?

This manual has been developed for engineers, planners, scientists and managers working in local government, the development industry, environmental and planning consultants, State government agencies and water resource suppliers and managers. Sections of the manual are also relevant to individual landowners and community groups.

The three main groups responsible for environmental stormwater management are the development industry, local government and State government agencies.

### 4 How can it help me?

Increasingly, we are faced with the need to meet multiple outcomes when considering stormwater in the built environment. This manual provides practical advice on planning for, implementing and assessing the success of stormwater management initiatives.

The manual particularly highlights the importance of considering stormwater at the earliest possible planning stages, it outlines successful approaches, case studies and discusses proven planning approaches. There is a particular emphasis on source controls through planning mechanisms, regulation and education. Included are specific design guidelines for structural controls that can be useful close to the source of the stormwater as well as further down the catchment.

**Local Government** will find this manual useful to:

- understand key stormwater management concepts
- acknowledge stormwater values and the benefits of protecting these values
- plan for new development and assess development applications
- give improved certainty in decision making affecting stormwater issues
- ensure the inclusion of stormwater management principles in local or district structure planning, local planning strategies, Town Planning Schemes and their amendments
- integrate stormwater planning with strategic planning
- develop stormwater management plans
- plan and design new stormwater management infrastructure
- help identify opportunities to improve environmental performance of all stormwater management infrastructure

- instigate innovative use of public open space that meets social and environmental outcomes for stormwater management
- save time and money when preparing stormwater management plans
- work to ensure that operational activities are consistent with stormwater management principles
- assist in developing practical programs aimed at increasing community understanding and awareness
- recommend stormwater management approaches that require less maintenance, time and money, and
- guide retro-fitting and catchment improvement projects.

**Development industry** will find this manual useful to:

- understand key stormwater management concepts
- acknowledge stormwater values and the benefits of protecting these values
- give improved certainty in decision making affecting stormwater issues
- save time and money when preparing outline development and stormwater management plans
- plan and design new developments and stormwater management infrastructure
- assist with innovative solutions for meeting stormwater management and outline development plans
- provide stormwater management approaches which will reduce construction costs, and
- standardise the quality of implementation for new and redevelopments.

**Natural resource management agencies, water resource managers and government regulators** will find this manual useful to:

- understand key stormwater management concepts
- acknowledge stormwater values and the benefits of protecting these values
- plan for conservation, enhancement and appropriate development
- protect wetlands, waterways and water supplies through promoting adoption of Best Management Practice Principles for stormwater management in land use planning and management
- set conditions
- prepare standards, guidelines and policies to protect water resources
- provide advice and information on management of stormwater to stakeholders
- assess the performance of stormwater management approaches
- assess statutory planning documentation at the regional and local scale and stormwater management audits
- ensure inclusion of Water Sensitive Urban Design principles in strategic guidelines, Structure Plans, Outline Development Plans, rezoning applications and subdivision plans, and
- plan community education campaigns.

**Landholders, individuals and community groups** will find this manual useful to:

- understand key stormwater management concepts
- acknowledge stormwater values and the benefits of protecting these values
- assist in implementing best practice for water management, including water capture and reuse and minimising stormwater pollution
- purchase property with an improved awareness of best management practices for stormwater management
- contribute to planning and implementation of local stormwater management plans, and
- guide ‘on-catchment’ improvement projects that involve local stormwater management.

## 5 How is it presented?

The manual comprises a suite of guiding papers that are relevant to the management of stormwater, in accordance with best management practice. The stand-alone chapters allow for ease of reference, handling and updating.

1 INTRODUCTION	Outlines the purpose of the manual, its intended audience and benefits.
2 UNDERSTANDING THE CONTEXT	Describes the principles and objectives that underpin the manual.
3 BEST PLANNING PRACTICE FOR STORMWATER MANAGEMENT	Outlines statutory requirements that control potential ‘point source’ pollution and regulate industries and the siting of appropriate facilities.
4 WATER SENSITIVE URBAN DESIGN	Outlines urban design principles within the framework of ‘Water Sensitive Urban Design’, that maximise localised retention and reuse of stormwater and manage ‘non-point source’ pollutants.
5 STORMWATER MANAGEMENT PLANS	Provides guidelines on the preparation of Stormwater Management Plans for specific development and whole of catchment scale projects.
6 RETROFITTING	Presents structural tools for improving water quality in established urban and built areas through modification of existing conveyance systems, if implementation of ‘at source’ pollution control alternatives are not feasible.
7 NON-STRUCTURAL CONTROLS	Describes the initiatives available to manage the quantity and reduce pollution of stormwater by optimising practices of local council operations, construction companies and householders, through mechanisms such as council regulation, community education and participation.

8 EDUCATION AND AWARENESS FOR STORMWATER MANAGEMENT	Presents ways to prepare and deliver education programs to reduce stormwater pollution from household and business activities.
9 STRUCTURAL CONTROLS	Presents engineered, structural measures that may need to be applied to residual water quality and flow issues that cannot be controlled through non-structural measures.
10 PERFORMANCE MONITORING & EVALUATION	Provides information on establishing a formal, regular, rigorous system of data collection that tracks trends and performance of stormwater management approaches.
11 IMPLEMENTATION	Presents advice on implementing the manual.
12 FURTHER INFORMATION	Contacts References Glossary

## 6 How to use this manual

Information in the manual is generic and needs to be adapted to suit particular sites and circumstances. It is recommended that you use this guide after having carefully considered the circumstances prevailing within the applicable catchment, redevelopment or development area. Stormwater management techniques should not be implemented in isolation, but as part of an overall management plan (Figure 1). A checklist of issues to consider when developing stormwater management plans and strategies and a decision-making process for the selection of best management practices are outlined in Chapter 5.

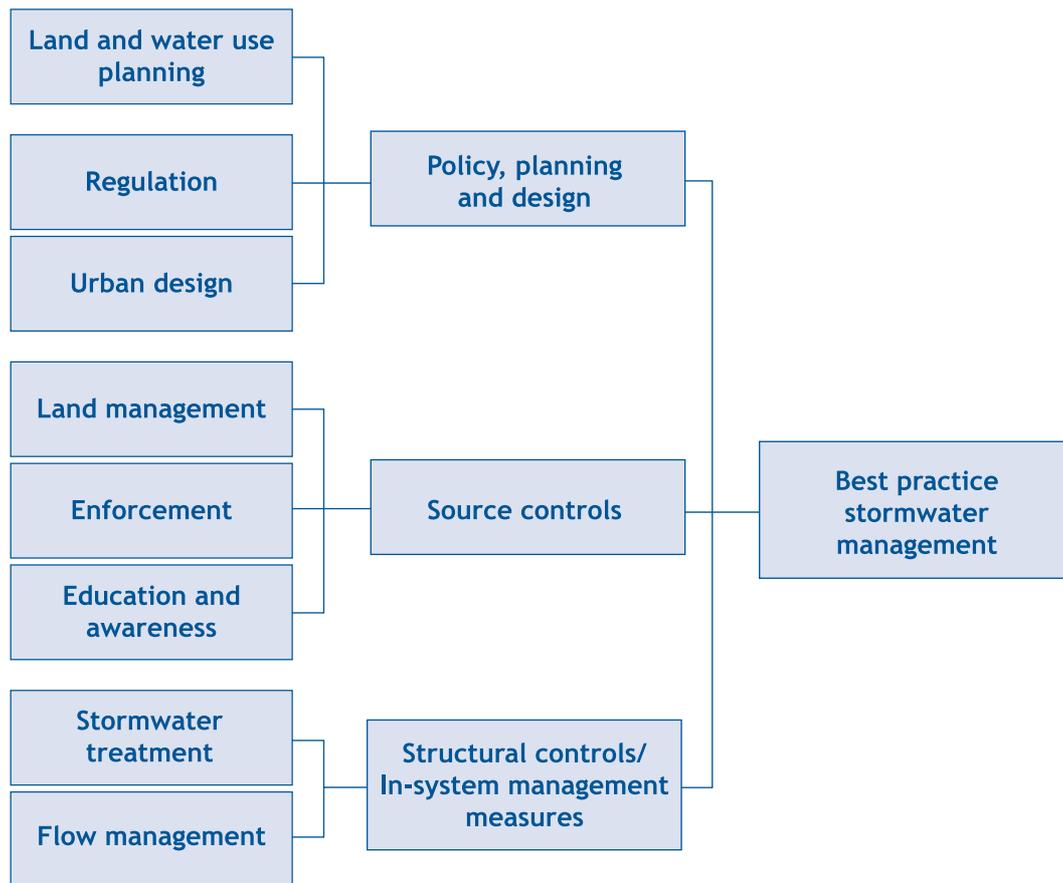


Figure 1: Stormwater management requires the integration of a range of measures (ARMCANZ/ ANZECC, 2000)

## 7 How was this manual prepared?

This manual has been prepared in separate chapters that are being released as soon as they are completed. This means that the information can be provided as soon as possible, rather than waiting for the whole manual to be finished. Each chapter is designed as a stand-alone document, as well as forming an essential part of the whole manual.

This manual has been prepared by the Department of Environment with consultation, guidance and advice from the Stormwater Working Team. The team consists of representatives from State and local government, industry and the community. Each chapter has been prepared by sub teams from the Department of Environment, representatives from the Stormwater Working Team, and other participants called on for their expertise in particular areas. The participants on these sub teams are listed at the beginning of each chapter. Feedback was given by the Stormwater Working Team on each of the chapters prepared by the sub teams.

The Department thanks and sincerely appreciates the time, valuable advice and input given by the participants.

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Department of Planning and Infrastructure	Mr Sean Collingwood
Eastern Metropolitan Regional Council	Mr Mick McCarthy
Housing Industry of Australia	Ms Verity Allan (Until June 2003) Ms Sheryl Chaffer (From September 2003)
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LandCorp	Mr Bruce Low
Main Roads Western Australia	Mr Jerome Goh
Urban Development Institute of Australia	Mr Glenn Hall
Water Corporation	Mr Roger Bulstrode
Western Australian Local Government Association	Mr Michael Foley

## 8 References

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Stormwater  
Management  
Manual for  
Western Australia

2  
Understanding  
the context



Department of  
Environment

*Cover photograph: Bannister Creek Drain Restored to a Living Stream, Lynwood*

# Stormwater Management Manual for Western Australia

## 2 Understanding the context

Prepared by Lisa Chalmers and Sharon Gray, Department of Environment  
Consultation and guidance from the Stormwater Working Team



February 2004

## Acknowledgments

This manual chapter was prepared by Lisa Chalmers and Sharon Gray, Department of Environment with consultation and guidance from the Stormwater Working Team. Constructive feedback on the delivery framework was given by; Verity Klemm, Bill Till and Antonietta Torre. Sincere thanks to the following people who provided valuable feedback or information on the drafts; Leon Brouwer, Martyn Glover, Jerome Goh, Mike Lindsay, Bruce Low, Sasha Martens, Mick McCarthy, Elizabeth Morgan, Greg Ryan, Peter Ryan, Rachel Spencer, Bill Till and Antonietta Torre.

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February 2004

## Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the *State Water Strategy* (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Catchment Management Branch of the Department of Environment.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

This chapter explains why stormwater management is important and the issues that face stormwater managers. Stormwater management requires careful design, planning and implementation to avoid a number of potential problems in the quality of the receiving natural and built environment. It is also important that stormwater management is considered in the context of the catchment and sub-catchment, rather than focusing on the site level. This manual focuses on best management practice techniques that address these issues. An understanding of the following potential issues will help in the decision making for appropriate policy and planning, source controls and in system management measures:

- water quality in the receiving environment
- water quantity in the receiving environment
- healthy ecological communities
- flood management
- total water cycle management, and
- quality of life.

Considering this wide range of issues, an holistic approach to stormwater management is needed. The water cycle has complex interactions between surface flows, groundwater hydrology, water quality, channel form, aquatic habitat and riparian vegetation characteristics of a watercourse. The impact that the hydrological relationships in turn have on human health, recreation and quality of life are all factors to consider when determining what the community wants to achieve when managing stormwater. Effective management of stormwater means managing social, economic and environmental values in built environments (ARMCANZ/ANZECC, 2000). This chapter also discusses the key roles and responsibilities for stormwater management in Western Australia.

# Understanding the concepts of the Stormwater Manual for WA

## 1 Why are built environments drained?

When rain falls on undeveloped land, most of the water will soak into the topsoil and slowly find its way to the nearest receiving waterway, wetland or groundwater. A small portion of rainfall in undeveloped catchments, around 10–15%, will become direct surface runoff and most of this will be generated by only a few intense rainfall events a year. Runoff moves slowly through the catchment because the ground surface is rough due to the presence of vegetation. This means that the effect of rainfall is spread out over hours and even days. Short, heavy storms have little impact on flow rates in surface receiving waters because the major movement of water to receiving surface waters is through groundwater. For example, the rate of groundwater movement through the sandy sediments of the superficial aquifer of the Swan Coastal Plain ranges from about 50 to 150 m/year depending on location.

When a catchment is developed, the proportion of land covered by impervious surfaces (roads, parking areas, compacted soils, roofs, driveways and pavements) is increased and this can reduce the area available for stormwater infiltration. Where stormwater has been traditionally managed through open drains and piped drainage, up to 80% of the rainfall volume can become direct runoff. However, new approaches in stormwater management aim to prevent pollution at the source, maximise infiltration to reduce stormwater runoff, recharge groundwater and minimise change to the natural water balance. The removal of catchment vegetation cover contributes to increased runoff, as there is reduced transpiration rates and less removal of water from the soil by plants. Therefore, retaining native vegetation is an important feature of stormwater management.

In traditionally drained built environments, there is a reduction in natural water catchment storage when floodplains and natural wetlands are in-filled for development. At the same time, paved surfaces are smoother than natural surfaces, so water can travel faster across the surface and will reach the receiving waters more quickly. In traditional stormwater management systems, peak flow rates can increase by a factor of up to ten. In these conditions, waterways have to hold larger and often sudden or rapidly peaking runoff flows.

Groundwater is naturally very close to the surface over much of the Perth metropolitan area. To enable development and prevent seasonal inundation when groundwater levels rise in winter, drains have been installed to intercept and lower the peak groundwater table. In these areas, stormwater and groundwater management is inseparable and techniques to minimise the risk of pollution to stormwater will be different in areas where low groundwater levels allow stormwater infiltration close to the surface.

The effects of catchment urbanisation, using a traditional drainage approach on stormwater runoff characteristics, can be summarised as follows:

- increased peak discharges, runoff volume and velocity
- decreased response time
- increased frequency and severity of flooding, and
- change in characteristics of urban waterways from ephemeral to perennial systems (Wong *et al*, 2000).

Figure 1 shows the components of the water cycle or hydrological cycle. Figure 2 shows the changes in the water cycle as a result of urbanisation and demonstrates that infiltration is greatly limited in urban, industrial, commercial and residential catchments, and that runoff is greatly increased.

The changes in stream hydrology geometry in response to urbanisation are shown in Figures 2 and 3. The figures show that the increase in imperviousness results in greater runoff, and that receiving surface water volumes are likely to be greater.

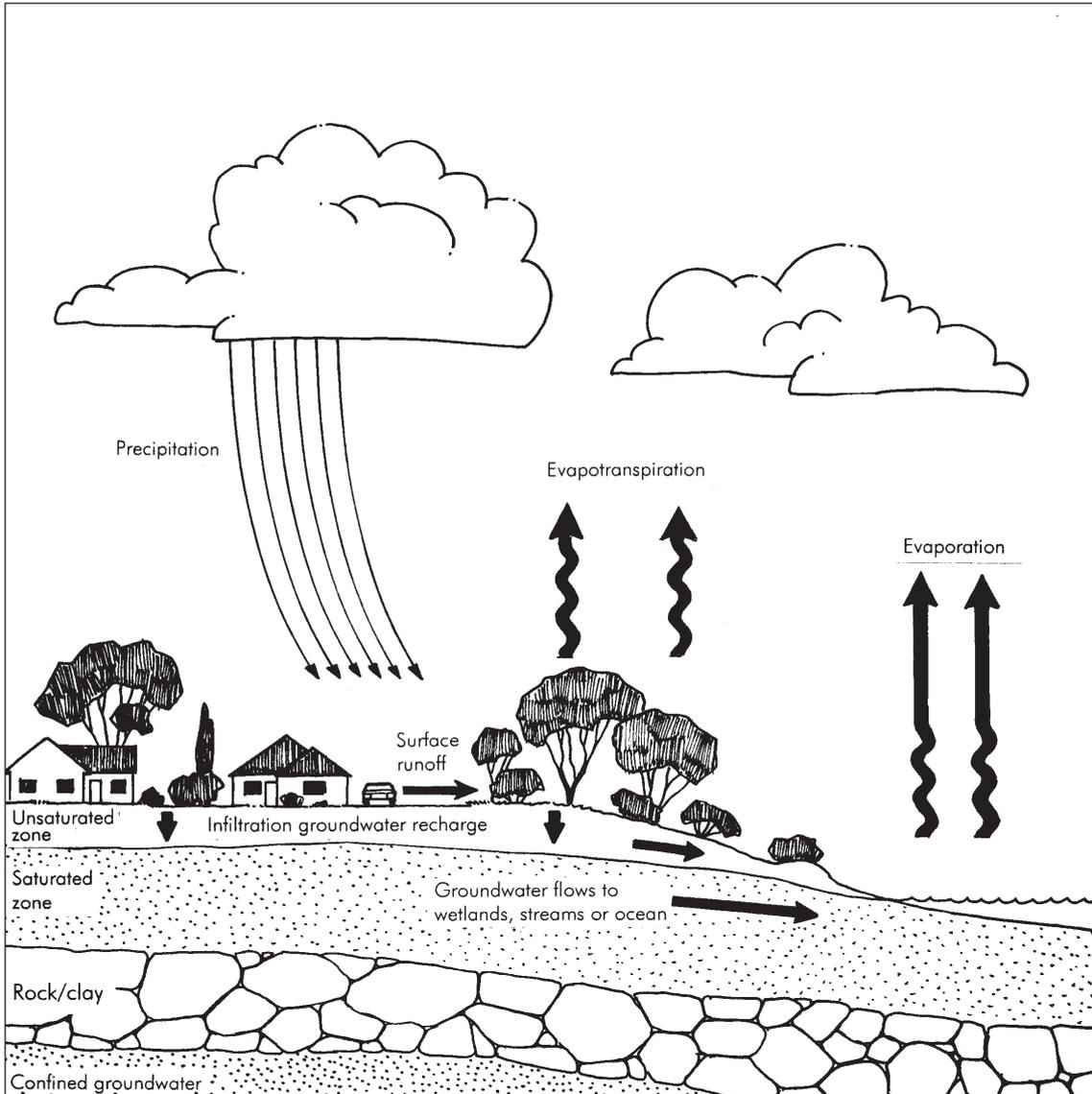


Figure 1: The hydrological cycle

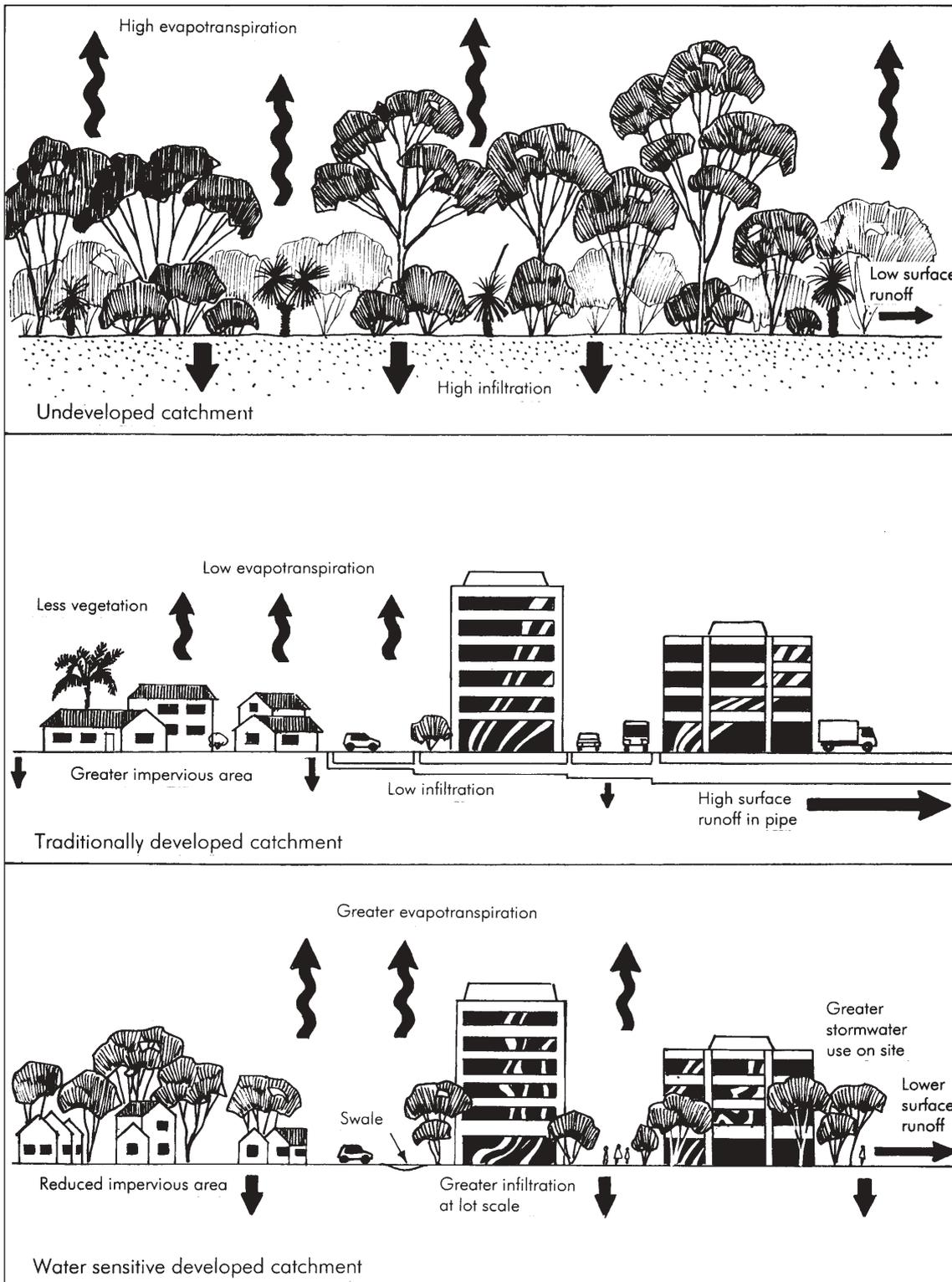


Figure 2: Effect of development on the catchment hydrology for low intensity rainfall events

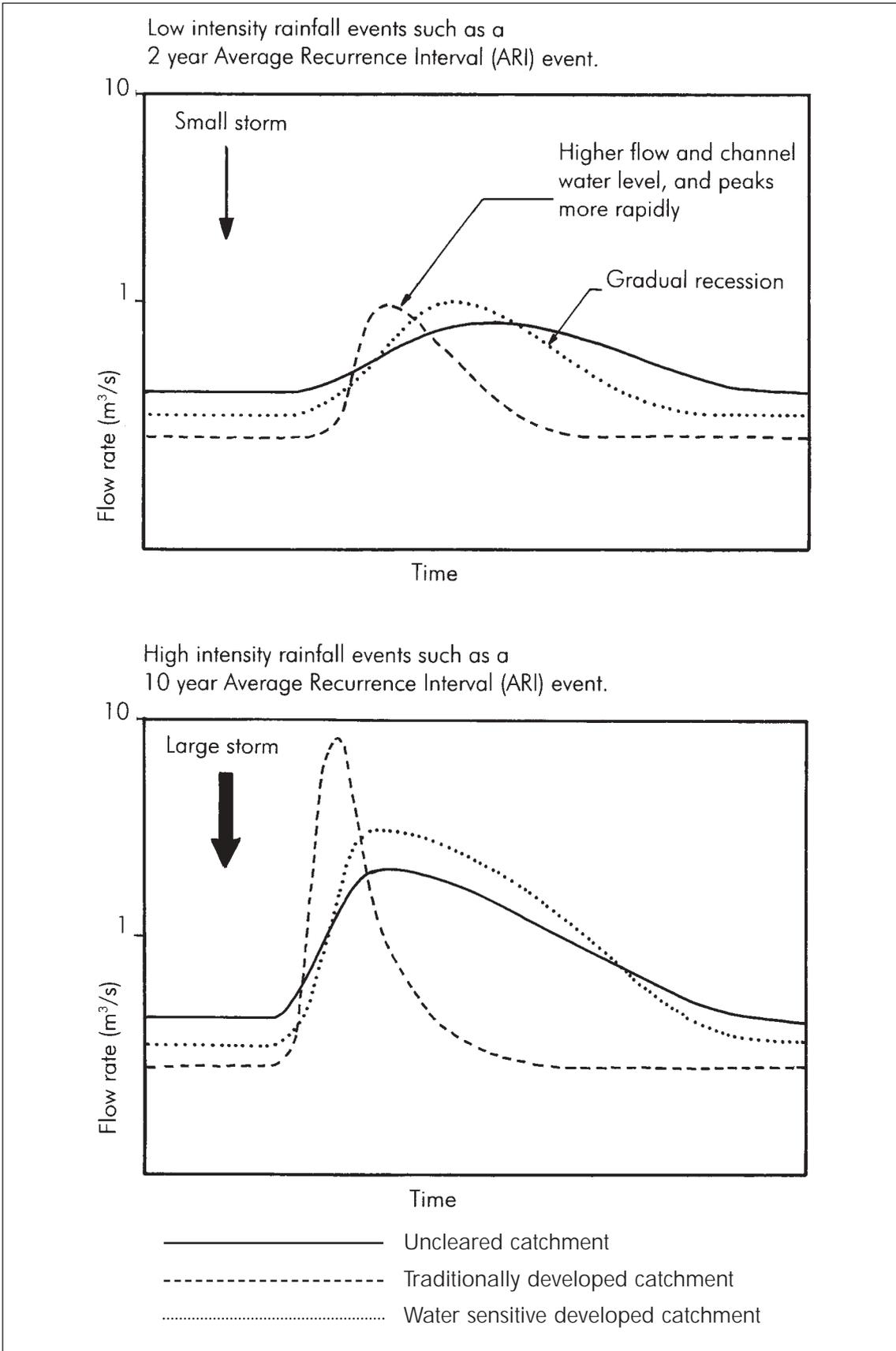


Figure 3: Differences in stream flow hydrographs between traditional land development and water sensitive development

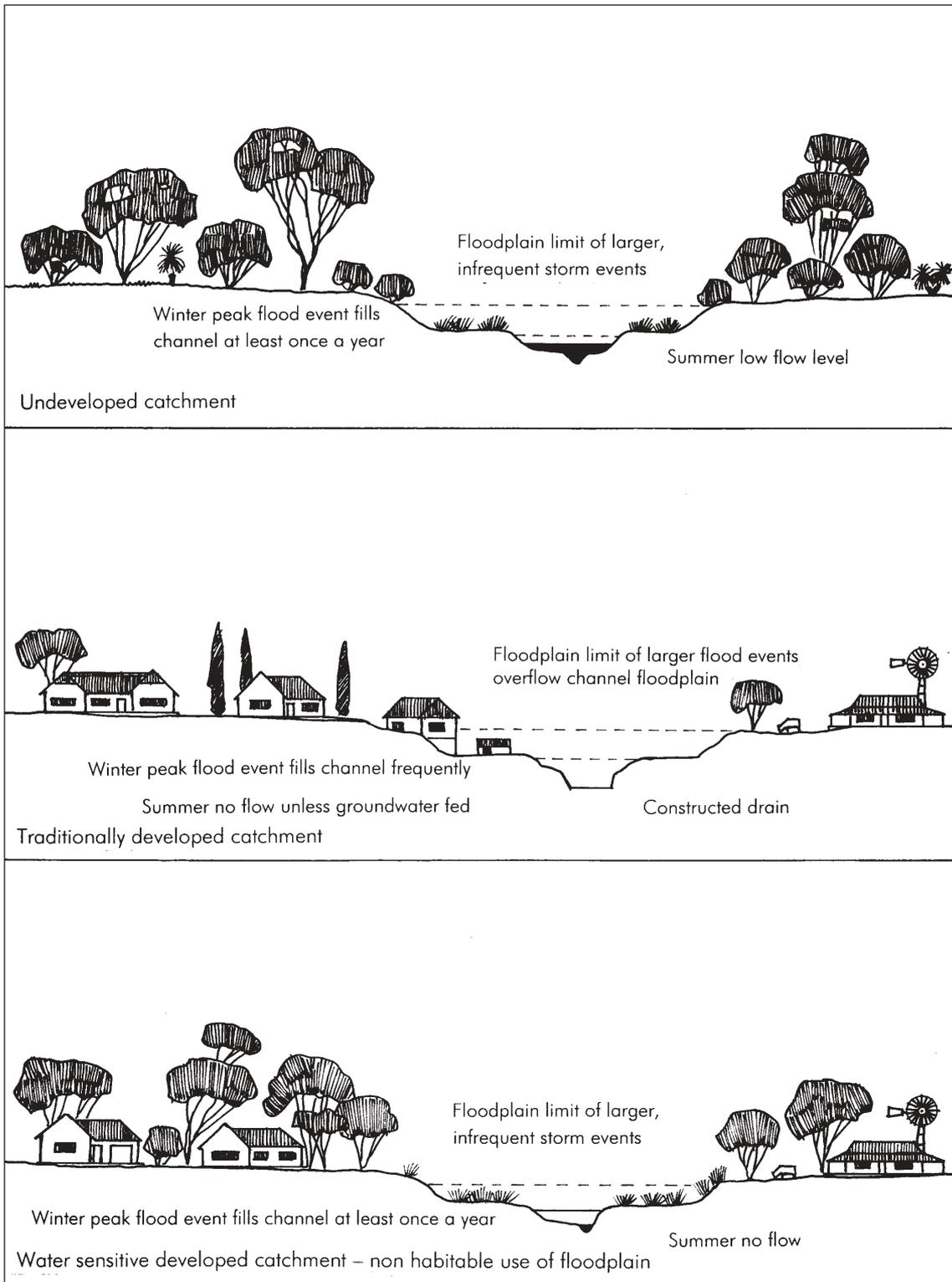


Figure 4: Response of stream geometry to traditional land development and water sensitive development

## 2 How are built environments drained?

Stormwater systems in WA were originally developed in response to flood prevention, to control groundwater levels and to enable development to occur. Consequently, the traditional emphasis of stormwater management has been one of efficiently collecting and conveying runoff and groundwater from residential, commercial and industrial areas into nearby lower areas such as natural waterbodies, wetlands, streams, rivers, estuaries and the marine environment. Conveyance has employed a combination of underground pipes and linear 'engineered' overland flow paths. Little or no consideration has traditionally been given to the 'downstream' consequences of a conveyance-dominated approach.

Residential development on the Swan Coastal Plain has differed from other areas in Australia, in that there has been a requirement for all rainwater that falls on a property to be retained and infiltrated using soakwells where soil conditions are appropriate. In addition, dry flood detention basins were often scattered across suburbs, usually one in every few streets throughout residential areas, which allowed stormwater to be stored throughout the catchment rather than in a single, end-of-catchment storage system. The stormwater then penetrates the soil and recharges the superficial aquifer. These approaches have resulted in significant benefits to the quality and quantity of stormwater, however, they are not enough to protect stormwater quality because there are still significant areas of urban surfaces such as roads and commercial areas that direct stormwater to drains and waterways.

A new approach termed 'Water Sensitive Urban Design' (WSUD) was developed in the late 1980s for urban planning and design. WSUD provides a framework that incorporates stormwater related issues in urban areas for water quality, water quantity and water conservation, plus broader environmental and social objectives as explicit design objectives and criteria (Water and Rivers Commission, 1998a). The emphasis of WSUD has been on stormwater as a valuable resource rather than the conveyance and disposal of traditional systems. The WSUD experience gained in Western Australia over the last decade has been incorporated into this manual, and in particular in Chapter 4.

Contemporary stormwater management is aimed at reducing the impacts of development on the natural water cycle (Victorian Stormwater Committee, 1999; ARMCANZ/ANZECC, 2000; Institution of Engineers Australia, 2003). Stormwater management now emphasises stormwater quality, health of aquatic ecosystems and public amenity, in addition to managing stormwater quantity. By necessity, stormwater management needs to be broadly based, requiring multi-disciplinary inputs.

A notable shift has also occurred in the reduced emphasis on 'end of pipe' water quality treatment solutions, and an increased emphasis on the application of 'preventative' measures (Victorian Stormwater Committee, 1999; ARMCANZ/ANZECC, 2000). These include:

- retention of existing natural drainage lines (ie. natural bio-chemical treatment processes)
- 'at-source' non-structural controls (e.g. education, Council maintenance practices), and
- use of small-scale infiltration systems (e.g. distributed infiltration to address small frequent runoff events at little additional cost: ie. down to less than 1:1 Average Recurrence Interval events).

### 3 What are the issues?

Stormwater management requires careful design, planning and implementation to avoid a number of potential problems in the quality of the receiving natural and built environment. It is also important that stormwater management is considered in the context of the catchment and sub-catchment, rather than focusing on the site level. This manual focuses on best management practice techniques that help address these issues and it is important to note that some of these issues are also associated with traditional conveyance systems. An understanding of the following potential issues will help in the decision making for appropriate policy and planning, source controls and in system management measures:

- water quality in the receiving environment
- water quantity in the receiving environment
- groundwater management
- flood management
- healthy ecological communities
- quality of life, and
- total water cycle management.

#### 3.1 Water quality in the receiving environment

The conveyance stormwater drainage system was designed on the assumption that stormwater would remain benign in nature as it passed through the urban catchment. However, the built environment has many sources of pollutants that can contaminate the runoff as it passes through the catchment. The runoff can become contaminated with metals, oils and petrol from vehicles; organic debris, litter, silt and dust, fertilisers, animal waste, pesticides from gardens and detergents from car washing. In conveyance drainage systems, the contaminated water is then discharged directly into waterways and other receiving water bodies.

There are many reasons to ensure that stormwater quality remains clean. In Western Australia, a large portion of our drinking water is harvested from beneath urban environments. Hence, it is in the community's interest to ensure that the stormwater is kept clean and infiltrated as close as possible to the point where it falls as rain, before it becomes contaminated. Present methods of treatment do not remove all contaminants that may leach from suburbia into the water table. With over 130 000 private bores in Perth, the quality of infiltrated stormwater will affect extracted water used on gardens and other sources if not properly managed (Water and Rivers Commission, 1998c). The importance of protecting the biodiversity of our urbanised environments is fundamental for healthy environments and society. Ensuring that best management practices are in place is essential. For example, if detergents and oils enter our drains and waterways, they can cause damage to the water proofing on birds feathers or prove toxic to birds when preening. They can also deplete water oxygen levels as the oils and detergents break down, causing fish deaths and changes in algal communities.

Increased volumes, peak discharges and velocities usually associated with traditional conveyance in stormwater management results in significant mobilisation of pollutants and their consequent accumulation in receiving water bodies. Polluted runoff has been identified as the most significant contributor to the deterioration of water quality in natural and artificial waterways in many parts of Western Australia (Welker, 1995).

There are three major categories of pollutant mobilisation, transport and interception pathways and processes, having major implications for the selection and design of management measures. They relate to porous deep soil, clay/loam shallow soil and impervious areas (e.g. rooves and pavements). The first category is porous sands, commonly found on the Swan Coastal Plain. This soil type rapidly infiltrates rainfall at source, filtering out particulate material but facilitating through-flow of fine colloidal organic material and dissolved forms of nutrients and toxicants to groundwater. Discharges for these areas will be predominantly via groundwater. The primary pollutant interception mechanism will be through biofilm on sediments of soaks, natural waterways or ephemeral wetlands. The second category is the podsollic loam soils over heavy clay subsoils (very common in the Eastern States cities but having similar properties to iron podzols, peats and clays found at Hazelmere and Helena Valley in Perth). These systems have limited rates of infiltration and lead to a high incidence of surface overflow. Nutrients, metals and organic material are rapidly adsorbed onto the surfaces of suspended solids and are transported to the receiving waterways and wetlands. The primary pollutant mechanism is sedimentation of suspended solids and oxidation of organic materials. The third category is the impervious areas common to all urban areas. These systems have extreme peak discharge rates and high rates of delivery of pollutants to receiving waters in the absence of natural interception components. They are high in suspended solids, heavy metals and vehicle emissions. The primary pollutant interception mechanism is sedimentation of suspended solids and oxidation of organic material and nutrients in the sediments (Breen & Lawrence, 2003).

More than 70% of urban pollution (apart from trace metals) generally comes from diffuse (non-point) sources dispersed over large areas, with the remainder coming from point sources such as effluent outlets (Chiew *et al*, 1997). With urbanisation, pollutant concentration levels have generally increased. For example, the amount of phosphorus applications on 1 ha in a typical Perth residential area is estimated to be 40 kg/ha/yr (Gerritse *et al*, 1990). Transport related surfaces (roads, driveways and carparks) comprising up to 70% of the impervious surface area in built catchments, represents a significant contributor of suspended solids, trace metals, polycyclic aromatic hydrocarbons and nutrients. Urban commercial activities have been identified as the main source of litter generation (Wong *et al*, 2000).

Stormwater pollutants originate from a variety of non-point sources, including motor vehicles, construction activities, erosion and surface degradation, spills and leachates, miscellaneous surface deposits and atmospheric deposition. Table 1 summarises the common sources of the various potential pollutants. In terms of ecological impact, the most significant potential pollutants are suspended solids/sediment, oxygen demanding material (ie. organic material, including leaf litter), nutrients and micro-organisms. Oils, surfactants and litter also have ecological impacts in addition to a more immediate aesthetic impact (Wong *et al*, 2000).

While substances such as suspended solids and nutrients are important in the healthy functioning of the aquatic ecosystem, excessive concentrations of these substances in natural waterbodies is detrimental. An increase in suspended solids results in a decrease in the availability of light through the water column. Large inputs of nutrients can cause excessive algal growth, which will lead to decreased oxygen levels and light availability. The resultant bloom's algal species could be toxic, leading to closure of the waterbody (Hosja *et al*, 1994). Other forms of aquatic flora and fauna are affected by decreases in light and oxygen levels, gradually causing an overall deterioration of the waterbody. The short-term impact of toxic contaminants such as heavy metals is organism mortality, while the long-term impacts are associated with chronic exposure and bio-accumulation of contaminants through the food chain (Wong *et al*, 2000).

As significant amounts of organic and inorganic pollutants are bound to sediment, the minimisation and control of sediment in runoff, principally by minimising runoff as close to its source as possible, is now a fundamental component of effective stormwater quality management (Wong *et al*, 2000).

Dry weather flows in stormwater systems can originate from groundwater, garden watering, commercial/industrial processes and associated activities, leaking water or reticulated sewerage pipes and illegal discharges. Dry weather flows tend to be less prevalent in sandy soils, except in sandy areas where drainage systems are cut into the groundwater table and therefore flow all year. Overflow from septic tanks also becomes a part of flows via groundwater input during wet and dry weather conditions. Water from these sources has a higher potential to contribute to pollutant loading and steps to deal with these flows need to be taken separately, but in conjunction with, measures to manage flows from rainfall events.

**Table 1. Common sources of pollutants and pressures to stormwater (ARMCANZ/ANZECC, 2000).**

Potential pollutant/pressures	Common source
Sediment	<ul style="list-style-type: none"> <li>Soil erosion during land development, building</li> <li>Stream bed/bank erosion</li> <li>Particulates from pavement and vehicle wear</li> <li>Re-suspension of previously sedimented material</li> <li>Atmospheric deposition of particulates</li> <li>Spillage/illegal discharge of particulates</li> <li>Discharge of organic matter (e.g. leaf litter, grass)</li> <li>Particulates from car washing</li> <li>Particulates from the weathering of buildings/structures</li> </ul>
Nutrients	<ul style="list-style-type: none"> <li>Weathering of bedrock</li> <li>Erosion of soils having adsorbed nutrients</li> <li>Release from sediments as a result of decomposition of organic material</li> <li>Washoff of fertiliser</li> <li>Sewer overflows/septic tank leaks</li> <li>Animal/bird faeces emissions and washoff</li> <li>Detergents from car washing</li> <li>Spillage/illegal discharge</li> <li>Atmospheric deposition</li> <li>Algae and plant decomposition</li> <li>Leaching of excessive nutrients from agricultural and horticultural landuses</li> </ul>
Oxygen demanding substances	<ul style="list-style-type: none"> <li>Washoff of organic matter from urbanised environments and agriculture</li> <li>Atmospheric deposition</li> <li>Sewer overflows/septic tank leaks, sewage effluent discharge</li> <li>Animal/bird faeces emissions and washoff</li> <li>Spillage/illegal discharges</li> </ul>

pH (acidity)	<p>Atmospheric deposition</p> <p>Industrial spillage/illegal discharge</p> <p>Washoff of organic material and decomposition</p> <p>Erosion of roofing material</p> <p>Mobilisation of acid sulfate soils as a result of drainage or soil stripping</p>
Micro-organisms (including pathogens)	<p>Animal/bird faeces emissions and washoff</p> <p>Sewer overflows/septic tank leaks, sewage effluent discharge</p> <p>Washoff of organic material and decomposition</p>
Toxic organics	<p>Washoff, drift of pesticides, erosion of soil having adsorbed herbicides</p> <p>Spillage/illegal discharge</p> <p>Sewer overflows/septic tank leaks, sewage effluent discharges</p>
Heavy metals	<p>Atmospheric deposition of particulates</p> <p>Particulates from vehicle wear and emissions</p> <p>Sewer overflows/septic tank leaks, sewage effluent discharge</p> <p>Particulates from weathering of buildings/structures</p> <p>Release from sediments as a result of decomposition of organic material</p> <p>Industrial spillage/illegal discharge</p>
Gross pollutants (litter and debris)	<p>Pedestrians and vehicle emissions, wear, littering</p> <p>Spills from waste collection systems</p> <p>Leaf-fall from trees</p> <p>Disposal of lawn clippings</p> <p>Spills and accidents</p>
Oils and surfactants	<p>Weathering of asphalt pavements, release from sediments, spillage/illegal discharges, emissions, leaks from vehicles, surfactants from car washing</p> <p>Discharge of organic matter high in natural oils</p> <p>Organic matter</p> <p>Contaminated runoff from light industrial areas and service stations</p>
Increased water temperature	Removal of riparian vegetation
Runoff from impervious surfaces	Discharge of groundwater that is high in salinity as a result of drainage, or elevation of the groundwater level as a result of urbanisation.
Salinity	Wastewater effluent discharges

### 3.2 Water quantity in the receiving environment

If runoff from built environments is not correctly managed there can be an increase in the volume and rate of water flowing into and through natural waterways, causing erosion of stream banks and vegetation. There may be a change in urban waterways from ephemeral to perennial systems, which will have consequences on its ecology and channel form. Increased erosive forces caused by increased water quantity and velocities may change the waterway channel form. This can result in deeper or wider channels and erosion of banks and the channel bed. The channel may also move laterally to accommodate the flows. Undermining of the banks by the changed hydrology can cause a loss of riparian vegetation that holds the banks and exacerbate the problems. The erosion of bank material also leads to sedimentation of downstream waterways and estuaries that can cause ecological loss and in some cases may cause problems to our use of waterways for navigation. Engineered infrastructure can also cause changes in hydrology, flow regimes and sediment movements.

A summary of the effect of increased imperviousness on waterway ecology and systems are highlighted in Table 2.

**Table 2. The effect of increased imperviousness on waterway ecology and system processes.**

Increased imperviousness leads to:	Flooding	Habitat loss	Erosion	Channel widening	Stream bed alteration
Increased volume	✓	✓	✓	✓	✓
Increased peak flow	✓	✓	✓	✓	✓
Increased peak duration	✓	✓	✓	✓	✓
Increased stream temperature		✓			
Decreased base flow		✓			
Sediment loading changes	✓	✓	✓	✓	✓

In some cases, the efficiency of conveyance drainage systems results in less water being received by waterways and wetland environments. Natural flows may be diverted away from receiving waters or the efficiency of the drainage system means that the water is removed too quickly from the environment. Many waterways and wetlands receive water from groundwater as well as overland flow. Removal of water from a catchment through traditional piped drainage systems can result in less groundwater contribution due to the reduced recharge of the groundwater. As a result, the groundwater contribution or base flow in the waterbodies is reduced. This may have an effect on the geomorphological processes such as the ability of the waterway to retain its form (such as pools and riffles), as well as ecological impacts. Maintaining the natural hydrology of waterways and wetlands in the urban environment is an important factor in stormwater management.

### 3.3 Groundwater management

Groundwater is the water that is held in fully saturated pore spaces and fractures of soil and rock. The sandy soils around Perth may contain from 10 to 35% water by volume. Under natural conditions groundwater moves very slowly and flows under the influence of gravity, moving from where the rainfall soaks into the groundwater, in some case into wetlands and rivers and eventually out to sea. The top of the

saturated groundwater level is known as the watertable. The depth to the watertable varies according to location, geology, season and long-term climate variations. Regional groundwater levels are mapped in the Perth Groundwater Atlas (Water and Rivers Commission, 2003). However, the Atlas was developed for bore construction and is not of sufficient level of accuracy for land development design.

During the dry summer season on the Swan Coastal Plain, the watertable drops in response to reduced recharge by rainfall, the increased rate of evapotranspiration by plants and general evaporation from groundwater fed wetlands. In winter, rainfall replenishes the groundwater and the watertable rises, coming to the surface in some low-lying areas. Many wetlands in south-west WA are surface expressions of the watertable. Water levels in these wetlands rise and fall seasonally with the watertable (Figure 5). Seasonal drying is natural for many wetlands and the flora and fauna has adapted to these ephemeral cycles. Larger variations than the normal seasonal fluctuations can damage groundwater-dependent ecosystems. The watertable and wetlands also respond to longer-term climate trends. For example, a long run of unusually dry years from 1976 to 1990 in the South West lowered the watertable, leaving many previously ‘permanent’ lakes dry (Water and Rivers Commission, 1997).

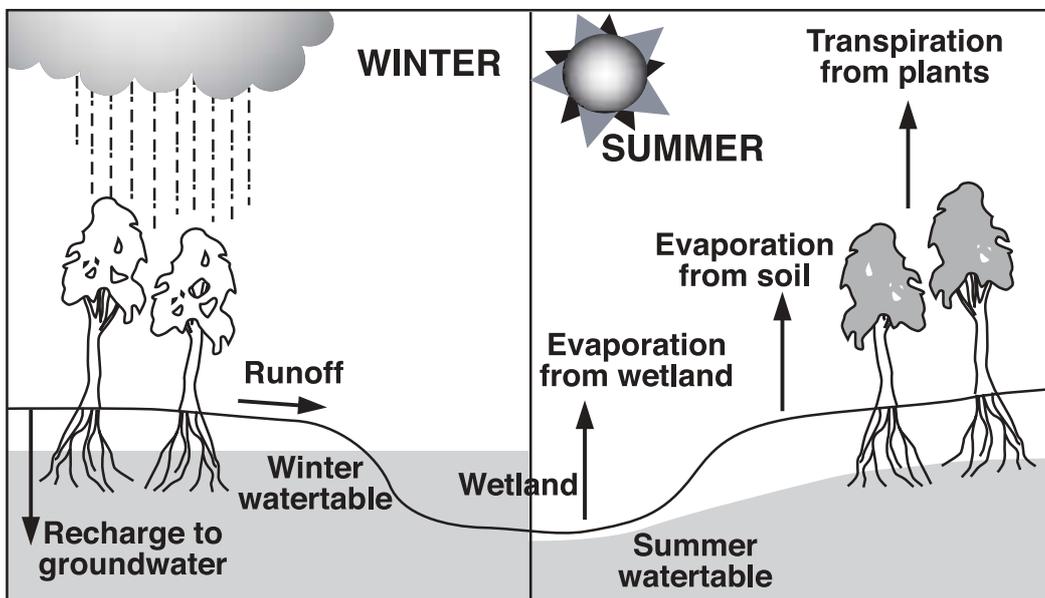


Figure 5: The seasonal groundwater cycle.

The watertable is naturally very close to the surface in some areas of the Swan Coastal Plain, where the aquifer is full and levels are regulated by evaporation of wetlands. Traditionally, to facilitate development in areas of high groundwater, drains were constructed to remove the groundwater when it reached a predetermined level, to reduce the risk of damage to infrastructure through inundation or flooding. These drains typically have flow in winter as the groundwater level rises, while in summer, the lower watertable levels mean that only a very small amount of groundwater enters these drains. These drains were directed to the nearest watercourse, however, due to impacts on receiving water bodies this practice is no longer acceptable.

Fortunately, there are many options available to ensure that stormwater remains clean and the groundwater dependent ecosystems are not damaged. The Water Sensitive Urban Design (Chapter 4), Non-structural Controls (Chapter 7) and Structural Controls (Chapter 9) chapters look at appropriate planning, bioretention, water reuse and the location of infiltration and retention systems, which provide alternatives to groundwater interception strategies.

### 3.4 Flood management

Flooding is a natural feature of our environment and is essential to maintain the physical form and ecological health of our waterways. In a highly impervious built environment, stormwater that would infiltrate the soil in an uncleared catchment, instead remains on the surface and increases the risk of flooding. Instead of optimising the rate of infiltration, the traditional way of dealing with the risk of local flooding has been to move the water quickly from the area of risk. While the traditional drainage system has reduced the risk of flooding over time, it has become apparent that there are many other stormwater management issues and impacts emerging through poor catchment management and/or the traditional piped drainage systems. The magnitude and nature of these impacts and issues are specific to individual catchments and can be influenced by other factors such as pre-development landuses.

Preferred ways to manage stormwater are discussed extensively in Chapters 7 and 9. By maximising infiltration of stormwater, the social and economic benefits increase because flooding can cause significant damage to property, infrastructure and can even present a risk to our health and lives. In summary, the benefits of controlling flooding are:

- reduced damage to property and associated financial and personal costs
- reduced risk of loss of life and health risks
- reduced risk of water pooling in sealed or heavy clay areas causing mosquito breeding sites and other health hazards, and
- increased potential for land development in low-lying areas.

### 3.5 Healthy ecological communities

It is important to note that flooding is a natural part of our waterway environment. The periodic changes in water level are crucial to the flora and fauna in floodplain rivers and are the primary source of productivity. Nutrients and particulate material are laterally exchanged between the floodplain and channel. Reproduction and other life cycles are also linked to this regular flooding.

Aquatic habitats may be lost through changes to the natural hydrology, changes in the bed material and bed shape of waterways, removal of in-stream objects such as snags and aquatic plants, and drainage of wetlands and floodplains. Damage to aquatic habitats causes a decrease in biodiversity.

Collecting and exporting the rainfall off site results in less groundwater recharge. This can result in the decline of some waterways and groundwater dependent wetlands.

Urbanisation has traditionally reduced the diversity of flora and fauna in receiving water bodies. This in turn has brought about a change in the composition of the ecological communities with some sensitive species being less abundant or being lost from that area. The change in ecological community structure may also allow pest species tolerant to the altered conditions to proliferate. Problems with drainage infrastructure such as bridges and culverts, may also alter flow patterns and fauna movement (ARMCANZ/ ANZECC, 2000).

In the Perth metropolitan area, there is about 260 000 ha of remnant native vegetation. The State Government *Bush Forever Plan* (2000) identifies about 51 200 ha (nearly 20%) as regionally significant. A further 114 000 ha (almost 44%) is managed by the Department of Conservation and Land Management or as water catchments for potable water supply. The remaining 96 000 ha (37%) are local biodiversity areas which are in private ownership, other State Government ownership or in Local Government reserves.

Approximately 14 400 ha of the local biodiversity areas have been zoned urban or for other intensive landuses under the Metropolitan Regional Scheme and are likely to be cleared (Perth Biodiversity Project, undated). It is important that as much remnant vegetation is retained for biodiversity and water quality values during the planning phase of subdivisions. Management plans can help ongoing maintenance in built areas. Retaining vegetation can help maximise infiltration, act as buffers to our waterways and wetlands and ensure the structural integrity of the waterways. Retaining as much vegetation as possible will contribute to the water quality of the Swan-Canning River system and other waterways and wetlands in the State.

### 3.6 Quality of life

The quality of an environment can be greatly influenced by the way stormwater is managed. Carefully designed stormwater systems can help contribute to attractive and livable communities. Chapter 4 provides ideas on how stormwater can be managed in an urban environment to achieve multiple outcomes, such as natural streams, multiple use corridors and attractive public open space. If stormwater is managed poorly, it can affect our lifestyle and health. Specific design elements that help minimise health and safety risks are discussed in Chapters 7 and 9.

Inadequate catchment and stormwater management can pose a public health risk. Stormwater treatment systems that have water for more than three to four days can harbour mosquitoes and midges. Mosquitoes are normally just a nuisance, but occasionally may be a health hazard due to mosquito borne diseases such as Ross River Virus and Murray Valley encephalitis. Chapter 3 discusses the issue of adequate planning to ensure that buffers are provided around waterways and wetlands. Design criteria to ensure that stormwater systems minimise the risk of mosquito breeding are discussed in Chapter 9. When forming stormwater management plans for an area, decisions will need to be made on the risks of mosquito borne diseases, flooding, social and environmental factors.

Traditional drainage can have potential public hazard risks, due to the often steep sides of trapezoidal drains and detention basins and sumps, requiring fencing or other protective measures.

Collecting and exporting the rainwater off-site results in less groundwater recharge in built up areas. A drop in groundwater levels can affect the performance of domestic and public supply bores. A recharge of stormwater close to source ensures a replenishment of this valuable resource.

There is a loss in the variety of uses available to the community (e.g. recreation) if the water quality is degraded or stormwater treatment systems detract from the aesthetics of an area.

### 3.7 Total water cycle management

Stormwater management requires consideration of the whole water cycle. Water supply, sewerage and stormwater activities have traditionally been managed separately in water authorities. This limits the ability to see them as resources and to achieve the benefits gained from their consideration as a whole. Total water cycle management, or integrated water cycle management, recognises that water supply, stormwater and sewage services are interrelated components of catchment systems, and therefore must be

dealt with using an holistic water management approach that reflects the principles of ecological sustainability. Water efficiency, re-use and recycling are integral components of total water cycle management and should be practised when any water is extracted from river and groundwater systems.

The water cycle is an endless global process of water circulation that involves:

- precipitation (rainfall)
- flows, including infiltration into aquifers
- interception and storage (dams and aquifers)
- treatment and supply
- water use
- management, treatment and transfer of stormwater or wastewater
- discharge to rivers and oceans
- evaporation and transpiration, and
- cloud formation (then the cycle begins again with precipitation).

The cycle is a continuous whole, yet utilities have historically separated management of water supply systems from wastewater and stormwater systems. Recent advances in water treatment technology and urban planning have increased the number of water supply options available to utilities and consumers. Furthermore, the scarcity of water in some areas has meant that solutions must be found beyond augmenting the traditional nineteenth century water supply infrastructure to satisfy end-use requirements. A sustainable water supply needs to consider the entire global process of 'the water cycle'. The technology now exists to shortcut the total water cycle and capture and re-use previously harvested water resources, such as wastewater and stormwater, without waiting for the cycle of evaporation and precipitation to be completed. Essentially, water conservation calls for an holistic appreciation of the total water cycle. Water conservation is therefore inextricably linked to water re-use.

Stormwater and domestic water recycling present the more accessible options for re-use (Government of Western Australia, 2003). A hypothetical model of a decentralised stormwater and wastewater residential supply system predicted a 72% decrease in the average annual water supply imported from an external source, a 25% decrease in average annual stormwater discharge and a 100% decrease in average annual wastewater discharge (Speers & Mitchell, 2000).

Stormwater is also a valuable water resource that, if managed appropriately, can be utilised to supplement household, commercial/industrial, streetscape and parkland water supply needs, while ensuring the maintenance of the groundwater aquifer supply and surface water ecosystems. Appropriate total water cycle management will consider the seasonality of rainfall. For example, winter rain in Perth would need to be stored for irrigation over summer when little rainfall is received. In most cases in Perth, recharge to groundwater on site acts as a suitable storage for rainfall that can be drawn over summer and does not present problems of loss of water through evaporation that would occur through storage ponds.

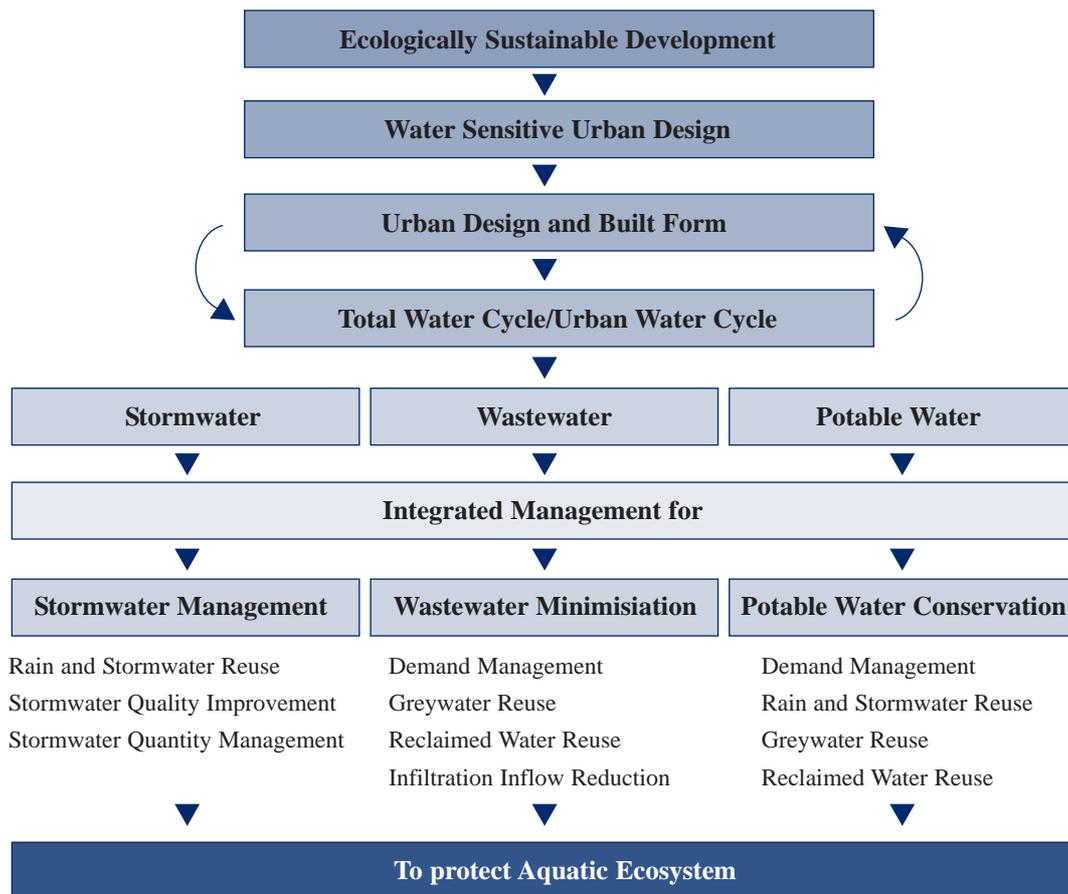


Figure 6: Interactions between ESD, WSUD and the Urban Water Cycle (Institution of Engineers, 2003)

#### 4 What do we want to achieve when managing stormwater?

Considering the wide range of issues that arise when managing stormwater in the environment, an holistic approach needs to be taken in stormwater management. The water cycle has complex interactions that exists between surface flows, groundwater hydrology, water quality, channel form, aquatic habitat and riparian vegetation characteristics of a watercourse. The impact that the hydrological relationships in turn have on human health, recreation and quality of living are all factors to consider when determining what the community wants to achieve when managing stormwater. Effective management of stormwater means managing social, economic and environmental values in built environments (ARMCANZ/ANZECC, 2000).

## 4.1 Stormwater management objectives for WA

A multiple objective approach has been adopted to stormwater management in Western Australia in line with the *National Water Quality Management Strategy* (ARMCANZ/ANZECC, 2000). Aims with the following issues include:

### **Water quality**

- To maintain or improve the surface and groundwater quality within the development areas relative to pre-development conditions.

### **Water quantity**

- To maintain the total water cycle balance within development areas relative to the pre-development conditions.

### **Water conservation**

- To maximise the reuse of stormwater.

### **Ecosystem health**

- To retain natural drainage systems and protect ecosystem health.

### **Economic viability**

- To implement stormwater management systems which are economically viable in the long-term.

### **Public health**

- To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of property**

- To protect the built environment from flooding and waterlogging.

### **Social values**

- To ensure that community social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

- To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

### **Water quality**

Stormwater managers should aim to maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions. The stormwater should be protected as close to source as possible, by infiltration to the groundwater where the soil conditions and depth to groundwater permit. If this is not possible, water quality should be protected via in-system treatment approaches before it enters the receiving water bodies.

### **Water quantity**

Stormwater managers should aim to maintain the total water cycle balance within development areas relative to the pre-development conditions. By managing the quantity and rate of delivery of surface flow, water quality and the impact on groundwater aquifers and other receiving waterbodies is reduced.

### **Water conservation**

Stormwater managers should aim to have effective use of water in the urban system. Reducing demand and maximising the efficiency of water use contribute to water conservation. Re-use of stormwater runoff for supplementing water requirements by the household, commercial premises, street landscaping and parklands should be factored into stormwater management design and planning. The recharge of groundwater aquifers with stormwater also needs to be maximised as a water conservation objective, to ensure long-term sustainable supply of groundwater for domestic and public use.

### **Ecosystem health**

Stormwater management should protect, maintain and restore waterway, wetland, estuarine and coastal biodiversity. Managers need to enhance ecosystem health and protect existing values of waterways, wetlands, estuaries, marine and associated vegetation from development impacts.

### **Economic viability**

It is important that the long-term economic viability of a stormwater management system is considered in the development of a stormwater management strategy. If the ongoing maintenance costs of treatment devices are difficult to afford on an ongoing basis, this may detract from the effectiveness of devices in the long-term (ARMCANZ/ANZECC, 2000). In many cases, the perceived cost of alternative stormwater treatment systems results in reluctance to change. However, in reality or when demonstrated, the long-term costs may be significantly lower than conventional systems. In addition, the value of stormwater in the built environment is taken into account and reflects its true social, environmental and economic contributions.

### **Public health**

One of the key roles of stormwater management is to improve the safety of our urban environment. There are a number of issues that may be considered to minimise risk to public health and safety. These include the risk to:

- public health from mosquitoes from constructed wetlands and wetland systems
- the community and property from flooding
- of injury to the public and operational personnel from structural controls infrastructure, and
- people caught in waterways during floods.

### **Protection of property**

One of the key reasons for stormwater management arising was to protect the built environment from flooding and waterlogging. The cost of damage to property includes financial and personal costs and it is important to ensure that our urban environments have minimal risk of damage from water.

## Social values

To ensure that community social, aesthetic and cultural values are recognised and maintained when managing stormwater. Changes in community values and expectations has meant that in terms of stormwater management, it is no longer adequate to consider flood protection alone. Community values now encompass concern for improved access to open space and a variety of recreation opportunities, quality of life, aesthetic living environment, conservation of Aboriginal heritage sites, environmental protection and ecologically sustainable development.

This evolution of community values is addressed by the multiple objective approach that is being taken in stormwater management. The standard of environmental and amenity quality now needs to be considered equally with that of flood protection.

## Development

The way we manage new developments and maintain existing areas is important to ensure that our environment and communities are sustainable. Cost effective and best management practice stormwater management should be implemented through planning and development in accordance with sustainability and precautionary principles.

# 5 How will we achieve these stormwater management objectives?

## 5.1 The stormwater management framework

This chapter looks at how the objectives for stormwater management in Western Australia are achieved. The stormwater management framework has a number of components that make up the policy and planning context and the delivery framework for achieving the objectives for stormwater management in Western Australia. The principles and objectives are implemented through three key areas: the State planning framework, the State policy framework and the delivery approaches which together contribute to sustainable stormwater management.

The stormwater management framework components that contribute to the desired **stormwater management objectives** are:

- stormwater management principles
- delivery approaches
- policy framework, and
- State planning framework.

## 5.2 Principles for stormwater management in Western Australia

In Western Australia, there are a number of principles that underpin the objectives for stormwater management. These principles should be addressed when undertaking the planning and implementation of stormwater management. They should:

- incorporate water resource issues as early as possible in the landuse planning process;
- address water resource issues at the catchment and sub-catchment level;
- ensure stormwater management is part of the total water cycle and natural resource management;
- define stormwater quality management objectives in relation to the sustainability of the receiving environment;
- determine stormwater management objectives through adequate and appropriate community consultation and involvement;
- ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity;
- recognise stormwater as a valuable resource and ensure its protection and conservation and reuse; and
- recognise the need for site specific solutions and implement appropriate non structural and structural solutions.

## 5.3 The approaches for stormwater management

The approaches provide planners, developers and government with a guide to implementing the objectives and principles of stormwater management. These eight approaches are the checklist for on-ground implementation and are based on the objectives for Water Sensitive Urban Design (CSIRO, 1999). Some example techniques showing how they can be achieved are also given. Details on design guidelines for Source Controls, Non Structural and Structural Techniques are presented throughout the manual.

### **Protect water quality**

*Stormwater remains clean and retains its high value*

Implement best management practice on-site.

Implement non-structural controls, including education and awareness programs.

Install structural controls at source or near source.

Use in-system management measures.

Undertake regular and timely maintenance of infrastructure and streetscapes.

### **Protect infrastructure from flooding and inundation**

*Stormwater runoff from infrequent high intensity rainfall events is safely stored and conveyed*

Safe passage of excess runoff from large rainfall events towards watercourses and wetlands.

Store and detain excess runoff from large rainfall events in parks and multiple use corridors.

Safely convey excessive groundwater to the nearest watercourse.

**Minimise runoff**

*Slow the migration of rainwater from the catchment and reduce peak flows*

Retain and infiltrate rainfall within property boundaries.

Use rainfall on-site or as high in the catchment as possible.

Maximise the amount of permeable surfaces in the catchment.

Use non-kerbed roads and carpark.

Plant trees with large canopies over sealed surfaces such as roads and carpark.

**Maximise local infiltration**

*Fewer water quality and flooding problems*

Minimise impervious areas.

Use vegetated swales.

Use soakwells and minimise use of piped drainage systems.

Create vegetated buffer and filter strips.

Recharge the groundwater table for local bore water use.

**Make the most of nature's drainage**

*Cost effective, safe and attractive alternatives to pipes and drains*

Retain natural channels and incorporate into public open space.

Retain and restore riparian vegetation to improve water quality through bio-filtration.

Create riffles and pools to improve water quality and provide refuge for local flora and fauna.

Protect valuable natural ecosystems.

Minimise the use of artificial drainage systems.

**Minimise changes to the natural water balance**

*Avoid summer algal blooms and midge problems and protect our groundwater resources*

Retain seasonal wetlands and vegetation.

Maintain the natural water balance of wetlands.

No direct drainage to conservation category wetlands or their buffers, or to other conservation value wetlands or their buffers, where appropriate.

Recharge groundwater by stormwater infiltration.

**Integrate stormwater treatment into the landscape**

*Add value while minimising development costs*

Public open space systems incorporating natural drainage systems.

Water sensitive urban design approach to road layout, lot layout and streetscape.

Maximise environmental, cultural and recreational opportunities.

**Convert drains into natural streams**

*Lower flow velocities, benefit from natural flood water storage and improve waterway ecology*

Create stable streams, with a channel size suitable for 1 in 1 year ARI rainfall events, equivalent to a bankfull flow.

Accommodate large and infrequent storm events within the floodplain.

Create habitat diversity to support a healthy, ecologically functioning waterway.

A stormwater management hierarchy approach for managing urban stormwater is taken in Western Australia. The hierarchy will help guide which approaches are appropriate for specific situations and is an evolution of the stormwater management hierarchy in the National Water Quality Management Strategy (ARMCANZ/ANZECC, 2000) to meet local conditions.

The stormwater management hierarchy applied in WA is to:

- i. **Retain and restore natural drainage lines** – retain and restore existing valuable elements of the natural drainage system, including waterway, wetland and groundwater features and processes.
- ii. **Implement non-structural source controls** – minimise pollutant inputs principally via planning, organisational and behavioural techniques to minimise the amount of pollution entering the drainage system.
- iii. **Minimise runoff** – infiltrate or re-use rainfall as high in the catchment as possible. Install structural controls at or near the source to minimise pollutant inputs and the volume of stormwater.
- iv. **Use in-system management measures** – includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps.

These steps require the preservation of the valuable features of the water environment, control of the pollution at the source, and only proposes management measures within stormwater systems for residual impacts that cannot be cost-effectively mitigated by source or near source controls.

## 5.4 Related State and National strategies

One of the key mechanisms for achieving the outcomes for stormwater management is to ensure that the stormwater objectives meet and contribute to other natural resource management policies and strategies.

These strategies in turn assist in the implementation of the desired stormwater management outcomes. A brief discussion of national, State and regional strategies that are relevant to stormwater management follows.

### 5.4.1 National strategies

#### **National strategy for Ecologically Sustainable Development**

The *National Strategy for Ecologically Sustainable Development* (Commonwealth of Australia, 1992) sets out national objectives and principles for development that improves the total quality of life while maintaining the ecological processes on which life depends. The principles of Ecologically Sustainable Development (ESD) are listed as:

- The precautionary principle – if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- Inter-generational equity – the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.
- Conservation of biological diversity and ecological integrity – conservation of biological diversity and ecological integrity should be a fundamental consideration.

- Improved valuation, pricing and incentive mechanisms – environmental factors should be included in the valuation of assets and services.

The application of ESD to management of stormwater therefore aims “*to develop and manage in an integrated way, the quality and quantity of surface and groundwater resources and to develop mechanisms for water resource management which maintain ecological systems while meeting economic, social and community needs*” (ARMCANZ/ANZECC, 2000).

### **National Water Quality Management Strategy**

The National Water Quality Management Strategy is comprised of a suite of papers providing guidance on aspects of the water cycle, including ambient and drinking water quality, monitoring, groundwater, rural land and water, stormwater, sewage systems and effluent management for specific industries. The principle objective of the Strategy is:

*‘To achieve sustainable use of the nation’s water resources by protecting and enhancing its quality while maintaining economic and social development’.*

The strategy emphasises a number of overarching principles for application to water quality management. These are:

- ecologically sustainable development
- integrated/total catchment management
- best management practices, including the use of acceptable modern technology and waste minimisation and utilisation, and
- the role of economic measures and application of the user pays and polluter pays principles.

### **Australian Guidelines for Urban Stormwater Management**

The Australian Guidelines for Urban Stormwater Management (ARMCANZ/ANZECC, 2000), a component of the National Water Quality Management Strategy, provides a nationally consistent approach for managing urban stormwater in an ecologically sustainable way. The Guidelines outline current best practice in stormwater planning and management in Australia.

The broad principles leading to effective stormwater management, as listed in the ‘Australian Guidelines’ are:

- hydrology – minimise the impact of urbanisation on the hydrology of a catchment, including base and peak flow
- water quality – minimise pollution entering the stormwater system and remove any residual pollution
- vegetation – maximise the value of indigenous riparian, floodplain and foreshore vegetation, and
- aquatic habitat – maximise the value of physical habitats to aquatic fauna within the stormwater system.

## 5.4.2 State strategies

### **Draft State Sustainability Strategy**

The Western Australian State Sustainability Strategy '*Focus on the Future (Consultation Draft September)*' (Government of Western Australia, 2002) defines sustainability as meeting the needs of current and future generations through simultaneous environmental, social and economic improvement. The Strategy outlines actions to promote and encourage long-term progress towards sustainability, including new initiatives, policy and legislative change and institutional reform. Additionally, the Water Corporation and Department of Environment operate a number of programs directed at water conservation. The Strategy has a vision that water is used with care and is provided sustainably to meet needs and recommends the following objectives to:

- reduce water consumption
- extend responsibility for water supply to the planning system (water sensitive design) and to local government (regional councils) for groundwater supplies
- achieve significant wastewater reuse, and
- investigate long-term innovative water supply options that have broad sustainability outcomes.

### **A State water strategy for Western Australia – *Securing Our Water Future***

This Strategy recognises that Western Australia has reached a critical point in the way in which we use and reuse our precious water resources. The current water shortage experienced by the Perth community has shown that the efficient use of water is no longer a response to the current drought but in fact an essential step in learning to live with less water without compromising our way of life. The State Water Strategy was formed embracing a wide range of input from community members, including those who took part in a series of Water Forums across WA in 2002 and delegates to the Water Symposium at Parliament House (October 7-9, 2002).

The Strategy has five main objectives:

- i. Improving water use efficiency in all sectors.
- ii. Achieving significant advances in water reuse
- iii. Fostering innovation and research.
- iv. Planning and developing new sources of water in a timely manner.
- v. Protecting the value of our water resources.

### **State Water Quality Management Strategy**

The National Water Quality Management Strategy guidelines are supported in WA via the State Water Quality Management Strategy (Government of Western Australia, 2001). The State Water Quality Management Strategy requires that the series of National Water Quality Management Strategy guidelines be implemented via development of relevant strategies and plans in WA.

The guiding principles and general strategies outlined in the State Water Quality Management Strategy establish the philosophical base and approach for water quality management in WA and will be applied by all government agencies involved in water quality management (Government of Western Australia, 2001).

## **Draft Statewide Waterways Management Strategy**

The Statewide Waterways Management Strategy is currently being prepared. It will be a management framework that will enable available resources to be used wisely while allowing for the protection and enhancement of the State's many waterways for the next 20 years. A Draft Policy *Statewide Policy No. 4 Waterways WA: A policy for statewide management of waterways in Western Australia 2000* has already given a statement of the vision, guiding principles and objectives of Statewide waterways management. The Vision for statewide waterways management is:

*'Healthy waterways that provide for a range of environmental and human needs.'*

The economic, environmental and social guiding principles outlined in the Policy for statewide management of waterways form the context of stormwater management in relation to waterways. The key aims in the draft strategy are to:

- identify waterway condition, values and pressures;
- safeguard our significant waterways;
- restore and maintain waterway health;
- improve the way we manage waterways;
- balance values, expectations, ecology and uses; and
- challenge what we do in the future.

## **Wetland protection policies**

The Government's objectives applying to all wetlands on the Swan Coastal Plain (Water and Rivers Commission, 2001) are for the management and restoration of degraded wetlands, and preservation of 'Conservation Category Wetlands'. The statutory basis for protection of permanently inundated wetlands (lakes) on the Swan Coastal Plain is the *Environmental Protection (Swan Coastal Plain Lakes) Policy* (EPA, 1992). Conservation Category Wetlands and wetlands protected under the *Environmental Protection (Swan Coastal Plain Lakes) Policy* (EPA, 1992) shall not be used in stormwater management systems. Policy direction is guided by the Wetlands Conservation Policy for Western Australia (Government of Western Australia, 1997).

### **5.4.3 Regional strategies**

#### **Natural resource management strategies**

Natural resource management (NRM) is "*The ecologically sustainable management of the State's land, water, air and biodiversity resources for the benefit of existing and future generations, and for the maintenance of the life support capability of the biosphere*" (Government of Western Australia, undated). Natural resource management has been adopted across Australia, in recognition of the complex set of inter-related systems, natural and human, that comprises the catchment environment. NRM embraces:

- a holistic approach to natural resource management within catchments, marine environments and aquifers, with linkages between water resources, vegetation, landuse, and other natural resources recognised;
- integration of social, economic and environmental issues;
- cooperation and coordination between landholders, community groups, government agencies and other natural resource users and managers within the catchment; and
- community consultation and participation (Government of Western Australia, undated).

Within an NRM framework, the potential exists for using non-engineered solutions to manage stormwater that has complementary benefits such as protection of native biodiversity, enhanced value of ecosystem services and improved quality of life for residents. An NRM approach provides the means to assess the biophysical impacts of water management and the interactions of these impacts with social and cultural aspects of urban life. In Western Australia, there are formal arrangements between State government agencies and community-based regional groups to prepare Natural Resource Management Strategies for whole regions.

Six Natural Resource Management strategies are being developed for regions around the State. The Commonwealth and State expectations for regional natural resource management strategies is for them to set out the partnership between the community and government in managing natural resources at a regional scale. The purpose of the strategies is to ensure that key National and State environmental policies and programs are addressed in the regions. The strategies will contribute to the overall stormwater management outcomes.

## 5.5 The planning framework and stormwater management

Western Australia's planning system is relatively complicated, with many levels and processes functioning to administer various aspects of landuse planning and related legislation. The planning framework is a significant avenue through which development aspects such as drainage, stormwater management and other infrastructure are designed and submitted.

The planning system in Western Australia is administered at three main levels. The first level is the Minister for Planning and Infrastructure who has the ultimate authority for planning in the State. The second level is the Western Australian Planning Commission, supported by the Department for Planning and Infrastructure, that has the responsibility for urban, rural and regional landuse planning and land development matters. The third level is Local Government, which is responsible for town planning in local communities (WAPC, 1996).

The town planning system in Western Australia comprises two key components. The first component is the strategic and policy development planning level that focuses on the 'big picture' or broad planning for future landuse infrastructure and service provision, integrating a wide range of economic, social and environmental considerations. Stormwater management policies and objectives can be incorporated in such instruments as Statements of Planning Policy, Regional Schemes and Structure Plans.

The statutory planning level is the legal arm of the planning system and makes use of the legislation and regulations to ensure appropriate processes of landuse, land supply and urban development. Key areas where stormwater management objectives can be incorporated into more specific controls include Local Government Town Planning Schemes, subdivision proposals and development applications.

Details on the range of planning instruments that affect how stormwater is implemented in the built environment are discussed in Chapter 3 of this manual.

## 6 Who is responsible for achieving these management objectives?

Stormwater management in Western Australia is currently under the jurisdiction of a number of organisations. The Department of Environment is responsible for policy development, setting environmental criteria and strategic planning. Local Governments are responsible for and manage stormwater within their jurisdiction. The Water Corporation has been licensed to provide drainage services for main or arterial drains in some *declared* areas of Western Australia. In rural areas, a 'Notice of Intention to Drain or Pump Water from Land' has to be sought from the Commissioner of Soil and Land Conservation for landholders proposing to construct a deep drain, an evaporation basin or to pump groundwater. A review of the institutional arrangements is currently being undertaken and a whole of government approach is being developed. The responsibilities for stormwater management may change pending the outcome of *A White Paper on Drainage Reform in WA*. In addition to the stormwater management system, there are additional responsibilities for all stakeholders in the built environment and it is essential that they employ best management planning and practices in their day-to-day activities as well as over the long-term. There are a range of roles and responsibilities that contribute to stormwater planning, construction and management.

### Key players in stormwater management

Who benefits from best practice stormwater management?	The community The environment All stakeholders
Who regulates stormwater management?	Environmental Protection Authority Western Australian Planning Commission The Commissioner of Soil and Land Conservation (rural) Department of Environment Swan River Trust Water Corporation (main drainage only)
Who manages stormwater?	Local Government with assistance from the community Landowners, individuals and community groups Commercial and industrial users Infrastructure Service Providers (including Water Corporation)
Who creates stormwater infrastructure?	Landholders Local Government Developers Water Corporation

### Landowners, individuals and community groups

Lot scale water management, reuse and conservation has the most significant impact on the quantity and quality of our water resources. Many of the management practices outlined in this manual can be implemented at the lot scale. Individual consumer behaviour has the greatest impact on minimising stormwater pollution and the volume of runoff generated. Consumer demands also drive the urban development industry and influence design for land development.

Pollutants generated from lot scale activities include:

- fertiliser and pesticides leached from crops, gardens and lawn areas
- litter and dumped refuse
- detergents, oil and grease wash from paved areas
- bacteria and organic matter from stock and pets
- nutrients from on-site wastewater disposal (eg. septic tank systems)
- organic matter, leaf litter and lawn clippings
- surfactants from car washing, and
- sediment from building/landscaping activities.

Multiplied by hundreds or thousands of land holdings in a catchment area, the cumulative effect of polluted runoff can be devastating to the receiving waters downstream.

Commercial and industrial landusers have a role to ensure that their activities do not contribute to the pollution of stormwater. The Department of Environment has a range of guidelines, policies and regulations to guide best practice that aim to ensure employers, landowners and employees operate with sound environmental practice.

Urban residents can also help conserve water resources by implementing water efficient household appliances, water reuse in households and alternative supplies to scheme water, such as rainwater tanks and garden bores.

Community awareness of the activities that they can undertake is heavily dependent on State and Local Government education and awareness programs. Activities that Local Governments and State agencies can undertake to support the community groups, landowners and individuals are covered in the Education and Awareness Chapter of this manual.

#### **Key stormwater roles for landowners, individuals and community groups**

- work with local governments and community groups to help prepare catchment/stormwater management plans
- ensure that day-to-day activities protect and conserve stormwater as a valuable resource
- ensure that activities do not contribute to the pollution of stormwater through applying best practice, and
- implement site management plans to guide activities.

#### **Local Government**

Local government authorities have the responsibility for landuse planning and therefore a significant ability to affect stormwater management, through the design, construction and maintenance processes for the provision of local infrastructure.

Suitable consideration of stormwater management during the location and conceptual planning of urban, commercial and industrial areas has the potential to minimise many of the impacts of land development on stormwater. Local government planners can help protect stormwater quality by ensuring the land is capable of sustaining urban development and follows the principles of water sensitive design to minimise the extent of impervious surfaces and provide adequate space for stormwater management and integrate stormwater quality treatment measures with public open space. New stormwater infrastructure should be designed to ensure the impact of stormwater on receiving environments is minimal.

Local government is responsible for the management of various parts of the built environment that may discharge directly into the stormwater system. These include local stormwater drains, roads, reserves, parks and car parks. Adopting a best practice environmental management approach in regard to the operation and maintenance of these resources is an essential element for improved stormwater management.

#### **Key stormwater roles for Local Government**

- plan for new development and assess development applications
- ensure inclusion of stormwater management objectives and principles in Town Planning Schemes, Outline Development Plans, rezoning applications, subdivision plans and development plans.
- implement total water cycle management principles as a requirement within new developments
- assess and plan operational activities that have potential to affect stormwater quality or quantity
- lead the development of catchment-based stormwater management plans
- plan and design new water management infrastructure, and
- help identify opportunities to upgrade existing natural and built infrastructure to improve environmental performance.

#### **Development industry**

Development affects stormwater quality, during the construction period and as a result of the increased areas of impervious surface.

Managing runoff in a water sensitive manner not only helps prevent problems associated with stormwater up front, but can also enhance the social and environmental amenity of the landscape. Developers have an important role to play in the adoption of a water sensitive approach to urban planning, design and development.

Management of stormwater is crucial during construction, as soil is often removed and left exposed to erosion. Massive sediment loads reaching receiving waters can be a consequence of poor site management. It is essential that construction activities are undertaken in such a way that contaminated runoff is not discharged off-site.

The level of impact on stormwater following construction depends on the site's specific landuse and layout. By minimising impervious areas and using water sensitive urban design concepts, the impact of development on stormwater quality can be minimised.

#### **Key stormwater roles for the development industry**

- ensure planning and design of new developments meet State and Local government policies and manual objectives
- ensure water management infrastructure, proposed in new and retrofitted developments, are innovative, cost effective and meet stormwater management objectives and principles, and
- encourage demand for developments that meet stormwater management objectives and principles.

## **Environmental Protection Authority**

The Environmental Protection Authority (EPA) is responsible for the protection of Western Australia's environment by application of statutory powers described in the *Environmental Protection Act 1986*. This Act overrides planning legislation. A major role of the EPA is to ensure that the environment is protected when development decisions are made. It does this by providing independent environmental advice to the Minister for the Environment so that environmental considerations are taken into account in the decision-making process. Another key instrument used by the EPA is the development of Environmental Protection Policies (EPPs). EPPs most often address area-specific environmental concerns but can also be used for statewide issues. The EPA is also responsible for developing a *State Monitoring and Evaluation Framework for Natural Resource Management* and *State of the Environment* reporting.

### **Key stormwater roles for the EPA**

- assess development proposals, and
- establish and review Environmental Protection Policies (EPP's)
- set conditions and provide advice on environmental management of stormwater, and
- assess the environmental performance of stormwater management.

## **Swan River Trust**

The Swan River Trust was set up in 1989 to coordinate the work necessary to balance the use and protection of the waterways and shorelines, and to restore degraded environments of the Swan and Canning rivers. The Trust was established under the *Swan River Trust Act 1988*. Under this Act, approval from the Swan River Trust is required to undertake developments within the Trust management area. The Trust supports the development of management plans for sensitive parts of the river system and provides advice to the Minister for the Environment, the Western Australian Planning Commission and local governments to guide the development of one of Perth's most precious natural features. It works with local government and landowners to control shoreline erosion. It also works to prevent pollution, clean up contamination and keep the waterways and shorelines clear of refuse and reduce the frequency and extent of nuisance algal blooms and prevent toxic algal blooms.

### **Key stormwater roles for the Swan River Trust**

- plan for the conservation, enhancement and appropriate development of the Swan-Canning river system
- prepare standards, guidelines, development control policies and management plans for the environmental protection of the Swan and Canning rivers
- provide advice to developers and undertake education and information programs for industry and key stakeholders, and
- guide the development approval process.

## Department of Environment

Under the *Environmental Protection Act 1986*, the Department of Environment (DoE) is responsible for the protection of Western Australia's environment by application of statutory powers. Under the *Rights in Water and Irrigation Act 1914*, DoE is responsible for ensuring that the State's surface and groundwater resources are managed to support sustainable development and conservation of the environment for the long-term benefit of the community. Under the *Metropolitan Water Authority Act 1982*, DoE is responsible for strategic planning for stormwater in the metropolitan regional area.

### Key stormwater roles for the Department of Environment

- develop strategies, policies, guidelines and management plans to protect water resources
- application of Best Management Practice principles for stormwater management to the assessment and guidance of development/planning proposals
- facilitate the implementation of Ministerial conditions and enforcement, where necessary
- encourage adoption of Best Management Practice principles for stormwater management through other non-regulatory opportunities
- support sustainable development and conservation of the State's water resources
- protect wetlands, waterways and water supplies through promoting adoption of best management practice principles for stormwater management in landuse planning and management
- provide advice and information to the development industry and stakeholders on the management of stormwater
- assess statutory planning documentation at the regional and local scale, and
- assess stormwater management plans.

## Western Australian Planning Commission

The Western Australian Planning Commission is the statutory authority with powers vested in it by the *Western Australian Planning Commission Act 1985*. The Commission prepares policies on many planning matters such as *Statements of Planning Policy* under *Section 5AA of the Town Planning and Development Act 1928-1986*. Less formal Development Control Policies are also prepared by the Commission and these are important for stormwater management planning as they can guide subdivision of land, development control, public open space and residential road planning.

### **Key stormwater roles for Western Australian Planning Commission**

- ensure that stormwater management principles and objectives are incorporated into the State Planning Strategy
- ensure that the Perth Metropolitan Region Scheme incorporates and supports stormwater management principles and objectives
- ensure that stormwater management principles and objectives are met when preparing and implementing country region schemes
- ensure that development control policies developed by WAPC meet stormwater management principles and objectives
- ensure that all subdivisions and development applications that are assessed by the DPI and decisions made by the WAPC meet stormwater management principles
- ensure that there is a Statement of Planning Policy, which incorporates stormwater management planning principles and objectives, and
- ensure inclusion of stormwater management principles and objectives in strategic guidelines, Structure Plans, Outline Development Plans, rezoning applications and subdivision plans.

### **Water Corporation**

The Water Corporation provides water supply and wastewater services to the metropolitan area, regional centres and communities. One of the key roles of the Corporation is to work with the Department of Environment to ensure that current water supply sources are sustainable and to source alternative and innovative supplies for water. Improved stormwater management can be seen as a potential source of water through both stormwater reuse and recharge of the groundwater system. The Corporation also provides drainage and irrigation services to households, businesses and farms throughout the State. In the metropolitan area, the Corporation manages main drains in some areas that receive stormwater from the extensive local government stormwater drains.

### **Key stormwater roles for Water Corporation**

- operational responsibilities for the management and implementation of water quality and environmental objectives in main drain stormwater systems
- maximise the recovery and reuse of stormwater as a cost effective and reliable source of water
- implement effective environmental management systems across the Corporation's planning, business and management process
- develop awareness of stormwater management requirements and responsibilities among employees, stakeholders and contract partners
- set standards for planning and design of stormwater infrastructure to protect the receiving environments from the impacts of urban development and to reduce the risks of flooding, and
- work with local government and developers to plan new sustainable drainage infrastructure in developing urban areas.

## Infrastructure providers

There are a number of infrastructure providers, such as Main Roads Western Australia and the Public Transport Authority, that need to take into account stormwater management when delivering and managing infrastructure and services to the community. One of the key guideline documents published by Main Roads WA is the Austroads, 2002, *Guidelines for Treatment of Stormwater Runoff from the Road Infrastructure*.

### Key stormwater roles for infrastructure providers

- ensure inclusion of stormwater management principles and objectives when designing and implementing infrastructure
- implement effective environmental management systems across their planning, business and management process
- ensure that environmental impact assessments are undertaken and management plans are prepared, implemented and address stormwater management issues and objectives, and
- develop awareness of stormwater management requirements and responsibilities among their employees, stakeholders and contract partners.

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# Stormwater Management framework for Western Australia

## Western Australian Stormwater Management Objectives

- Water Quality** – To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.
- Water Quantity** – To maintain the total water cycle balance within development areas relative to the pre development conditions.
- Water Conservation** – To maximise the reuse of stormwater.
- Ecosystem Health** – To retain natural drainage systems and protect ecosystem health.
- Economic Viability** – To implement stormwater management systems that are economically viable in the long term.
- Public Health** – To minimise the public risk, including risk of injury or loss of life, to the community.
- Protection of Property** – To protect the built environment from flooding and waterlogging.
- Social Values** – To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.
- Development** – To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise urban stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non structural and structural solutions.

Delivery Approach	Policy Framework	State Planning Framework
<ul style="list-style-type: none"> <li>• Protect Water Quality</li> <li>• Protect infrastructure from flooding and inundation</li> <li>• Minimise runoff</li> <li>• Maximise local infiltration</li> <li>• Make the most of nature's drainage</li> <li>• Minimise changes to the natural water balance</li> <li>• Integrate stormwater treatment into the urban landscape</li> <li>• Convert drains into natural streams</li> </ul>	<p><b>National Strategies</b></p> <ul style="list-style-type: none"> <li>• Ecologically Sustainable Development</li> <li>• National Water Quality Management Strategy</li> <li>• Australian Guidelines for Water Quality Management</li> </ul> <p><b>State Strategies</b></p> <ul style="list-style-type: none"> <li>• State Sustainability Strategy</li> <li>• State Water Strategy</li> <li>• Water Quality Strategy</li> <li>• Wetlands Policy</li> <li>• Waterways Strategy</li> </ul> <p><b>Regional</b></p> <ul style="list-style-type: none"> <li>• NRM regional strategies</li> </ul>	<p><b>Strategic Planning</b></p> <ul style="list-style-type: none"> <li>• State Planning Strategy</li> <li>• Statements of Planning Policy (SPPs)</li> <li>• Region Schemes</li> <li>• Regional Structure Plans</li> <li>• District Structure Plans</li> <li>• Local Structure Plans</li> <li>• Local Planning Strategies</li> </ul> <p><b>Statutory Planning</b></p> <ul style="list-style-type: none"> <li>• Town Planning Schemes</li> <li>• Outline Development Plans</li> <li>• Local Structure Plans</li> <li>• Subdivision</li> <li>• Development Control Guidelines</li> <li>• Development Approvals</li> </ul>
<p style="text-align: center;"><b>Stormwater Management Hierarchy</b></p> <ol style="list-style-type: none"> <li>1. Retain and Restore Natural Drainage lines</li> <li>2. Implement non structural source controls</li> <li>3. Minimise Runoff</li> <li>4. Use in-system management measures</li> </ol>		

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3  
Best Planning  
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Management



Department of Water  
Government of Western Australia

*Cover photograph: New urban subdivision, Hammond Park. (Source: Department of Water.)*

# Stormwater Management Manual for Western Australia

## 3 Best Planning Practice for Stormwater Management

Prepared by Peter Howard and Emma Monk, Department of Water  
Consultation and guidance from the Stormwater Working Team



Department of **Water**  
Government of **Western Australia**

June 2007

## Acknowledgments

This chapter was prepared by Peter Howard and Emma Monk, Department of Water. Sincere thanks to everyone that provided comments, particularly the following people who provided information or feedback: Julio Navarrete and Ken Dawson - Department for Planning and Infrastructure; Carissa Lloyd - Swan River Trust; Shelley Shepherd - Essential Environmental Services; Bill Till, Verity Klemm and Julie Tilleke - Department of Water.

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# Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the State Water Strategy (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Drainage and Waterways Branch of the Department of Water.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

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To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

# 1 Introduction

## 1.1 Aim of the best planning practice for stormwater management chapter

The aim of this chapter is to provide references to documents that contain further information about integrating land and water planning and implementing water sensitive urban design.

## 2 Policy and guidance documents

Land use planning proposals in Western Australia can be assessed under the *Environmental Protection Act 1986*. Proposals may be subject to formal review, if the Environmental Protection Authority (EPA) determines that the environmental risks are significant. To assist landowners and their consultants in planning proposed land use changes, the EPA has published a guidance document titled: *Environmental Guidance for Planning and Development*, Draft Guidance Statement No. 33 (2005).

Additionally, the Department for Planning and Infrastructure/Western Australian Planning Commission and the Department of Water are working together to integrate land and water planning and implement water sensitive urban design.

The currently available planning policy and guidance documents are:

Government of Western Australia 2003, State Planning Policy 2, *Environment and Natural Resources*.

Government of Western Australia 2006, State Planning Policy 2.9, *Water Resources*.

Western Australian Planning Commission 2004, *Liveable Neighbourhoods*, Element 5 - Urban Water Management.

Another key guidance document *Achieving Water Sensitive Urban Design: a framework to integrate land use planning with water resource management on the Swan Coastal Plain* is being developed. This provides guidance for how water resources should be considered at each stage of the land use planning process. As stated in the draft document:

*“The framework is designed to facilitate better management and use of our urban water resources by ensuring an appropriate level of consideration is given to the total water cycle at each stage of the planning system. It intends to assist regional and land use planning, district, local, subdivision and development phases of the planning process and may be applied to both new greenfield and urban renewal projects. It should be applied to proposed residential, commercial, industrial and rural residential uses and development.”*

The framework’s objective is to provide guidance on the implementation of State Planning Policy (SPP) 2.9 and may be adopted by the Western Australian Planning Commission as a schedule of the SPP or as a separate guidance document. The Department of Water will also adopt the document as an agency policy.

The Department of Water is also preparing a guideline that will assist developers incorporate urban water management at the subdivision scale. Contact the Drainage and Waterways Branch of the Department of Water for the latest information on this guideline.

In addition to the above planning documents, there might be other applicable planning documents for specific areas, such as other local and State planning policies.

The electronic version of this chapter will be updated with the latest information on applicable planning policy guidelines and can be accessed from <<http://stormwater.water.wa.gov.au>>.

### 3 Contacts

For more information on the progress of the framework document, you may contact:

Directorate of Environment and Sustainability, Department for Planning and Infrastructure.  
Address: 469 Wellington Street, Perth WA 6000. Telephone: 9264 7575.

or

Land Use Planning Section, Drainage and Waterways Branch, Department of Water. Address: The Atrium, Level 4, 168 St Georges Terrace, Perth WA 6000. Mail: PO Box K822, Perth WA 6942. Telephone: 6364 7600.

### 4 References

Environmental Protection Authority 2005, *Environmental Guidance for Planning and Development*, Draft Guidance Statement No. 33, Environmental Protection Authority, Perth, Western Australia. Available via <<http://www.epa.wa.gov.au>>.

Government of Western Australia 2003, State Planning Policy 2, *Environment and Natural Resources*, State Law Publisher, Perth, Western Australia. Available via <<http://www.wapc.wa.gov.au/Publications>>.

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Government of Western Australia



*Cover photograph: Catchment management planning workshop. (Source: Department of Water.)*

# Stormwater Management Manual for Western Australia

## 5 Stormwater Management Plans

Prepared by Emma Monk and Lisa Chalmers, Department of Water  
Consultation and guidance from the Stormwater Working Team



Department of Water  
Government of Western Australia



April 2007

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## Summary

The aim of this chapter is to provide a process for the preparation, implementation and review of stormwater management plans. Stormwater management plans address how urban stormwater quantity and quality should be managed to protect ecological, social/cultural and economic values. A stormwater management plan is used to assist decision making to ensure that remedial measures (structural and non-structural) in existing developed areas are undertaken in a cost-effective, integrated and coordinated manner, and decisions in relation to new development (including redevelopment) are made with the implications for stormwater impacts taken into account.

There are many reasons for preparing a stormwater management plan, including to:

- improve budget coordination and stormwater related spending;
- reduce road and building flooding risks;
- reduce public health/safety and environmental impact risks from stormwater infrastructure;
- reduce water quality issues (e.g. algal blooms and fish deaths) in receiving water bodies;
- reduce impacts from water quantity issues (e.g. declining local groundwater levels, erosion of water bodies, or altered water regimes in receiving water bodies);
- improve coordination within and between agencies and groups; and
- establish processes and contingencies to address emergency/pollution issues and to adopt a proactive stormwater management approach.

A stormwater management plan is a document that addresses urban stormwater from a management perspective, rather than a development perspective, to ensure that the economic, ecological and social/cultural values of the area are protected and enhanced and that management issues are addressed in a coordinated manner. This chapter does not provide information for the preparation of plans that fulfil the planning requirements of new urban developments.

This chapter describes a process for preparing plans that address how to implement best practice urban stormwater management within a given area. A stormwater management plan can be prepared by local governments, catchment groups and regional natural resource management groups/councils for a local government area, a catchment area, or a sub-catchment (this is particularly relevant when local government areas or catchment areas are large and/or have many issues to address).

The process for preparing a stormwater management plan is outlined in Figure 1, and described in detail on pages 4-37. An example layout and content of a stormwater management plan is provided in Table 7 on pages 33-34, and a summary checklist of the process is on pages 34-35.

# 1 Introduction

## 1.1 Aim of the stormwater management plans chapter

The aim of this chapter is to provide a process for the preparation, implementation and review of stormwater management plans. A stormwater management plan is a document that addresses urban stormwater from a management perspective, rather than a development perspective, to ensure that the economic, ecological and social/cultural values of the area are protected and enhanced and that management issues are addressed in a coordinated manner.

This chapter outlines:

- What are stormwater management plans? (Section 2)
- Why prepare a stormwater management plan? (Section 3)
- Who prepares stormwater management plans? (Section 4)
- How do you prepare stormwater management plans? (Section 5)

## 1.2 Scope of the chapter

This chapter provides guidance for local government, regional council groups and catchment groups on preparing stormwater management plans that address how to implement best practice urban stormwater management within a given area. A stormwater management plan can be prepared for a local government area, a catchment area, or a sub-catchment (this is particularly relevant when local government areas or catchment areas are large and/or have many issues to address). The process described in this chapter is particularly applicable to proactively managing stormwater in areas that contain significant areas of traditionally drained urban land uses, or priority catchments<sup>1</sup>. The plans can include actions that provide mechanisms to ensure best practice stormwater management is included in future urban developments. See Section 2 for more information on the recommended scope of stormwater management plans.

The chapter does not provide information for the preparation of plans that fulfil the planning requirements of new urban developments; this is addressed in the land and water planning process. The *Draft State Water Plan – Water Planning Framework* (Government of Western Australia 2006) describes the hierarchy of water plans and interaction with the land use planning system at appropriate stages. The Department for Planning and Infrastructure and the Department of Water are preparing documents that will describe in more detail the integrated land and water planning framework and provide checklists to ensure that all information necessary to meet the planning requirements are met.

This chapter builds on the methodology, text and learnings from Western Australian and Australian guidelines and management plans, including: the Victorian Stormwater Committee (CSIRO 2000) *Urban Stormwater: Best Practice Environmental Management Guidelines* and the subsequent work by the Victorian EPA and Melbourne Water in refining the stormwater management planning process; the NSW Environmental Protection Authority's 1997 *Draft Managing Urban Stormwater: Council Handbook* (EPA NSW 1997); the *City of South Perth Integrated Catchment Management Plan* (JDA Consultant Hydrologists & Ecoscape 2004); the *Western Suburbs Regional Organisation of Councils – Regional Strategy for Management of Stormwater Quality* (JDA Consultant Hydrologists 2002); the *Stormwater Management Plan, Town of Victoria Park, Volume 2* (URS 2005); and the Eastern Metropolitan Regional Council's (WA) adaptation of the Victorian process (EMRC 2002), which was tested on the *Draft Canning Plain Catchment Management Plan* (Parsons Brinckerhoff, Acacia Springs Environmental & Ecological Engineering 2003). Text has also

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<sup>1</sup> Priority catchments are catchments or sub-catchments that are experiencing water quality or quantity problems resulting in part from inadequate stormwater management (e.g. catchments or sub-catchments of the Swan-Canning, Peel-Harvey and Vasse-Wonnerup estuaries).

been adapted from the *National Water Quality Management Strategy: Australian Guidelines for Urban Stormwater Management* (ARMCANZ & ANZECC 2000).

This chapter is the first version of a Western Australian guideline for preparation of stormwater management plans. Once the process has been piloted, the content of the chapter can be revised and examples and case studies can be developed and included in the document. It is envisaged that this chapter and the process described will evolve as local experience develops in the preparation of these plans.

### 1.3 Terminology and key definitions

**Average recurrence interval (ARI):** The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration.

**Drainage water:** Consists of stormwater runoff and/or shallow groundwater that have been intercepted by drains.

**Receiving environment:** Areas that receive stormwater runoff, including: wetlands, waterways, coastal waters/dunes, groundwater and bushland areas.

**Stormwater:** Stormwater is water flowing over ground surfaces and in natural streams and drains, as a direct result of rainfall over a catchment. Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow.

**Threat:** A threat is considered to be an activity or land use with potential to damage the local or receiving environment social/cultural, ecological or economic values, via impacts to stormwater quantity or quality.

**Urban:** Land used for residential, rural-residential, commercial or industrial development (includes regional townsites).

**Values:** Values may include economic values (e.g. water use, aquaculture, stormwater reuse), ecological values (e.g. aquatic fauna and flora, urban bushland) and social/cultural values (e.g. historical, public health and safety, recreational, visual amenity, spiritual).

**Water bodies:** Waterways, wetlands, coastal marine areas and shallow groundwater aquifers.

### 1.4 The target audiences

This chapter has been written for agencies and groups that prepare stormwater management plans – that is, local governments, catchment groups and regional natural resource management groups/councils. However, it is mostly aimed at local governments to help them prepare a plan to improve stormwater management in their area.

## 2 What are stormwater management plans?

Stormwater management plans address how urban stormwater quantity and quality should be managed to protect ecological, social/cultural and economic values. A stormwater management plan is used to aid with decision making to ensure that (a) remedial measures (structural and non-structural) in existing developed areas are undertaken in a cost-effective, integrated and coordinated manner and (b) decisions in relation to new development (including redevelopment) are made with the implications for stormwater impacts taken into account. The plans are similar to local government operational plans (such as Remnant Vegetation Management Plans).

In some catchments, a stormwater management plan will also address the management of groundwater drainage, since stormwater and groundwater drainage discharge are often managed with the same systems.

A stormwater management plan can be prepared for a local government area, a catchment area, or a high priority sub-catchment (this is particularly relevant when local government areas or catchments are large and have many issues to address). Where a municipal boundary divides a catchment and the stormwater from one local government area discharges into another, any plans prepared for the area should propose strategies to work with neighbouring local governments to address cross-catchment stormwater management issues. If a stormwater management plan covers a catchment area and more than one local government, this will require collaboration between relevant local government authorities and possibly the local natural resource management catchment council/group.

A stormwater management plan should recommend actions based on cost, effectiveness in protecting or restoring the ecological, social/cultural and economic values of the catchment and receiving environments, opportunities for implementation, and capability of the stormwater manager to implement. The plans should also define mechanisms and arrangements for the implementation of these actions, including management, funding, performance review, monitoring, reporting and future revision of the plan (ARMCANZ & ANZECC 2000).

The process described in this chapter can also be used to develop plans that address broader catchment issues or broader water cycle issues (i.e. water supply, wastewater, water for the environment, drainage), such as an integrated catchment management plan or a total water cycle management plan.

### 3 Why prepare a stormwater management plan?

There are many reasons for preparing a stormwater management plan, including to:

- improve budget coordination and stormwater related spending;
- reduce road and building flooding risks;
- reduce public health/safety and environmental impact risks from stormwater infrastructure;
- reduce water quality issues (e.g. algal blooms and fish deaths) in receiving water bodies;
- reduce impacts from water quantity issues (e.g. declining local groundwater levels, erosion of water bodies, or altered water regimes in receiving water bodies);
- improve coordination within and between agencies and groups;
- establish processes and contingencies to address emergency/pollution issues and to adopt a proactive stormwater management approach.

Stormwater management plans provide objectives for how stormwater should be managed in an area and a process to manage stormwater in a considered and coordinated manner that targets priority issues. Ensuring that priority issues are managed with the most appropriate measures improves the way that budgets are assigned and spent. Having an agreed plan also provides a clear pathway for preparation of future budgets and projects.

Stormwater management plans can provide a process to apply a consistent, holistic best practice stormwater management approach for developed and developing areas. Plans are particularly useful for improving stormwater management in established urban areas, where the land use planning process for individual redevelopment sites is often at an insufficient scale for stormwater management improvement. Plans also provide opportunities for improving stormwater management practices in established urban areas that are not undergoing redevelopment activities.

Stormwater management plans also provide a mechanism for recognising the impacts of stormwater on

the receiving environment. Environmental management issues should be grouped under topics or assets and management actions developed to address them. The stormwater management plan and other plans such as remnant vegetation management plans, floodplain management plans, wetland management plans and waste management plans will provide improved environmental management in a catchment or local government area.

An important outcome is that plans establish a basis for ongoing commitment, cooperation and coordination between stakeholders.

## 4 Who prepares stormwater management plans?

A stormwater management plan can be prepared by local government, catchment groups or regional natural resource management groups/councils, or by a multiple partner group. The primary author is usually determined by the scope of the plan (see Section 2) or the main trigger (see Section 3) behind the identification of the need for a plan.

## 5 How do you prepare a stormwater management plan?

A stormwater management plan should include a review of:

1. Stormwater frameworks and issues within national, State and regional contexts.
2. Reports prepared for the study area.
3. Catchment values to be protected, stormwater threats and recommended management options.
4. Management options.

The *Decision Process for Stormwater Management in WA* (Department of Environment & Swan River Trust 2005) should be referred to when preparing stormwater management plans. It provides a decision framework that should be applied when planning and designing stormwater management systems.

It is expected that the plan will be prepared largely using existing or readily available information held by councils, government agencies and natural resource management (NRM)/catchment management groups, in addition to a catchment audit and input from the community. Water quality monitoring data or modelling is not essential, but would be very useful for identifying threats and developing management options.

Figure 1 shows the process for preparing stormwater management plans.

Simpler plans could be prepared by local governments that do not have extensive urban areas (e.g. some regional towns), or could be used as preliminary plans before preparation of more extensive plans. These simpler plans can be prepared either by selecting suitable steps from Figure 1, or by not doing each step as comprehensively as the process discussed in this chapter.

**Step 1 Preliminary activities**

Identify relevant stakeholders  
Gain stakeholder commitment  
Establish project framework and scope  
Define study sub-catchments  
Define information requirements

**Step 2 Identify current status – catchment characteristics, condition and practices**

Identify catchment characteristics and condition  
Identify land use activities  
Document and review current stormwater management systems, practices and processes

**Step 3 Identify values of receiving environments**

Identify and assess values of receiving environment

**Step 4 Identify stormwater threats**

Identify and assess activities or land uses with potential to damage the local or receiving environment social/cultural, ecological or economic values, via impacts to stormwater quantity or quality

**Step 5 Identify management objectives**

Identify the vision and short-term and long-term objectives  
Identify outcomes for performance monitoring and evaluation

**Step 6 Establish and implement a prioritisation process**

Identify priority management issues

**Step 7 Prepare a priority issues paper****Step 8 Consider management options and strategies**

Identify management options

**Step 9 Develop management actions****Step 10 Prepare an implementation plan**

Identify estimated costs and funding options  
Identify responsibilities and timelines  
Identify partnership arrangements to be established with stakeholders

**Step 11 Prepare stormwater management plan**

Prepare draft stormwater management plan  
Stakeholder review of plan  
Finalise stormwater management plan  
Approval of stormwater management plan

**Step 12 Implementation**

Implement recommended actions of the plan

**Step 13 Ongoing performance monitoring and review**

*Figure 1. A process for developing a stormwater management plan.*

## 5.1 Identify and engage stakeholders

The early stage of a stormwater management planning project requires the identification and involvement of all relevant internal and external stakeholders. As discussed in ARMCANZ and ANZECC (2000), keys to achieving more effective action include:

- generating commitment to a best practice approach;
- establishing agreed priorities and management strategies or actions; and
- establishing a basis for ongoing cooperation with and coordination between stakeholders.

The early identification of stakeholders and the development of a consultation plan will result in a management plan that is more likely to have identified relevant issues and be supported and implemented. For example, Indigenous heritage sites and values should be identified at the beginning of the planning process. Contact the Indigenous Support Unit at Department of Water to receive contact details for local Indigenous stakeholders.

Local government is generally responsible for the majority of stormwater management systems within a catchment; however, this will vary depending on the catchment. The Water Corporation has responsibility for the majority of the arterial (main) drainage systems in the Perth metropolitan area, while Main Roads Western Australia is responsible for stormwater systems on freeways and State roads under its control. State agencies such as Department of Water, Department of Environment and Conservation, Department of Health, Swan River Trust, Department for Planning and Infrastructure and Western Australian Planning Commission also have an important role in policy, planning and regulation. Many stakeholders, such as industry, businesses, residents and the community, influence the quality and quantity of stormwater. Other stakeholders, such as catchment / community groups, local Indigenous groups and regional natural resource management groups often have significant local catchment management knowledge and should be engaged. A discussion of stakeholder roles and responsibilities is provided in Chapter 2.

Stakeholders should be consulted to determine current practices in the catchment; its environmental condition, values and threats; and their vision or objectives for the catchment/stormwater management and suggested solutions.

Stakeholders should be provided with options for the level of participation and involvement in preparation of the plan. When a stormwater management plan is prepared by multiple partners (e.g. local government, NRM groups and Department of Water), up-front commitment (including funding/in-kind contributions and the timeline for preparation) will be required to ensure development and completion of the plan. This commitment could be obtained by preparation of a partnership agreement or suitable partnering arrangements signed by relevant parties.

It is good practice to identify long-term management responsibilities at the early stages of the planning process. Where the local government is the main driver/author of the plan, it should be decided early if the plan will be recommending actions that are the responsibility of numerous stakeholders. This will depend on the capacity and expectations of other stakeholders and will require effective engagement and ownership of the plan by the relevant stakeholders. Preparation and signing of partnership agreements/partnering arrangements could also increase key stakeholders' commitment to implementation of the plan.

The level of consultation of the general community will depend on the local issues (e.g. is the local community active in environmental management, or are there contentious issues), the consultation processes of the local government and the recommendations of the Project Steering Committee (see Section 5.2 for discussion of project teams). However, public consultation could include: (1) identification of values and priority issues, (2) identification of possible management actions and (3) review of the draft stormwater management plan. Refer to the *Community Involvement Framework* (Department of Environment 2003a) for more information about how to undertake community consultation.

Further information on consulting with stakeholders can be found at the Urbanwater.info website, particularly at <<http://www.urbanwater.info/catchment/audit/3-Stakeholders.cfm>>. Guidance on facilitating groups of stakeholders can be found in the *Facilitation Toolkit: A Practical Guide for Working more Effectively with People and Groups* (Keating 2003). Also see the references listed in Section 7.

## 5.2 Establish project teams

It is suggested that a group be formed within local government that consists of representatives (including senior officers) from across functional areas in local government (such as planning, engineering, environment, asset management, environmental health and parks and gardens) to oversee development of the plan. To increase the likelihood of Council support of the plan, it is recommended that the internal group includes at least one Councillor as a member. For example, the City of Stirling has formed a cross-functional group for the development of their Integrated Water Cycle Management Strategy.

For most stormwater management plans (particularly plans for local government areas and catchment areas), it is strongly recommended to have a Project Manager, Project Steering Committee and Project Working Group. For small-scale plans (e.g. a plan prepared for an existing industrial area), a Project Steering Committee and Project Working Group may not be necessary. The Project Manager, Project Steering Committee and Project Working Group would each play a critical role in ensuring that all relevant issues are identified and an appropriate level of commitment and involvement is secured throughout the study.

Their suggested roles and responsibilities are briefly discussed below; they are based on the local government being the main lead for the project. Alternatively, the main leader could be a catchment group or a regional natural resource management group.

### **Project Manager:**

The Project Manager is responsible for the overall coordination of the project, including liaison between the author (e.g. a consultant might be employed to write the plan) and local government staff involved in the project. The Project Manager will usually be a senior local government officer. The Project Manager (with help, if required, from project officers from Department of Water, the main drainage service provider and the regional NRM group) is responsible for ensuring that there is adequate representation, commitment and involvement from all relevant areas of local government and other agencies. The Project Manager is responsible for liaising with senior managers across functional areas within local government to ensure general satisfaction with outcomes of the planning process at key stages of the project. Where sign-off is required, it is the role of the Project Manager to consult with individual managers. The Project Manager is also responsible for leading the review process within the Project Steering Committee (incorporating comments from all stakeholders) and providing a concise set of feedback comments to the author.

### **Project Steering Committee:**

The Project Steering Committee is responsible for overseeing the project and will assist the author by providing guidance and feedback on development of the plan. The Project Steering Committee will generally consist of a group of preferably no more than ten people, with senior representatives of local government, Department of Water, Department of Environment and Conservation, the arterial (main) drainage service provider (e.g. Water Corporation), the regional NRM group (or NRM sub-regional groups, where appropriate), Department for Planning and Infrastructure, Department of Health (or the local government Environmental Health Officer) and at least one representative from local community groups/residents associations. Project Steering Committee meetings should be convened at critical milestones (e.g. to obtain endorsement of draft and final plans) and on an 'as needs basis' (e.g. to obtain the group's input on a specific issue) during the development of the stormwater management plan. The Project Steering

Committee's role at these key stages is to ensure satisfactory completion of milestones and quality of output. The Project Steering Committee should assist with the final prioritisation of management actions.

### **Project Working Group:**

The Project Working Group could include members of the Project Steering Committee, as well as other stakeholder representatives from local government, relevant State government agencies, regional NRM groups and community groups/residents associations/special interest groups. Its role would be to:

- identify and assess issues;
- facilitate communication with and input from representative stakeholder groups;
- review documentation; and
- provide comment and advice to the Project Steering Committee.

Workshops could provide the Project Working Group an opportunity for increasing the awareness and understanding of issues and opportunities related to management of urban stormwater. Project Working Group workshops should help encourage ongoing cooperation and coordination within local government and between local government and other stakeholders.

Sub-teams can also be established to research or discuss issues in more detail and make recommendations to the Project Working Group and the Project Steering Committee.

## **5.3 Establish project framework**

It is important that the project objectives, processes and timeframe are clearly defined, understood and accepted by all parties at the commencement of the project. Key dates for all meetings and workshops should be determined at this stage to maximise stakeholder involvement. It is the Project Manager's responsibility to ensure that participants have a clear understanding of the stormwater management planning process and the importance of their commitment and involvement in development of the plan.

The first task should be establishment of the overall framework for the plan and the preparation process, in consultation with stakeholders. The areas for discussion could include:

- roles and responsibilities of project partners;
- budget for preparation of the plan;
- establishing a timeline and key milestones for preparation of the stormwater management plan;
- the aim of the plan (see Section 5.3.1);
- the scope of the plan (see Section 5.3.2);
- the boundaries and sub-catchments for the plan (see Sections 5.3.3 and 5.3.4);
- public and other stakeholder consultation processes (see Section 5.1);
- scoping of information requirements, such as catchment condition, values and threats (see Sections 5.4, 5.5 and 5.6); and
- identifying an implementation and performance review program (see Sections 5.12 and 5.14).

### **5.3.1 Identify the aim of the stormwater management plan**

The aim of the plan should be determined at the beginning stage and it should be clearly stated in the plan documentation. An example aim would be: to improve the health and amenity of the catchment through improved stormwater management practices. Other examples are: to reduce the occurrence of algal blooms in X water body through improved stormwater management practices; or to identify opportunities to maximise the sustainable use of stormwater as a water source.

### 5.3.2 Identify the scope of the stormwater management plan

A stormwater management plan must clearly state its scope. For example, will it be addressing management of stormwater (i.e. rainfall runoff), or will it also be including modification of groundwater levels for urban development (as stormwater and groundwater drainage discharge are often managed via the same systems)?

### 5.3.3 Identify the stormwater management plan boundary

The stormwater management plan boundary must be identified. Will it be a local government, catchment, or sub-catchment (particularly relevant when local government areas or catchments are large and have many issues to address)? If a plan is prepared for a local government area that crosses more than one catchment, the plan should propose how the cross-catchment stormwater issues will be addressed. For example, neighbouring councils could form an operational partnership on how to manage cross-boundary stormwater issues. If a significant amount of stormwater discharges into a neighbouring council area, it is advisable that a joint management plan be developed. If the plan boundary is to be a catchment boundary, then the stormwater management plan will need to be a joint project between relevant local governments (if the catchment consists of more than one local government). For an example of a joint project, see the Western Suburbs Regional Organisation of Councils' *Regional Strategy for Management of Stormwater Quality* (JDA Consultant Hydrologists 2002).

### 5.3.4 Identify sub-catchments

The study area could be divided into a series of sub-catchments to form the basis for identifying values and threats and formulating and prioritising management actions. Sub-catchments should be delineated based on hydrological/hydrogeological boundaries, along with consideration of land use patterns and receiving environment types. Information sources include existing stormwater/drainage system detail, field inspection and topographic data. The type of receiving environment of the regional drainage network of each sub-catchment should be identified (e.g. a river, wetland, ocean, basin, park, reserve, or diffuse infiltration area). Figures showing the sub-catchments would then be prepared. These maps will help during preparation of the plan and they should be included in the draft and final stormwater management plans. Figure 2 shows an example of a sub-catchment map.

#### **Checklist – Project framework**

- Aim and scope of the plan have been established.
- Stakeholders' roles and responsibilities are understood.
- Stakeholders are committed to involvement in preparation of the plan (including provision of requested data, where relevant) and to implementation of the plan (where applicable).
- Stakeholders understand the nature of stormwater impacts and management.
- Key project objectives are clearly defined and understood.
- Study area boundary and sub-catchments have been determined.
- Available information and data has been requested.
- The timetable for the study has been established by relevant stakeholders (e.g. the Project Steering Committee and the Project Working Group).



Figure 2. Example of sub-catchment mapping, City of South Perth. (Source: JDA Consultant Hydrologists & Ecoscape 2004.)

## 5.4 Identify current status – condition, characteristics and practices

It is important to gain an understanding of the extent that existing activities and land uses might impact stormwater quantity and quality and receiving environments, and how existing processes within local

government, State agencies and community groups manage stormwater issues.

The stormwater management plan should consider the findings or recommendations of existing plans and reports that may affect stormwater management in the subject area. These documents will also include relevant information regarding the catchment condition, practices, values and threats. The following may be relevant:

- Regional and local natural resource management strategies
- Local, district or regional urban water management strategies and plans
- Drinking Water Source Protection Assessments and / or Plans
- Water allocation plans
- Catchment management plans
- Local government environment management plans (e.g. remnant vegetation management plans and waste management plans)
- State and Local Planning Schemes
- State and Local Planning Policies and Strategies
- State and local government State of the Environment Reports
- Environmental or stormwater management plans of neighbouring local governments, particularly if the catchment covers more than one local government area
- Biodiversity plans and strategies
- Wetland management plans
- Waterway management plans (such as River Action Plans)
- Floodplain management plans
- Water quality status reports
- Coastal area management plans
- Recreation plans / strategies

Where applicable, it is suggested that the information gathered about catchment characteristics and condition (Section 5.4.1), land use activities (Section 5.4.2) and stormwater management practices (Section 5.4.3) is produced in map (preferably GIS) format and presented as thematic overlays. This will help identify issues that require prioritised management. For example, by overlaying structural stormwater management measures and natural water bodies, the location of conveyance devices such as pipes and drains that are directly connected to natural water bodies can be identified.

A number of local governments in Western Australia are participating in the ICLEI Water Campaign™ program<sup>2</sup>. There are many links between the Water Campaign™ and the stormwater management planning process. Information collected by a local government through the Water Campaign™ may have direct relevance to the content of a stormwater management plan and vice versa. It is recommended that local governments working on a stormwater management plan and the Water Campaign™ link this work in order to maximise the benefits of both processes<sup>3</sup>.

#### 5.4.1 Identify catchment characteristics and condition

A good understanding of the current condition of the study area will provide a baseline from which any improvements or deterioration can be determined once the stormwater management plan is implemented.

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<sup>2</sup>The Water Campaign™ is a voluntary, international, freshwater management program that aims to build the capacity of local government to reduce water consumption and improve local water quality. The Water Campaign™ is delivered by ICLEI-Local Governments for Sustainability Australia/New Zealand (ICLEI-A/NZ) in collaboration with local and State governments, water authorities and the Australian Government. The Water Campaign™ is delivered in Western Australia by ICLEI-A/NZ in collaboration with the Department of Water as part of the Western Australian State Water Strategy.

<sup>3</sup>If your council would like advice on how to do this, or would like to learn more about the Water Campaign™, contact the WA Water Campaign™ Manager at ICLEI-A/NZ on (03) 9639 8688. Further information regarding the Water Campaign can also be accessed on the Water Campaign™ website <<http://www.iclei.org/anz/water>>.

Information about the catchment condition will also help with the identification of issues and the determination of priorities.

Note: Lack of information on the condition of the catchment and the receiving environment for many catchments is acknowledged as a constraint, but it should not prevent the preparation and implementation of a stormwater management plan. Numerous actions can be implemented to improve stormwater management. When data on the catchment is collected, it can be incorporated in an updated plan.

See Table 1 for some environmental condition information that should be gathered. Note: Website addresses are provided in Section 7. The Shared Land Information Platform (SLIP) provides access to the Government's land and geographic spatial information via one website. The SLIP website is being finalised and is due to be launched in mid-2007.

#### 5.4.2 Identify land use activities

Describe the current and proposed land use activities within the catchment. This is critical to understanding the current stormwater threats from certain land use types and likely impacts associated with future changes in land use. Planning scheme zones should be used as a basis for defining current and future land use activities. Aerial photography can be used to help identify current land use activities. A field inspection of the study area should be undertaken to confirm land use activities and determine current threats (see Section 5.6 for a discussion of threats).

In addition to long-term land uses, transient activities (such as building construction) should also be considered. This is particularly important for catchments that support continued urban growth, where considerable portions of land may exist in a developing state over an extended period. Mobile activities (such as mobile mechanics, vehicle washing / detailing and carpet cleaning) should also be considered.

Activities to be documented include those listed in Table 2. Potential sources of information are also provided. Note: Website addresses are provided in Section 7. The Shared Land Information Platform (SLIP) provides access to the Government's land and geographic spatial information via one website. The SLIP website is being finalised and is due to be launched in mid-2007.

#### 5.4.3 Identify existing stormwater management systems, practices and processes

When assessing stormwater management it is important to determine the characteristics of the existing stormwater management system, the maintenance of stormwater management devices, and the construction and maintenance of impervious surfaces (such as roads and carparks) and public assets (such as parks). Additionally, the way that day-to-day planning and management activities are undertaken should be reviewed, as they have a direct impact on stormwater management within the study area. These activities include:

- strategic planning for future development and land use;
- assessment and approval of development proposals;
- construction, management and maintenance of infrastructure;
- regulation, enforcement and education activities;
- internal and external coordination and communication between different levels and departments within local government and relationships with external agencies (i.e. organisational culture).

In undertaking these activities, local government applies certain procedures and policies based on various protocols, documents and planning tools. These provide the foundation for good stormwater management and reduce reliance on reactive management actions in the future.

**Table 1. Data sources for catchment characteristics and condition**

Data	Source
<p><b>Topography and soil type.</b> This includes acid sulphate soil risk, slope, permeability, erodibility, dispersivity and nutrient retention ability. This will determine risk to water quality from polluting land uses, risk of soil erosion, and risk of disturbance of acid sulphate soils during land development / land use activities and construction of stormwater management devices. Note: Only general soil type and acid sulphate soil information can be accessed from the recommended sources. Site assessments will need to be conducted to determine actual soil type, slope, permeability, etc.</p>	<p>Soil type from the SLIP website and Department of Agriculture; topography from the Landgate website; acid sulphate soil mapping from the Department of Environment and Conservation website.</p>
<p><b>Climate</b> (seasonal rainfall, duration of storms, evaporation rates). If possible, include rainfall average recurrence interval / rainfall intensity / peak discharges for the catchment.</p>	<p>Bureau of Meteorology.</p>
<p><b>Wetlands and their buffers</b> – location, type, management category and condition.</p>	<p>Department of Environment and Conservation website for the wetland mapping dataset and other wetland information (Note: the DEC website does not include data about specific wetland buffers); local government; NRM/Catchment/Friends of Groups.</p>
<p><b>Waterways and their foreshore areas</b> – location, type and condition.</p>	<p>Department of Water website; NRM/Catchment/Friends of Groups.</p>
<p><b>Groundwater levels and hydraulic conductivity of the soil</b> – regional and if possible, the shallow system (and how it is influenced by drains that intercept groundwater). Note: On-site tests will need to be conducted for local groundwater levels and hydraulic conductivity.</p>	<p>Department of Water website.</p>
<p><b>Surface water hydrology</b>, including floodplains, flooding and baseflow characteristics.</p>	<p>Department of Water.</p>
<p><b>Surface and groundwater quality</b> (this includes stormwater drains and receiving water bodies).</p>	<p>Department of Water website; local government; NRM/Catchment/Friends of Groups.</p>
<p><b>Remnant / native vegetation</b> – type, condition and linkages / corridors; rare, priority or threatened species; Threatened Ecological Communities.</p>	<p>Department of Environment and Conservation; BushForever mapping on the Western Australian Planning Commission’s website; local government; NRM/Catchment/Friends of Groups; aerial photographs; plant biodiversity database for the Perth Metropolitan Region via WALGA.</p>
<p><b>Native fauna</b>, including threatened and priority species.</p>	<p>Department of Environment and Conservation; Western Australian Museum’s FaunaBase website; NRM/Catchment/Friends of Groups.</p>
<p><b>Pests</b> - species and distribution.</p>	<p>Local government; Department of Health; NRM/Catchment/Friends of Groups; Department of Agriculture website; Department of Environment and Conservation’s FloraBase website.</p>

**Table 2. Land use activities and data sources**

<b>Land use activities</b>	<b>Information source</b>
<b>General land use types and zoning</b> (e.g. residential, rural-residential, commercial, light industry and general industry). Should distinguish between old and new industrial areas (due to different practices and associated risks).	Local government; Landgate website; Department for Planning and Infrastructure.
<b>Public open space/parks/other recreational areas/reserves/regional and national parks and reserves.</b> Categorise into passive (e.g. parks) and active (e.g. sports ovals and golf courses) recreation areas. Highlight areas of open space that might be suitable for stormwater management systems and/or storage of flood water during extreme rainfall events, without compromising the primary purpose of the open space area (such as recreation).	Local government; Landgate website; Department of Environment and Conservation (for regional and national parks and reserves).
<b>Public Drinking Water Source Areas</b> – Catchment Areas, Water Reserves and Underground Water Pollution Control Areas supplying public drinking water.	Department of Water.
<b>Major infrastructure services</b> (e.g. roads, public carparks, bridges, major sewerage pipelines, sewerage pumping stations and their overflow route/system).	Local government; Water Corporation; Main Roads Western Australia; Landgate website.
<b>Location of impervious surfaces</b> that have an opportunity to be retrofitted to introduce perviousness.	Local government.
<b>Licensed premises</b> under the <i>Environmental Protection Act 1986</i> and <b>potential point sources of pollution.</b>	Department of Environment and Conservation for licensed premises; local government.
<b>Illicit discharges</b> to the stormwater system (i.e. illegal or inappropriate waste streams, such as wastewater, entering the stormwater system).	Inspections (e.g. investigating the origin of pipes and drains that discharge into local government, Water Corporation or Main Roads Western Australia sumps and drains).
<b>Areas without reticulated sewerage</b> (i.e. areas with on-site wastewater disposal).	Local government; Water Corporation.
<b>Contaminated sites.</b>	Department of Environment and Conservation; Department of Health.
<b>Demographic characteristics and population projections</b> – to gauge the community's recreational needs and the desired use of water bodies.	Local government; Australian Bureau of Statistics.

The following management practices, activities and programs that contribute to stormwater management within the study area should be identified and documented (see Table 3). Note: Website addresses are provided in Section 7. The Shared Land Information Platform (SLIP) provides access to the Government's land and geographic spatial information via one website. The SLIP website is being finalised and is due to be launched in mid-2007.

**Table 3. Systems, practices and processes that contribute to stormwater management**

Data	Source
<p><b>Flow paths for stormwater runoff from minor (&gt; 1 year ARI and &lt; 10 year ARI) to major (&gt; 10 year ARI) rainfall events.</b> Calculations should be based on <i>Australian Rainfall and Runoff – A Guide to Flood Estimation</i> (Institution of Engineers Australia 2001).</p>	<p>Local government; Water Corporation.</p>
<p>Define any <b>regional drainage system</b> within the study area.</p>	<p>Local government; Water Corporation.</p>
<p><b>Location, type, size/capacity, condition and ownership of structural stormwater management devices</b> such as drains, pipes, pollutant traps, compensating basins, infiltration areas (e.g. swales, soakwells and basins), side entry pits, ‘living streams’ and constructed wetlands.</p>	<p>Local government; Water Corporation; Main Roads Western Australia; this information will eventually be on the SLIP website.</p>
<p><b>Identify stormwater management devices that:</b></p> <ul style="list-style-type: none"> <li>– are causing unreasonable flooding (including blocked drains or undersized basins, if known);</li> <li>– have public health and safety issues (e.g. mosquitoes, steep banks);</li> <li>– are directly connected to a receiving environment (e.g. a stormwater pipe or open drain discharging directly into a wetland or waterway);</li> <li>– are causing erosion/scouring;</li> <li>– are subject to high levels of sediment or litter accumulation;</li> <li>– are providing insufficient water quality treatment;</li> <li>– with modification, could provide other uses (e.g. recreation, amenity, water supply, or re-establishing the local water regime); and</li> <li>– are over-designed.</li> </ul> <p>This information in particular needs to be surveyed and entered into a database (preferably GIS) to enable efficient asset management.</p>	<p>Local government; Water Corporation; residents associations; NRM/Catchment/ Friends of Groups; field inspection.</p>
<p>Location of <b>impervious surfaces</b> that could be retrofitted to introduce perviousness, particularly priority areas such as those located near water bodies.</p>	<p>Local government; aerial photographs; field inspection.</p>
<p><b>Management of structural stormwater devices</b> (such as inspection/monitoring programs, frequency and methods of maintenance and who is responsible for maintenance).</p>	<p>Local government; Water Corporation; Main Roads Western Australia.</p>
<p><b>Road/pavement construction and maintenance practices</b> (e.g. street/footpath/carpark construction, repairs and sweeping). Include scheduled major upgrading/maintenance works to identify opportunities for introduction of improved stormwater management practices.</p>	<p>Local government; Main Roads Western Australia.</p>
<p><b>Management of local government premises</b>, such as waste/chemical management at depots and graffiti removal from buildings.</p>	<p>Local government.</p>
<p><b>Maintenance of parks/ovals/recreation areas</b> (e.g. fertiliser, water and pest management, plant selection, and management of prunings and lawn clippings).</p>	<p>Local government; owners of private recreation areas, such as golf courses and lawn bowls greens.</p>

Data	Source
<b>Waste management strategies</b> , such as recycling programs and litter management.	Local government; Department of Environment and Conservation; Regional Councils.
<b>Education and awareness programs</b> that reduce the impact of activities on stormwater quantity and quality.	Local government; Department of Environment and Conservation; Regional NRM groups; Swan River Trust; Regional Councils; Water Corporation; Department of Water.
Local government stakeholder <b>consultation</b> and involvement protocols.	Local government.
<b>Regulation and enforcement efforts.</b> Existing regulation and enforcement initiatives should be reviewed to consider their relevance to stormwater management and to gain insight into local government's and State government's capacity for implementing new initiatives that may be recommended as part of the stormwater management plan.	Local government; Department of Environment and Conservation.
<b>Emergency pollution response procedures.</b>	Fire and Emergency Services Authority of WA (FESA); local government; Department of Environment and Conservation.
<b>Employee training</b> (i.e. the training that employees of local government, Water Corporation, Main Roads Western Australia and local commercial/ industrial businesses receive).	Local government; Water Corporation; Main Roads Western Australia; local commercial/ industrial businesses.
Relevant information from the <b>land use planning process</b> , including the Town Planning Scheme, Local Planning Strategies, planning policies and corporate plans, Urban Water Management Strategies and Plans. The local government planning documents present opportunities to address stormwater management. The planning scheme and its supporting documents should be comprehensively reviewed to consider how they incorporate stormwater management. Opportunities for improvement should be identified to form the basis of recommended strategies. The components and functions of the approvals process should also be summarised (e.g. through the use of a flow chart), and opportunities identified to incorporate better stormwater management practices at the planning and approvals stages (e.g. development or updating of local planning policies).	Local government; Department for Planning and Infrastructure.

### Checklist – *Current condition, characteristics and practices review*

- Field investigations have been undertaken.
- Interviews and consultation with relevant local government officers and other stakeholders have been undertaken.
- All relevant information and data has been obtained, reviewed and catalogued.
- Maps of wetlands, waterways, remnant vegetation, Public Drinking Water Source Areas, the stormwater/drainage system and land uses have been prepared.
- Database (preferably GIS) of stormwater device management has been developed, which should include who is responsible for maintenance of the device.
- Current practices and processes have been reviewed, including the planning scheme, supporting documentation, the approval process, maintenance practices and the nature of coordination and resourcing.

## 5.5 Identify economic, ecological and social/cultural values

A key goal of the stormwater management plan is to protect and enhance the values of the local and receiving environments. Values may include economic values (e.g. water use, aquaculture, stormwater reuse), ecological values (e.g. aquatic fauna and flora, urban bushland) and social/cultural values (e.g. historical, public health and safety, recreational, visual amenity, spiritual). These values form the basis of what the community expects in terms of their interaction with, and enjoyment of, the local and receiving environment. Values help determine the importance of an asset and define the objectives for managing stormwater. They also determine factors that will be barriers or motivators to changing stormwater management practices. Economic, ecological and social/cultural values are discussed further below:

**Economic values:** Economic values include water body uses, stormwater use, economic values of the receiving environment (e.g. fishing and tourism), values of land used for stormwater management and values of land adjacent to stormwater management devices.

**Ecological values:** Ecological values are defined as 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 & ARMCANZ 2000) and from the effects of altered water regimes.

The ecological values of downstream environments (i.e. downstream environments that are located outside of the plan boundary) should also be included. This will be particularly important for values of receiving environments that relate to recognised conventions, regional agreements, policy or legislation (e.g. Ramsar wetlands, Conservation category wetlands, Resource Enhancement wetlands, Rare and Threatened Species protected under the *WA Wildlife Conservation Act 1950*, Regional Natural Resource Management Strategies, WA Environmental Protection Policies, and national registers).

**Social/cultural values:** Social values include public health and safety, recreational uses and visual amenity. Cultural values include historical and spiritual significance, and scientific and educational uses. To identify heritage sites, see the Register of the National Estate, the National Heritage List, sites protected under the *Aboriginal Heritage Act 1972*, sites registered under the *Heritage of Western Australia Act 1990*, and the Register of Heritage Places database.

Values should be categorised into specific value types, as shown in Table 4. Please note: the description in Table 4 provides examples of valuation issues; it does not provide all of the issues that would need to be considered when assessing values.

Existing plans and strategies, such as regional natural resource management strategies, registers and databases, catchment/environmental management plans, remnant vegetation management plans, wetland management plans, river restoration plans and urban water management plans/strategies will provide some values information. The identification of catchment characteristics and condition (Section 5.4.1) and land use activities (Section 5.4.2) will also provide some values information.

Where values have not been previously determined, they will need to be based on qualitative and anecdotal information. It is important that the value assessment focuses on aspects of the local and receiving environment that may be affected by stormwater. The assessment of values should be based on available information collated by the authors, advice provided by the Project Steering Committee, the Project Working Group, other stakeholders (e.g. State government agencies and the local community) and field investigations. Adequate community consultation is particularly important for determining values. This might require a community survey. However, to ensure that the community is not asked the same questions twice, it should be determined if they have previously been consulted to determine catchment values. See Section 5.1 for more information on consulting stakeholders.

The assignment of value ratings should then be based on the judgement of the Project Steering Committee and Project Working Group.

Within each sub-catchment, a description of the characteristics of each value type should be provided. The description should explain the specific nature of the value and its significance in a local and regional context (i.e. compared with similar value types in other sub-catchments within the study area).

**Table 4. Value Types**

<b>Value Category</b>	<b>Specific Value Types</b>	<b>Description</b>
<b>Economic</b>	Property/ infrastructure	Stormwater system contribution to protection of property/infrastructure from flooding. Property value associated with proximity to water. This may include values associated with visual amenity and access. Property values of land used for stormwater devices.
	Other	Economic benefits associated with receiving water bodies (e.g. fishing and tourism, or water used for public drinking water supply or irrigation). Economic benefits associated with using stormwater as a water source.
<b>Ecological</b>	Water bodies	Rareness or representation of that habitat type; water quality; habitat quality and diversity; extent, quality and rarity of flora and fauna species; extent of exotic species (such as weeds and feral animals); provision of flood conveyance and storage; forming part of an ecological corridor; drought refuge; capacity to improve water quality.
	Terrestrial areas	Extent and quality of natural communities, including quality, diversity and rarity of flora and fauna species; extent of exotic species; forming part of an ecological corridor.
<b>Social/ cultural</b>	Recreational amenity	Public access and utilisation for passive and active recreation; formal linkages; extent of open space; facilities such as car parks and picnic areas; continuity of open space; visual attractiveness.

Value Category	Specific Value Types	Description
Social/ cultural (continued)	Public health	Stormwater system contribution to minimisation of risk to public health and safety from flooding. Minimisation of risk to public health and safety from drowning in stormwater structures. Existence of aquatic foods that are safe for human consumption. Water bodies that are safe for primary (e.g. swimming) and secondary (e.g. boating and fishing) contact recreation due to absence of toxic algal blooms. Level of disease and nuisance vector insects (i.e. mosquitoes and midges). Public drinking water sources that are protected from contamination to ensure safe, good quality drinking water.
	Visual/ landscape amenity	Aesthetic appreciation of the natural and built environment, including consideration of natural and constructed structures, landscapes and places of importance; visual access; relationships to adjacent facilities.
	Indigenous cultural heritage	Places and sites of Indigenous heritage value such as artefact sites, landscape and places of significance (e.g. relating to story telling), ceremonial sites, campsites and trails.
	Non- indigenous cultural heritage	Places and sites of heritage value, including sites of pioneering significance, historical buildings and infrastructure, trails and transport routes.
	Scientific and educational	Components that can be monitored to improve understanding of the natural environment or stormwater devices. Areas that have high educational values.

Using the following scale, the receiving environments should be scored for their economic, social/cultural and ecological values:

- 1 = None, the attribute does not contribute to the value of the asset
- 2 = Minor, the attribute contributes to the asset at a local level
- 3 = Moderate, the attribute contributes to the value of the asset at a local and regional scale
- 4 = Important, the attribute contributes to the value of the asset at a local, regional and State scale
- 5 = Significant, the attribute contributes to the value of the asset at a local, regional, State and national level
- Unknown = unable to answer

An overall score for value can be obtained by adding the ecological, social/cultural and economic scores. A maximum score of 15 can be obtained. The high, medium and low value score bands are as follows:

- High = 10-15
- Medium = 5-9
- Low = 1-4

Alternatively, the methodology used for the Town of Victoria Park stormwater management plan (URS 2005) was to score the ecological, social/cultural and economic values as high (3), medium (2) or low (1) and add up all of the value scores for each receiving environment, then rank the receiving environments based on the total score.

## 5.6 Determine threats

This step involves identifying and confirming the nature and source of threats. A threat is considered to be an activity or land use with potential to damage the local or receiving environment's social / cultural, ecological or economic values, via impacts to stormwater quantity or quality.

Stormwater (and groundwater, if applicable to the scope of the plan) threats should be assessed and documented for each study sub-catchment. Table 5 provides a list of generic stormwater threats that could be considered when assessing threats for each sub-catchment.

Data will rarely be available on the impact of land use activities on receiving environments. However, an informed assessment can be based on professional judgement and experience, as well as factors such as local knowledge, field investigations, land use, monitoring data, spills history, complaints, age of infrastructure (ARMCANZ & ANZECC 2000) and advice provided by stakeholders. Discussions should take place with key people in local government, Department of Environment and Conservation, Department of Water, the NRM/catchment management group, the arterial (main) drainage service provider (if within a declared arterial (main) drainage service area) and other groups suggested in Section 5.1. It will be necessary to justify and explain the basis for assigning a rating to a particular threat. Proposed significance ratings should be reviewed and endorsed by the Project Working Group and Project Steering Committee before their final adoption. Assessing the current practices (Sections 5.4.2 and 5.4.3) will provide much information about threats. For example, if there is infrequent or no maintenance of stormwater infrastructure, the threats will be greater (such as increased localised flooding, increased pollutant discharges, or increased mosquito numbers).

A good estimate of water quality risks from various land use activities can be determined from the *Water Quality Protection Note: Land Use Compatibility in Public Drinking Water Source Areas* (Department of Environment 2004a).

A list of major site-specific and transient activities with potential to damage receiving environments should be prepared that identifies:

- the type of threat; and
- a significance rating of the threat.

Within each sub-catchment, each threat type is assigned a significance rating of 1 to 5 (see list below). In arriving at a significance rating, consideration should be given to the magnitude and the frequency of occurrence and if the threat is acute or chronic.

Threats could be scored:

1 = No threats of significance

2 = Minor

3 = Moderate

4 = Severe

5 = Extreme

Unknown

The high, medium and low threat bands are defined as:

High = 4-5

Medium = 3

Low = 1-2

Alternatively, the Town of Victoria Park Stormwater Management Plan (URS 2005) scored threats in a sub-catchment as high (3), medium (2) and low (1). These scores were summed and the sub-catchments ranked.

**Table 5. Generic stormwater threats**

<b>Threat</b>	<b>Cause</b>	<b>Key Impacts</b>
<b>Residential land use runoff</b>	Atmospheric deposition and build-up from traffic; car washing; fertiliser and pesticide application; animal wastes; poor waste management (domestic litter); lawn clippings and leaf litter; and pool emptying.	Increased flow, sediment, nutrients, litter, oxygen depleting material (e.g. leaves and lawn clippings), hydrocarbons, pathogens, trace metals, pesticides, salinity and surfactants.
<b>Industrial land use runoff</b>	Atmospheric deposition and build-up from traffic; poor waste management; accidental spills; and illegal discharges.	Increased flow, sediment, nutrients, litter, oxygen depleting material, hydrocarbons, pathogens, pesticides, surfactants, heavy metals, trace metals and solvents.
<b>Commercial land use runoff</b>	Atmospheric deposition and build-up from traffic; poor waste management practices; accidental spills; and illegal discharges.	Increased flow, sediment, nutrients, litter, oxygen depleting material, hydrocarbons, pathogens, trace metals and surfactants.
<b>Construction and development sites</b>	Vegetation loss; poor sediment and erosion control; uncontrolled wash-down of equipment; chemical spills; and poor management of waste and materials.	Increased sediment, litter, chemicals and hydrocarbons.
<b>Road and carpark runoff</b>	Atmospheric and vehicular deposition and accumulation; litter; and chemicals from traffic accidents.	Increased flow, sediment, litter, heavy metals, trace metals, hydrocarbons and chemicals.
<b>Surface runoff flow modification</b>	Changes to runoff characteristics due to constructed impervious surfaces and collection and disposal of stormwater.	Altered water regimes in natural water bodies; formation of acid sulphate soils; flooding of buildings, roads and paths.
<b>Groundwater level modification</b>	Modification of the natural groundwater levels to allow for development.	Stress to groundwater dependent ecosystems, such as wetlands; formation of acid sulphate soils.
<b>Open space runoff (e.g. golf courses and sporting grounds)</b>	Fertiliser and pesticide application and litter from public gardens, parks, sporting facilities, golf courses; and discharge of low quality water from ornamental lakes.	Increased nutrients, pesticides, litter and oxygen depleting materials.
<b>Inadequate maintenance of stormwater devices (e.g. drains, sumps, gross pollutant traps and side entry pits)</b>	Accumulation, then release of pollutants out of unmaintained or poorly maintained stormwater devices; blockages of devices from uncleared sediment, litter, etc.; water pooling due to blockages from uncleared litter, sediment, etc.	Increased sediments, heavy metals, trace metals, nutrients, oxygen depleting substances, toxins and hydrocarbons; flooding of buildings, roads and paths; increased mosquito numbers.

Threat	Cause	Key Impacts
<b>Landfill and contaminated sites</b>	Runoff or leaching from landfills and contaminated sites.	Increased oxygen depleting material, pathogens, sediments, nutrients, litter, trace metals, hydrocarbons and toxins.
<b>Septic and sewer leakage</b>	Groundwater infiltration and surface overflow from sewage systems.	Increased oxygen depleting material, pathogens and nutrients.

#### Checklist – Values and threats assessment

- Values and threats have been identified, assessed and documented.
- Significance ratings of values and threats have been reviewed and endorsed by the Project Working Group and Project Steering Committee.

## 5.7 Determine management objectives

Stormwater management objectives aim to define the outcomes sought in the management of stormwater to maintain, protect or restore values. The objectives should ideally define outcomes sought, rather than strategies to be employed, in order to facilitate flexibility and encourage innovation in the management of stormwater. Ideally, objectives should be SMART: specific, measurable, achievable, relevant and linked to a timeframe (ARMCANZ & ANZECC 2000).

The stormwater management planning process should define a vision for the catchment, short-term objectives and long-term objectives.

Establishing objectives will help develop desired outcomes for evaluation planning. Monitoring and evaluation plans should be prepared as part of the stormwater management plan development process. See Section 5.14 and Chapter 10 for more information.

Chapter 2 (Sections 4.1, 5.1, 5.2 and 5.3) and the *Decision Process for Stormwater Management in WA* (Department of Environment & Swan River Trust 2005) should provide a basis for stormwater management plan objectives. The applicable NRM Regional Strategy must also be reviewed, as regional management objectives may have been determined. Water quality targets might have been established by the Environmental Protection Authority, Swan River Trust or a catchment management body.

**Vision:** Describes the vision of the future catchment condition. It could include a statement about the condition of the catchment and/or a receiving water body in the next 20 to 40 years. A vision is something that the various stakeholders and the community can identify with and support and is an important step towards achieving the objectives of the stormwater management plan.

**Short-term objectives:** These are the objectives set for the resolution of specific issues over a short timeframe (less than 3-5 years). The timeframe must be specified. Example short-term objectives are:

- Identify and prioritise the retrofitting of existing stormwater management devices to meet the guidelines in Chapters 6 and 9 of the Manual.
- Develop partnerships with neighbouring local governments to improve stormwater management.

- Reduce mosquito problems in X sub-catchment through improved stormwater management.
- Improve habitat values of X stormwater structural control from low to medium.
- Increase overland flow towards X water body.
- Replace X drain with overland flow within the buffer/X metres of X water body.
- Reduce the amount of litter in stormwater runoff exiting X (name of major shopping centres / streets and major active recreation areas).
- Improve recreational access to X (name of waterway, wetland, etc.).
- Improve coordination and planning of asset / infrastructure maintenance.

**Long-term objectives:** The objectives set for the resolution of specific issues over a long timeframe (greater than 3-5 years). The long-term objectives should reflect the WA stormwater objectives and principles provided in the Preface. Example objectives are:

- Protect public and private buildings from flooding and waterlogging in the 100 year ARI event.
- Reduce the amount of impervious surfaces within the study area by X%.
- Reduce the amount of direct stormwater discharge into X receiving water body/bodies.
- Maintain the pre-development hydrologic regime and meet the ecological water requirements of the receiving environment (specific receiving environments can be named here).
- Increase the amount of stormwater reuse systems with the study area by X%.
- Reduce the X (e.g. total phosphorus or total suspended solids) concentration in X water body to X mg / L. Reduce the X (e.g. total phosphorus or total suspended solids) load to X water body by X%.
- Reduce the frequency/severity of algal blooms/fish kills within X water body by X%.
- Ensure stormwater structural controls meet public health and safety standards.
- Identify appropriate local government policies, schemes and process documents for the inclusion of stormwater management objectives and measures.
- Implement stormwater management objectives and measures to identified local government policies, schemes and process documents by 20XX.
- Increase opportunities for multiple uses of stormwater structural controls.

**Checklist – *Management objectives***

- Define a vision for the catchment and short-term and long-term objectives.
- Identify outcomes for performance monitoring and evaluation.

## 5.8 Define priority management issues

Part of the stormwater management planning process includes defining priority management issues to be addressed by actions in the stormwater management plan. The identification of condition, activities, values, threats and objectives plays an important role in determining the priority management issues.

### Prioritisation options include:

- Map overlays and/or GIS of the spatial information gathered in Sections 5.4, 5.5 and 5.6 can be used to highlight some of the obvious areas that require management. In particular, include overlays of wetlands, waterways, Public Drinking Water Source Areas and native vegetation; land use types; stormwater management infrastructure; major roads; contaminated sites; and stormwater systems causing flooding problems. These maps are also good tools for workshops and presentations.
- The *WA Salinity Investment Framework* (Department of Environment 2003b) process used multiple-criteria analysis to prioritise investment. A matrix of three bands of value and three bands of threat was used, which then determined high value, high threat (the top priority for management), low value, low threat (the lowest priority for management), and so on (see Figure 3). The process documented in Sections 5.5 and 5.6 will produce the three bands of values and threats (high, medium and low). This process was adapted further by the South West Catchments Council during development of the *South West Regional Strategy for Natural Resource Management* (South West Catchments Council 2005), by incorporating the condition of the asset. See Figure 4 for an adaptation of this process, which incorporates the value, threat and condition. Projects that overcome the threats to Tier 1 assets are the priority projects, then projects can be determined for Tier 2 assets. Some assets might be impacted by multiple threats and some projects can address more than one threat. The priority should be to invest in assets of high value or with multiple values. The next priority is to invest in assets in best condition. Then invest in assets that are subject to the highest threat. Then the following factors should be considered: level of community interest is high; condition of the asset is deteriorating; high likelihood of success and/or a technically feasible solution; desirable cost-benefit ratio; etc.
- A panel (e.g. a Steering Committee) can be used to quickly prioritise the highest risks and develop suitable management actions. The panel can use various facilitation/prioritisation processes to assist decision-making. See the *Facilitation Toolkit: A Practical Guide for Working more Effectively with People and Groups* (Keating 2003) and the on-line toolbox (<<http://www.coastal.crc.org.au/toolbox/>>) for how to facilitate groups.
- See Appendix A for an example of an assessment process. This process was adapted from CSIRO (2000); however, it is very complicated and has the most value for catchments that are complex and where obviously high priority risks are already undergoing management.

Assets		Value		
		High	Medium	Low
Threat	<b>High (Existing and/or near and substantial &lt;2020)</b>	<b>1st Tier</b>	<b>2nd Tier</b>	<b>3rd Tier</b>
	<b>Medium (Intermediate time and/or not a great extent 2020-2075)</b>	<b>2nd Tier</b>	<b>2nd Tier</b>	<b>3rd Tier</b>
	<b>Low (Long term &gt;2075 or already impacted significantly)</b>	<b>3rd Tier</b>	<b>3rd Tier</b>	<b>3rd Tier</b>

Figure 3. *WA Salinity Investment Framework* prioritisation process (Department of Environment 2003b).

Threat/Value		Value		
		High	Medium	Low
Threat	High	Tier 1	Tier 2	Tier 3
		High condition	High condition	High condition
		Medium condition	Medium condition	Medium condition
		Low condition	Low condition	Low condition
	Medium	Tier 2	Tier 2	Tier 3
		High condition	High condition	High condition
		Medium condition	Medium condition	Medium condition
		Low condition	Low condition	Low condition
	Low	Tier 3	Tier 3	Tier 3
		High condition	High condition	High condition
		Medium condition	Medium condition	Medium condition
		Low condition	Low condition	Low condition

Figure 4. Adaptation of the South West Regional Strategy for Natural Resource Management prioritisation process (South West Catchments Council 2005).

For more information on risk assessment, see *Australian/New Zealand Standard Risk Management AS/NZS 4360:1999* (Standards Association of Australia 1999) and *Handbook: Environmental Risk Management – Principles and Process HB 203:2006* (Standards Association of Australia 2006).

#### Checklist – Priority management issues

- A prioritisation process has been established.
- Priority management issues have been identified.

## 5.9 Prepare a priority management issues paper

This stage involves development of an issues paper that highlights key management issues by bringing together the outcomes from the identification of current catchment condition, characteristics and practices, and the prioritisation process. The paper provides an opportunity to reflect on the work undertaken to date and to confirm the key outcomes with the internal local government stormwater management group, Project Working Group, Project Steering Committee and other stakeholders. It also offers an opportunity to maximise local government and stakeholder ownership of the outcomes of the plan. For example, it could be sent to the local government Councillors for noting.

The paper should:

- Summarise the outcomes of the prioritisation process.
- Identify gaps between current stormwater management and best practice.
- Identify obvious barriers and constraints to achieving progress towards best practice. Barriers can include technical issues (such as lack of available land), funding and resistance to change practices. Section 2.3 of Chapter 7 and Chapter 8 provide information on education programs that help to overcome barriers.
- Describe the priority management issues, their extent and implications.

It should be written in a direct and concise style, suitable for an audience of senior managers, Councillors and community members not directly involved in the stormwater management planning process.

#### **Checklist – *Priority management issues paper***

- A priority management issues paper has been prepared.
- A priority management issues paper has been sent to the Project Working Group, Project Steering Committee, senior local government officers and Councillors.
- The Project Working Group and Project Steering Committee have reviewed and endorsed the priority management issues. These priority management issues should form the basis for developing management actions.

## 5.10 Identify management options

Options for addressing the priority management issues should be identified. These should include a range of both structural and non-structural controls and involve retrofitting existing developed areas and existing structural controls. The following questions should be asked when determining the potential options:

- Is it addressing the protection or restoration of a high priority asset or value?
- Can it address multiple threats and protect or provide multiple values (e.g. does it reduce public health/safety risks or reduce algal bloom outbreaks; or does it provide recreation values, or habitat values, or water conservation or supply opportunities, as well as stormwater management functions)?
- Is it cost-effective (i.e. are there sufficient benefits for the cost)? Costs should include life-cycle planning, construction and maintenance costs.
- Is there adequate capacity for implementation (i.e. are there sufficient resources, expertise and powers)?
- Are there opportunities for implementation (e.g. is it practical, such as sufficient space to install a particular structural control or to allow access for maintenance equipment)?
- What are the maintenance requirements (frequency, cost and methods)?
- Can it be integrated with other stormwater management measures and therefore form part of a treatment train?
- Who will be responsible for implementation?
- Will it be acceptable to the community?
- Does it encourage partnerships between stakeholders?

Detail about management options is provided in other chapters of the Manual, particularly Chapters 6, 7, 8 and 9.

Financial, social and ecological elements must be assessed to determine the most appropriate strategies – this is often termed triple bottom line assessment. See the guidelines produced by the Cooperative Research Centre for Catchment Hydrology (2005) on triple bottom line assessment of urban stormwater management measures.

Expertise will be required to select a set of possible actions that may meet the needs of the study area. People undertaking this role must be broadly familiar with the benefits and constraints of all possible options. As this is a major challenge for one person, a multi-disciplinary team approach is recommended.

#### **Checklist – Management options**

- A range of structural and non-structural control options that would address the priority management issues have been identified.

## 5.11 Develop management actions

After suitable management options have been identified, a suite of management actions should be selected and documented in the stormwater management plan. Management actions should address existing issues, as well as measures to prevent possible issues from occurring in the future. They might also involve catchment monitoring and review when insufficient information currently exists (such as water quantity and quality monitoring or additional ecological studies).

Regional natural resource management strategies and catchment management plans should be reviewed to ascertain their management strategies, actions and targets and to see how the stormwater management plan fits within that context.

Management actions should be developed in consultation with the internal and external stakeholders that will be responsible for implementation.

The following list includes some management actions that should be included in a stormwater management plan (where applicable).

- **Funding.** Establish a budget and dedicated source of funding to implement the management plan actions. The funding program should be sent to Council for review and endorsement.
- **Undertake water quantity and quality modelling and additional ecological studies,** if required to assist development of future actions.
- **Establish water quality and quantity targets,** if none exist for the study area.
- **Develop and implement a water quality monitoring program,** including a sampling and analysis plan to identify pollution sources, establish baseline water quality data and establish water quality targets.
- **Minimise effective imperviousness<sup>4</sup>** in the study area. Stormwater management plans must determine the location of impervious surfaces and which pipes/drains discharge directly into waterways, wetlands and coastal waters and how the imperviousness and direct connection will be minimised. Minimising effective imperviousness significantly improves the quality of stormwater that discharges to receiving environments and helps re-establish the pre-development hydrologic regime. See Walsh et al. (2004) for more information on how water quantity management improves water quality in receiving waterways. Refer to Chapters 6 and 9 for methods to increase perviousness and minimise direct connection. Reduction of effective imperviousness can be achieved by:

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<sup>4</sup>Effective imperviousness is the combined effect of the proportion of constructed impervious surfaces in the catchment, and the connectivity of these impervious surfaces to receiving water bodies.

- the retention of pervious surfaces (e.g. bushland, parkland and street plantings);
  - retaining small rainfall events at-source through the installation of infiltration systems (such as pervious paving, swales and soakwells) or using stormwater on-site (e.g. rainwater tanks);
  - identifying impervious surfaces that are suitable to be replaced with pervious surfaces and undertaking phased replacement;
  - the removal of pipes/drains that discharge directly into waterways, wetlands and coastal waters and the introduction of overland flow across vegetated surfaces.
- **Improve the protection and restoration of wetlands and waterways** (i.e. in accordance with Chapter 2 principles and approaches). In particular, wetland and waterway buffers should be established and maintained and the pre-development hydrologic regime should be re-established, where appropriate. For example, the stormwater management plan could state the values of the wetlands and waterways and the principles and approaches for their management (such as revegetation of wetlands and waterways and their buffers). However, it is preferable for detailed management actions to be documented in wetland and waterway management plans. Refer to *A Guide to Managing and Restoring Wetlands in Western Australia* (Department of Environment and Conservation, in preparation) and the *River Restoration Manual* (Water and Rivers Commission/Department of Environment 1999-2003). If environmental, wetland or waterway management plans have been developed, then actions recommended in the stormwater management plan should be consistent with those plans.
  - **Retain native vegetation wherever possible and plant local native plants in Council plantings.** Implementation might require preparation or alteration of Council policy or guidelines regarding remnant vegetation management and Council plantings. It might also involve development of a vegetation management strategy and actions to implement the *Sustainable Landscaping Strategy* (North Metro Catchment Group Inc. 2006).
  - **Review stormwater management infrastructure** for quantity management and quality treatment effectiveness. See Chapters 7 and 9 for more information.
    - Develop a program for planned inspection and condition monitoring of infrastructure, including a system for reporting monitored issues, such as localised flooding or mosquito breeding. This will allow for maintenance to occur when the ‘need arises’, rather than conducting maintenance on a timed basis.
    - Review infrastructure for quantity capacity (this will require modelling) and water quality treatment effectiveness where this detailed information does not exist.
    - Include data about infrastructure that have been identified as requiring retrofitting.
    - Develop a system of data management. For example, develop an asset/infrastructure maintenance database.
  - Development and implementation of an **asset/infrastructure management program** that is costed (so that projects can be budgeted) and includes an action timeline. The program should include construction and maintenance of local government roads, carparks, pavements, premises/buildings, vehicles, gardens/reserves and stormwater management infrastructure (e.g. sumps, soakwells, drains, gully pits, etc.). This also includes maintenance activities such as road/pavement sweeping; side entry pit education; and fertilisation, plant selection and maintenance in streetscapes and parks (e.g. prepare and implement a parks and reserves management plan). Pollutant hotspots (e.g. side entry pits located at the bottom of hills) should be identified so that they are added to a program for more regular inspection and maintenance. The program should include provision for convenient updating of infrastructure records, preferably an electronic system. A stormwater infrastructure register should be established. New infrastructure would be registered on the database as part of the development approval process. This would help local government monitor what is currently installed and predict future local government maintenance requirements. Asset management programs should also be prepared by other infrastructure providers, such as Main Roads Western Australia and Water Corporation. See Section 2.2 of Chapter 7 for more information.

- **Retrofitting** stormwater infrastructure and catchments to implement treatment trains, to improve stormwater infrastructure performance, to integrate stormwater infrastructure within the urban landscape (e.g. integrated within public open space, rather than installed within fenced-off areas), to reduce public health/safety risks, or to improve stormwater quality treatment. For example: Retrofit X drain to create a vegetated swale within the buffer of X water body. See Chapter 6 for more information about retrofitting.
- Recommend which **local government policies, processes and planning instruments** require amendment. Development Control Plans/Town Planning Schemes/Design Guidelines/Local Planning Strategies and Policies might require amendment (or production) to address stormwater management and to ensure that best practice is implemented in new developments. This might also require internal local government development assessment and approvals processes to be amended to incorporate improved stormwater management. There should be a clear process for integrating stormwater quantity and quality management practices within the local government processes, as they are often managed separately and water quality management often involves less obvious stormwater management issues (such as road/pavement construction and maintenance, and street tree selection and maintenance). This could also include working with other stakeholders (such as other local governments, State government agencies and regional NRM groups) on the preparation of catchment or sub-catchment integrated catchment management plans.
- Investigate opportunities for potential **stormwater reuse** (as a water source) for systems that currently discharge directly to the coast or to estuaries, subject to the receiving water bodies receiving their ecological water requirements.
- **Improve coordination/communication arrangements**, including improving coordination and communication internally between different sections of the local government (e.g. planning, environmental health and engineering sections), and between local government and external stakeholders. Identification of deficiencies will form the basis for the formulation of management strategies to guide local government. For example, Glenorchy City Council (Tasmania) established a Stormwater Management Coordinating Committee where officers from different sections (e.g. planning, environmental health and road and hydraulics engineering) met regularly to coordinate stormwater and waterway management (Derwent Estuary Program 2005). The City of Stirling (WA) has formed a similar group. As discussed in Chapter 7, the section managing the local government's stormwater program should be able to draw upon a wide range of skills to implement the program, including skills in town planning, law, civil engineering, community consultation, marketing, environmental management, psychology and statistics. Using the philosophy of 'adaptive environmental management', stormwater managers need to be prepared to engage in responsible risk-taking, leading to improved understanding, program modification and ultimately better outcomes. A culture of responsible risk-taking within the organisation typically requires strong leadership and continual reinforcement.
- **Undertake education/capacity building projects.** A capacity building project should target activities that are a known significant risk to the management of stormwater and receiving water bodies. Many activities cause environmental harm, so the limited resources should be directed at practices that will reduce risk. Industry capacity building programs could be undertaken (e.g. Motor Trade Association of Western Australia's Green Stamp Program <<http://www.mtaw.com.au>>) – either forming a partnership with an existing program, or working with the relevant agencies, industry associations and NRM/catchment groups to develop a program. Capacity building programs could be used to address risks from mobile activities. Education projects could include activities such as installation of local government demonstration sites (e.g. catchment-friendly gardens). See Chapters 7 and 8 for more information on developing education programs.
- **Regulation and enforcement** applies to enforcement of controls on construction sites, pollution offences, etc. through the use of Unauthorised Discharge Regulations 2004. See Sections 2.4.2 and 2.4.3 of Chapter 7 for more information.

- **Emergency/pollution response.** For example, review local government and Main Roads Western Australia emergency response plans (ensure that waterways, wetlands, open drains/living streams, stormwater detention/retention areas and public drinking water source reservoirs and bores are shown on maps/datasets that should be used during emergency responses).
- **Litter and gross pollutants.** Implement a carpark, road and pavement sweeping program. Install adequate (type and number) litter bins at litter hotspots and have an emptying schedule. Undertake litter cleanup days and litter prevention education. Install litter traps (as a back-up to all of the other actions that must be undertaken) at runoff points from litter hotspots (e.g. within carparks of commercial areas such as shopping centres) and have a maintenance program to ensure they do not become pollution sources. Installing numerous smaller litter traps throughout the catchment (close to the pollution sources) reduces the risks from overflowing and litter biodegradation compared to relying on large litter traps placed at outfalls to receiving water bodies. See Sections 2.2.3 and 2.2.4 of Chapter 7 for information on litter management strategies and Chapter 9 for information on structural (e.g. gross pollutant traps) litter treatment options.
- **Pollution sources.** Include specific actions (i.e. non-structural controls) or structural devices that should be implemented to address specific pollution sources, particularly in priority sub-catchments. For example, conduct further investigation of pollution sources, such as identifying and addressing industrial/commercial sites discharging directly into stormwater drains, sumps and basins. See Chapters 7, 8 and 9 for more information.
- **Document stormwater management requirements for new developments.** These can be included in local government documents such as Development Control Policies.
- **Establish management targets that could include targets for water quality and quantity.**
- **Establish a monitoring and evaluation plan** to assess if the stormwater management plan is being implemented and if the actions are resulting in measurable change. See Section 5.15 and Chapter 10.

Detailed examples of management actions can be found in the following reference:

Derwent Estuary Program 2005, *A Model Stormwater Management Plan for Hobart Regional Councils – a Focus on the New Town Rivulet Catchment*, Derwent Estuary Program, DPIWE, Tasmania. Available from: <<http://www.derwentriver.tas.gov.au>>.

#### **Checklist – Management actions**

- Management actions that are clearly linked to priority management issues have been identified.

## 5.12 Prepare an implementation plan

The stormwater management plan should include action cost estimates and how actions will be funded. The plan should provide indicative costing for each action or program (if the actions can be grouped into programs) as this will be useful for planning and budgeting works. These issues can be identified in an implementation plan, which should be included in the stormwater management plan.

The implementation plan should clearly define who is responsible for implementing actions and include an implementation timeline. Table 6 provides an example of the structure of an implementation plan table. Note: An actual implementation plan would contain more specific information.

If a stormwater management plan has actions for other agencies/groups, there should be a formalised agreement or partnership arrangement with the other agencies/groups regarding implementation of the recommendations. This agreement or partnership arrangement should be prepared while the implementation plan is developed.

**Table 6. Example structure of an implementation plan table**

Threat	Value	Management Action	Estimated cost		Responsibility	Timeline	KPIs
			Capital	Ongoing			
Inadequate maintenance of stormwater devices	Aquatic habitat	Review stormwater infrastructure for quantity management and quality treatment effectiveness.		xxx	Local government, Water Corporation and Main Roads WA.	2007	Stormwater infrastructure review completed.
	Property/ infrastructure	Develop and use electronic infrastructure management program.		xxx	Local government.	2007, then ongoing.	Infrastructure management program developed and implemented.
Surface runoff flow modification	Aquatic habitat Property/ infrastructure	Install infiltration systems (e.g. pervious paving, soakwells and swales).	xxx	xxx	Local government, Main Roads WA, developers and landowners.	2007, then ongoing.	Number of infiltration systems installed.
		Introduce stormwater use systems (e.g. rainwater tanks).	xxx	xxx	Local government and landowners.	2008, then ongoing.	Number of Council stormwater use systems installed.
		Identify impervious surfaces that can be replaced with pervious surfaces.		xxx	Local government.	2008, then ongoing.	Identification and documentation of impervious surfaces suitable for replacement.
		Replace impervious surfaces with pervious surfaces.	xxx	xxx	Local government.	2009, then ongoing.	Number of impervious areas replaced with pervious surfaces.
		Replace direct discharge into water bodies (e.g. via pipes) with overland flow systems on a prioritised basis.	xxx	xxx	Local government, Water Corporation and Main Roads WA.	2008, then ongoing.	Number of direct discharge systems replaced with overland flow systems.
Etc.							

The implementation plan will also need to include a performance monitoring and review program. It is recommended the performance monitoring and review program be developed in the planning phase of the project. For example, Key Performance Indicators (KPIs) or similar measurement tools can be used. See the *Draft Herdsman Lake Integrated Catchment Management Plan* (North Metro Conservation Group Inc. 2007) for example KPIs. See Section 5.15 for more information.

#### **Checklist – Implementation plan**

- Responsibilities for implementation of management actions have been agreed.
- An implementation plan has been prepared.

### 5.13 Produce Stormwater Management Plan documents

It is recommended that the Stormwater Management Plan be produced in two volumes. The first volume should contain a summary of the stormwater management plan, its management actions, the implementation plan and figures. Further details on the process and supporting documentation should be in the second volume.

A draft plan should be prepared for review and comment by stakeholders, including the Project Steering Committee and Project Working Group.

The final plan should be referred to project partners and the local government for review and endorsement, including adoption by Council.

The final plan should be available for public access, on the local government or regional NRM group website and in copies held in the Council library.

Table 7 provides an example layout and contents of a stormwater management plan.

The following plans have been prepared in Western Australia, which can be reviewed as stormwater management plan examples:

- *City of South Perth Integrated Catchment Management Plan* (JDA Consultant Hydrologists & Ecoscape 2004). Available via <<http://www.southperth.wa.gov.au>> (search for ‘catchment management plan’).
- *Stormwater Management Plan, Town of Victoria Park* (URS 2005). Available by contacting the Town of Victoria Park 9311 8111 or <[admin@vicpark.wa.gov.au](mailto:admin@vicpark.wa.gov.au)>.
- *Western Suburbs Regional Organisation of Councils – Regional Strategy for Management of Stormwater Quality* (JDA Consultant Hydrologists 2002). Available by contacting JDA Consultant Hydrologists on 9388 2436 or WESROC on 9387 0953.

#### **Checklist – Stormwater management plan**

- A draft plan, preferably in two volumes (with extra details and supporting documentation included in volume two), has been prepared.
- A draft plan has been submitted to stakeholders for review and comment.
- The plan has been finalised and made available for public access.

**Table 7. Example layout and contents of a stormwater management plan**

<b>Layout</b>	<b>Contents</b>
Title Page	Provide the title, date and authors.
Acknowledgments	Acknowledge individuals, groups and organisations for assistance, support or funding provided for the project.
Contents	Contents page.
Glossary	Include explanations of terminology used in the plan. Lists of abbreviations and acronyms (if used) and their meanings should be included.
List of Tables	
List of Figures	
Management Plan Recommendations	List the management plan recommendations (such as when the plan should be reviewed) and the management actions.
Summary	Provide a summary of the intent and major findings of the plan.
Introduction	Sections likely to be included could be: a background to the study; location of the study area; scope of the plan; objectives of the plan; and key definitions. See Sections 5.3.1 – 5.3.3 for information to include.
Catchment Context	This section places the plan in the context of the catchment and describes the relationship between the catchment and stormwater management. It should include a description of the link between the plan and other strategies, plans and relevant legislation. See Sections 5.3.3, 5.3.4, 5.4 and 5.4.1.
Approach	Explain the plan preparation process. This may include a description of the methods employed for information collection, stakeholder consultation, prioritisation assessment and management strategy determination. See Sections 5.1, 5.2, 5.8, 5.9 and 5.10.
Sub-catchments	Explain how sub-catchments were delineated and provide a figure showing the sub-catchment locations. See Section 5.3.4.
Study Area Characteristics	This should include information on: climate; geology, soils, topography; wetlands; waterways; groundwater; surface drainage (e.g. floodplains); surface water and groundwater quality; remnant vegetation; fauna; and historical and existing land use. See Sections 5.4.1 and 5.4.2.
Existing Stormwater Management Practices and Processes	Review: stormwater management devices; catchment hydrology and flow paths of minor and major rainfall events; planning documents; maintenance practices; capacity building (including staff training and education programs); regulation and enforcement; and emergency/pollution response. See Section 5.4.3.
Ecological, Social/Cultural and Economic Values	Identify ecological, social/cultural and economic values of the local and receiving environments and how these values were determined. The process for values identification is in Section 5.5.
Threats	Identify threats to the local or receiving environments and how these threats were determined. See Section 5.6 for the process of determining threats.
Management Objectives	Document the vision and short-term and long-term objectives. Section 5.7 describes the establishment of visions and objectives and provides example objectives.
Priority Management Issues	Document the priority management issues. See Section 5.8 for more information.

Layout	Contents
Management Actions	This section should state the proposed management actions to address the priority management issues. The process for determining actions is in Sections 5.8, 5.9 and 5.10. Example management actions are provided in Section 5.11.
Implementation Plan	Include an implementation plan documenting how the stormwater management plan will be implemented. See Section 5.12 for the process for preparing an implementation plan and Section 5.14 for how to implement the stormwater management plan.
Performance Monitoring and Review	Document how the stormwater management plan will be monitored and reviewed. See Section 5.15 for more information.
Conclusions and Recommendations	Include a summary of the catchment characteristics. Conclude with the major issues and opportunities and the recommendations of the plan.
References	
Appendices	Extra details such as questionnaire results, calculation results, etc.

### 5.13.1 Summary of checklists for preparation of a stormwater management plan

- Aim and scope of the plan have been established.
- Stakeholders' roles and responsibilities are understood.
- Stakeholders are committed to involvement in preparation of the plan (including provision of requested data, where relevant) and to implementation of the plan (where applicable).
- Stakeholders understand the nature of stormwater impacts and management.
- Key project objectives are clearly defined and understood.
- Study area boundary and sub-catchments have been determined.
- Available information and data has been requested.
- The timetable for the study has been confirmed by relevant stakeholders (e.g. the Project Steering Committee and the Project Working Group).
- Field investigations have been undertaken.
- Interviews and consultation with relevant local government officers and other stakeholders have been undertaken.
- All relevant information and data has been obtained, reviewed and catalogued (preferably in a GIS format).
- Maps of wetlands, waterways, Public Drinking Water Source Areas, remnant vegetation, the stormwater/drainage system and land uses have been prepared.
- Database (preferably GIS) of stormwater device management has been developed, which should include who is responsible for maintenance of the device.
- Current practices and processes have been reviewed, including the planning scheme, supporting documentation, the approval process, maintenance practices and the nature of coordination and resourcing.

- Values and threats have been identified, assessed and documented.
- Significance ratings of values and threats have been reviewed and endorsed by the Project Working Group and Project Steering Committee.
- A vision and short-term and long-term objectives have been defined.
- Outcomes for performance monitoring and evaluation have been identified.
- A prioritisation process has been established.
- Priority management issues have been identified.
- A priority management issues paper has been prepared.
- A priority management issues paper has been sent to Project Working Group, Project Steering Committee, senior local government officers and Councillors.
- The Project Working Group and Project Steering Committee have reviewed and endorsed the priority management issues. These priority management issues should form the basis for developing management actions.
- A range of structural and non-structural control options that would address the priority management issues have been identified.
- Management actions that are clearly linked to priority management issues have been identified.
- Responsibilities for implementation of management actions have been agreed.
- An implementation plan has been prepared.
- A draft plan, preferably in two volumes (with extra details and supporting documentation included in volume two), has been prepared.
- A draft plan has been submitted to stakeholders for review and comment.
- The plan has been finalised and made available for public access.

## 5.14 Stormwater management plan implementation

To assist project implementation, a project tracking system could be created to follow the status of individual projects from concept to completion. The purpose is to store essential data on the design, construction, maintenance and performance of individual projects. The tracking system should be designed to store data that is needed to brief key managers and stakeholders, such as the current status of all projects. As discussed in Center for Watershed Protection (2005), three tasks are used to create a project tracking system:

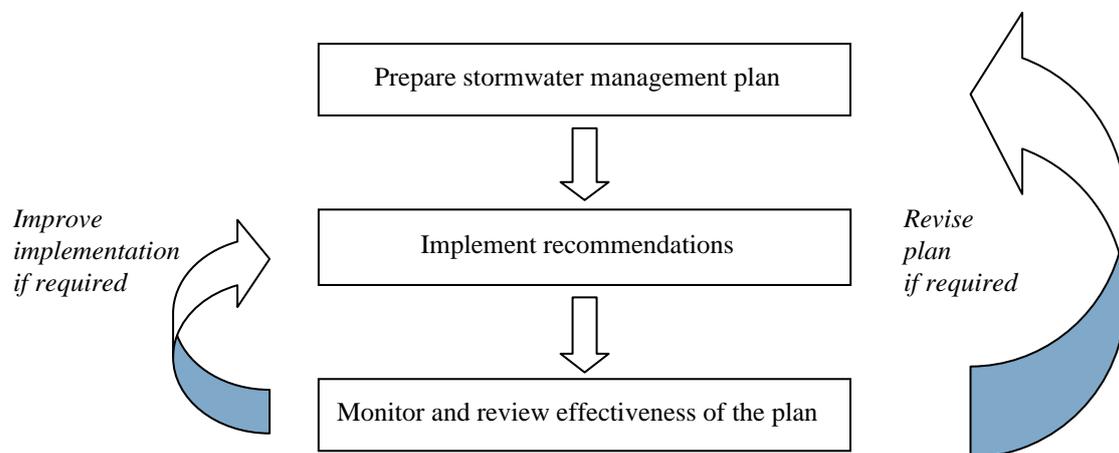
1. **Determine key project management information to track.** This can include information on cost, location, type of device/project, installation date, inspection schedule and maintenance performed.
2. **Continuously update project information into tracking system.** The tracking system should be updated several times per year to include new project information.
3. **Periodically report on status of project implementation.** The tracking system should be reviewed at least once a year to make sure project data is current. A short report should be prepared that summarises the status of implementation, with an emphasis on project successes and failures that can be used to adjust future project implementation.

A local government implementation team should be formed. This team should include operational (e.g. maintenance staff) and management staff, to ensure that practical implementation issues are considered, as well as ensuring there is upper management support and sufficient funding for projects. The implementation team might include the same people as the local government team formed for development of the plan.

An external group should be involved in the review of implementation of the stormwater management plan. It is recommended that a group be created that meets regularly (e.g. quarterly or bi-annually) to plot progress of the plan. Public reporting can include both a progress report on the plan's implementation and reporting on the outcomes achieved by the plan's actions (ARMCANZ & ANZECC 2000).

## 5.15 Performance monitoring and review

Stormwater management plans should be viewed as live documents that are actively consulted, reviewed and revised. Implementation of the actions should be reviewed annually. The timing of the annual review should allow for review outcomes to be incorporated within budget planning cycles. The stormwater management plan should also specify when the whole plan should be reviewed (e.g. in 5 years).



Specific milestones, objectives and outcomes should be identified in the stormwater management plan, which enable monitoring and review of the implementation process. The following could be monitored:

- If actions have been implemented.
- Changes in stormwater management practices.
- Reductions in stormwater threats.
- Changes in stormwater quality.
- Changes in the quality/health of receiving water bodies.
- Changing or new priorities.

Actions should be reviewed to determine if they require alteration due to acquisition of further information or recognition that the original actions were not entirely appropriate (Water and Rivers Commission 2001).

The effectiveness of the plan could be assessed by asking the following evaluation questions (adapted from Water and Rivers Commission 2001):

- What worked in relation to helping achieve the objectives?
- What did not work?
- Were the project objectives met?
- Did anything change as a result of the action?
- Were there any unexpected results from the plan?

- What would be done differently next time?
- What evidence is there that the plan made a difference?
- Have people changed their management practices?
- Are the problem areas getting better?
- Have community values / expectations changed?

See Chapter 10 for information about how to monitor and evaluate structural and non-structural stormwater management devices.

## 6 References

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Center for Watershed Protection 2005, *Urban Subwatershed Restoration Manual No. 2: Methods to Develop Restoration Plans for Small Urban Watersheds*, Version 2.0, Center for Watershed Protection, Washington, United States of America. Available via <<http://www.stormwatercenter.net>>.

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Department of Environment and Conservation (in preparation), *A Guide to Managing and Restoring Wetlands in Western Australia*, Department of Environment and Conservation, Perth, Western Australia.

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- Keating, C. 2003, *Facilitation Toolkit: a Practical Guide for Working more Effectively with People and Groups*, Department of Environmental Protection, Water and Rivers Commission and Department of Conservation and Land Management, Perth, Western Australia. Available via <<http://community.environment.wa.gov.au>>, go to Community/Community Involvement. Note: this information will eventually be located on <<http://www.dec.wa.gov.au>>.
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- Water and Rivers Commission 2001, *Planning for Waterways Management: Guidelines for Preparing a River Action Plan*, River Restoration Report No. RR14, Water and Rivers Commission, Perth, Western Australia. Available via <<http://www.water.wa.gov.au>>, go to Water Management/Waterways/River Restoration.

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## 7 Further reading and useful websites

### Planning:

Center for Watershed Protection 2005, *Urban Subwatershed Restoration Manual No. 2: Methods to Develop Restoration Plans for Small Urban Watersheds, Version 2.0*, Center for Watershed Protection, United States of America. Available via <<http://www.cwp.org>>.

Derwent Estuary Program 2005, *A Model Stormwater Management Plan for Hobart Regional Councils – a Focus on the New Town Rivulet Catchment*, Derwent Estuary Program, DPIWE, Tasmania. Available via <<http://www.derwentriver.tas.gov.au>>. This provides detailed information about the process of preparing an example stormwater management plan (including questionnaires used to survey stakeholders).

Environmental Protection Authority 2005, *Environmental Guidance for Planning and Development, Draft Guidance Statement No. 33*, Environmental Protection Authority, Perth, Western Australia. Available via <<http://www.epa.wa.gov.au>>.

Queensland EPA March 2001, *Model Urban Stormwater Quality Management Plans and Guideline: Prepared to Assist Local Governments Meet their Obligation under the EP (Water) Policy 1997*, Local Government Unit, Environmental Operations Division, EPA, Brisbane, Queensland.

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### Consultation:

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Department of Environment 2003, *Community Involvement Framework*, Department of Environment, Perth, Western Australia. Available via <<http://community.environment.wa.gov.au>>, go to Community / Community Involvement. Note: this information will eventually be located on <<http://www.dec.wa.gov.au>>.

Keating, C. 2003, *Facilitation toolkit: a practical guide for working more effectively with people and groups*, Department of Environmental Protection, Water and Rivers Commission and Department of Conservation and Land Management, Perth, Western Australia. Available via <<http://community.environment.wa.gov.au>>, go to Community / Community Involvement. Note: this information will eventually be located on <<http://www.dec.wa.gov.au>>.

## Websites:

Bureau of Meteorology website: <<http://www.bom.gov.au>>.

Bush Forever web page via the Western Australian Planning Commission's website: <<http://www.wapc.wa.gov.au>>, search for Bush Forever.

Department of Agriculture website: <<http://www.agric.wa.gov.au>>.

Department of Environment and Conservation website: <<http://www.dec.wa.gov.au>>.

Department of Environment and Conservation's Florabase website: <<http://florabase.dec.wa.gov.au>>.

Department of Water website: <<http://www.water.wa.gov.au>>.

Landgate (formerly Department of Land Information) website: <<http://www.landgate.wa.gov.au>>.

Urbanwater.info website: <<http://www.urbanwater.info>>.

SLIP website: <<https://www2.landgate.wa.gov.au/slip/portal/home/home.html>>.

WALIS website: <<http://www.walis.wa.gov.au>> for general queries about spatial information.

WALGA website: <<http://www.walga.asn.au>>.

Western Australian Museum's Faunabase website: <<http://www.museum.wa.gov.au/faunabase>>.

## 8 Acronyms

ARI	Average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ANZECC	Australian and New Zealand Environment and Conservation Council
GIS	Geographic information system
ICLEI	Local Governments for Sustainability Australia/New Zealand
NRM	Natural resource management
SLIP	Shared Land Information Platform
WALGA	Western Australian Local Government Association
WALIS	Western Australian Land Information System

## Appendix A – Example process for defining priority management issues

Some factors to be considered are:

- Risk assessment needs to determine if a risk is inherent (i.e. based on general risks from that type of activity) or managed (e.g. site management practices may reduce the risk – however, managed risk can only be determined if information on management actions for that site is available).
- Viv Read & Associates (2005) recommended the following regarding risk assessment:
  - The scale of the current risk (providing a sense of proportion between each of the threat types).
  - The locations of highest risk.
  - The trend of the risk (increasing, decreasing or stable).
  - The estimated time to full impact (or cessation) of the risk.
  - The responsiveness to intervention (works to reduce the risk).

The following process has been copied from the CSIRO (2000) *Urban Stormwater: Best Practice Environmental Management Guidelines*. However, it is a very complicated process that has most value in catchments that are complex and where obviously high priority threats are already undergoing management.

The approach adopted for prioritising stormwater management issues is based on risk assessment. Risk assessment involves estimating potential risks from stormwater threats to local and receiving environment values. The assessment should consider the magnitude of each threat and value, as confirmed by the Project Working Group, and the sensitivity of a particular value to a given threat.

Within each sub-catchment, each threat type is assigned a significance rating of Low, Moderate, High or Very High. These qualitative ratings will be translated to a quantitative rating on a 1 to 4 scale as part of the risk assessment. In arriving at a significance rating, consideration should be given to the quantity of pollutant load generated and the frequency of occurrence. Discussions should take place with key people in local government, Department of Water, Department of Environment and Conservation, the catchment management group, Water Corporation and others. It will be necessary to justify and explain the basis for assigning a rating to a particular threat. Proposed significance ratings will be reviewed and endorsed by the Project Working Group and Project Steering Committee before their final adoption.

Risk magnitudes should be calculated for all combinations of values and threats within each sub-catchment by assigning a numerical score for each qualitative rating (i.e. 1 = Low, 2 = Moderate, 3 = High and 4 = Very High). A sensitivity score from 1 to 4 is also assigned depending on the influence of the threat on the specific value. Values that are very highly sensitive to a given threat should be assigned a score of 4, while values that are not sensitive should be assigned a score of 1. For example, if visual amenity in a specific sub-catchment is highly ranked, it will be sensitive to stormwater threats that produce pollutants that directly impact on aesthetics of the receiving water body (e.g. litter). Alternatively, a particular stormwater threat within a sub-catchment may occur downstream of a specific value. Therefore, the value will not be sensitive to the threat.

Using this approach, the risk magnitude for each combination of value and threat should be calculated as follows:

$$\text{Risk} = \text{Value} \times \text{Threat} \times \text{Sensitivity}$$

For each sub-catchment, the combination of specific threats, values and their sensitivities can be expressed as a matrix. Figure 5 provides an example of a risk matrix for a sub-catchment, where sensitivity is shown

in the top right corner of each risk cell. Risk cells have been shaded in accordance with magnitude, with darker cells representing higher risks.

By listing specific risks from all sub-catchments in order of their magnitude, management priorities can be defined for different threats and locations across the study area. The identification of management priorities from this list should focus on specific risks that generate the highest risk magnitude (e.g. the top 25 risks).

City of Hume - Lower Moonee Ponds Creek			Stormwater Threats								
			Waterway Degradation	Residential Runoff	Industrial Runoff	Commercial Runoff	Arterial Road Runoff	Developing Industrial	Developing Residential	Building Site Runoff (Lot Scale)	
			3	2	3	4	4	3	2	2	
Receiving Values	Environmental	In-Stream Habitat	1	9	6	12	8	16	12	8	8
		Riparian Flora/Habitat	3	9	6	9	12	12	9	6	6
	Cultural	European Heritage	3	18	6	9	12	12	9	6	6
		Aboriginal Heritage	4	36	8	12	16	16	12	8	8
	Amenity	Recreational	3	18	12	18	24	24	18	12	18
		Visual/Landscape	2	18	12	18	24	24	12	8	12
	Stormwater	Flood Protection & Conveyance	1	3	6	6	8	4	3	2	2
		Water Quality Treatment	1	9	6	9	8	8	9	6	4
	Economic	Tourism	3	18	12	18	24	24	18	12	12
		Property Value	2	12	8	12	16	8	12	8	8

Sensitivity = 2

Threat(2) x Value(2)  
x Sensitivity(2)  
= Risk(8)

Figure 5. Example risk matrix. (Copied from WBM Oceanics Australia 2000, cited in CSIRO 2000.)

Stormwater  
Management  
Manual for  
Western Australia

Retrofitting **6**



Department of  
Environment



*Cover photograph: Liege Street Constructed Wetland, Cannington. (Source: Tom Atkinson, SERCUL)*

# Stormwater Management Manual for Western Australia

## 6 Retrofitting

Prepared by Antonietta Torre, Emma Monk and Lisa Chalmers, Department of Environment,  
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Consultation and guidance from the Stormwater Working Team



Department of  
Environment



February 2006

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### We welcome your feedback

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# Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the *State Water Strategy* (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Catchment Management Branch of the Department of Environment.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

The aim of this chapter is to explain the issues to be addressed when retrofitting existing urban developments and individual stormwater management devices in urban areas throughout Western Australia.

Retrofitting is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area.

Retrofitting can occur at the lot, block/neighbourhood or catchment scale. Redeveloping or upgrading existing developments and infrastructure particularly presents opportunities for retrofitting.

Retrofitting can achieve the following multiple objectives:

- Reduce flooding risk
- Improve public health and safety
- Improve water quality
- Restore and/or conserve environmental condition
- Create more attractive and liveable neighbourhoods
- Enhance the cultural values of the urban water landscape
- Improve use of open space and enhance recreational opportunities
- Improve community environmental awareness
- Increase cost effectiveness
- Demonstrate best management practices
- Utilise stormwater as a valuable resource to reduce potable water use

This chapter provides brief descriptions of several best management practices that are particularly relevant to retrofitting. It also provides case studies and examples that demonstrate how to undertake retrofitting projects.

The *Decision Process for Stormwater Management in WA* (Department of Environment and Swan River Trust, 2005) should be referred to when planning retrofitting projects. A flow chart showing the simplified design process for retrofitting projects is provided on page 13.

# 1 Introduction

## 1.1 Aim of the retrofitting chapter

The aim of this chapter is to explain the issues to be addressed when retrofitting existing urban developments and individual stormwater management devices in urban areas throughout Western Australia.

## 1.2 The target audiences

This chapter has been written primarily for the following audiences:

- Local and State government agencies with responsibilities and interests in stormwater management (such as Department of Environment, Water Corporation, Main Roads and Department for Planning and Infrastructure) who may be upgrading existing stormwater management systems, developing catchment/regional management strategies, or assessing urban redevelopment proposals.
- Developers and their consultants who may develop proposals for urban redevelopment.
- Community groups or community members who may develop proposals to upgrade existing stormwater management systems, or develop catchment management plans.

## 1.3 Terminology and key definitions

**Average Recurrence Interval (ARI)** is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration.

**Detention** is defined as the process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design ARI event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.

**Non-structural controls** are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments.

**Receiving water bodies** include waterways, wetlands, groundwater and coastal marine areas.

**Retention** is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation. Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design ARI event.

**Retrofitting** is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area.

**Source controls** are non-structural or structural best management practices to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source and protect receiving environments.

**Structural controls** are permanent, engineered devices implemented to control, treat or prevent stormwater pollution and/or to reduce the volume of stormwater requiring management.

**Urban development** is residential, rural-residential, commercial and industrial development.

## 1.4 Background

Most urban<sup>1</sup> areas in Western Australia have traditional (predominantly piped and drained) drainage systems to reduce the risk of flooding by expediting the removal of stormwater from developed areas and lowering groundwater tables in some areas. In existing urban areas, there is the opportunity to achieve more than the single outcome of flood mitigation. There is an increasing awareness of the need to manage water quality in stormwater management systems and an increasing realisation of the potential role of these systems as important environmental assets. 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. For much of Western Australia's urban areas, traditional stormwater infrastructure is nearing the end of its useful life and there is now the opportunity to replace these systems with the new multi-functional approaches to stormwater management discussed in this chapter.

To maximise the benefits of and opportunity for retrofitting, a whole of catchment planning approach is required. Planning for retrofitting should examine opportunities to improve management of stormwater at-source, in-transit and at end-of-pipe/catchment. Implementing numerous small-scale retrofit projects throughout the catchment can have a major overall impact on the health of receiving water bodies<sup>2</sup>. The key is to ensure that pollutant generation is minimised or prevented, pollutant transport pathways are 'disconnected', or pollutants are treated or captured before they reach the main drain or receiving water body. The National Water Quality Management Strategy (NWQMS) promotes distributed, at-source control of both stormwater quantity and quality (ARMCANZ and ANZECC, 2000). The role of at-source controls is paramount to the success of retrofitting. Preventing pollution and reducing the volume of stormwater requiring treatment are essential components of best practice stormwater management. Information on pollution prevention practices and community education for stormwater management is provided in Chapters 7 and 8, respectively.

The focus on source controls does not eliminate the need for in-system and end-of-pipe/catchment measures. End-of-pipe/catchment treatment measures may still be required in cases of high pollutant loading or contaminated soil or groundwater leading to residual impacts that cannot be cost-effectively mitigated by source or near-source controls. End-of-pipe/catchment techniques are also required in specific situations, such as where there are no retrofit opportunities elsewhere in the system, or treatment of water quality is required in the period before the source controls and treatment train measures take effect. This is particularly relevant for retrofitted systems where there may be some years before the accumulated contaminant sources in the drainage and groundwater systems are controlled.

Best practice is likely to include a combination of at-source, in-system and end-of-pipe/catchment measures. The guiding principle for retrofitting is the treatment train approach. A treatment train approach involves the implementation of a combination of different methods in sequence or concurrently to achieve the best management of stormwater. Different techniques remove different types of pollutants and a number of techniques are often required to treat the range of pollutants that may be present in stormwater. The treatment train approach provides a multiple barrier to protect water quality. This approach also reduces the loading on individual stormwater management devices and increases the potential for stormwater management devices to function effectively, even during flooding events.

Retrofitting a traditional drainage system provides the opportunity to reduce changes to the natural water balance caused by development. The two main aims of retrofitting traditionally developed urban areas are to (adapted from Argue, 2004, and Department of Environment, 2004):

---

<sup>1</sup> Urban development is residential, rural-residential, commercial and industrial development.

<sup>2</sup> Receiving water bodies include waterways, wetlands, groundwater and coastal marine areas.

- Re-establish the total water balance within development areas relative to the pre-development conditions by reducing runoff through increased stormwater retention.
- Restore natural drainage systems as close as practicable to the pre-development state.

Retrofitting includes increasing temporary storage of stormwater, on-site reuse of water and increasing infiltration, for example by reducing the area of impervious surfaces. Impervious surfaces (such as bituminised and paved areas) that are directly connected to water bodies by stormwater pipes and drains can act as highways for runoff and potential pollutant transport. Impervious surfaces that convey runoff directly into water bodies (e.g. carparks draining directly to the street's drainage system that then discharges directly into a water body) can be disconnected and stormwater directed instead into permeable systems, such as soakwells, bioretention areas, swales, garden beds and vegetated open spaces, or the impervious surfaces can be replaced with pervious paving. Best practice stormwater management should retain<sup>3</sup> and detain<sup>4</sup> runoff and aim to infiltrate where possible. Retaining and detaining runoff reduces the impact on downstream water bodies (e.g. reduces erosion of waterways and drowning of wetland vegetation) and attenuates runoff peaks for flood protection of downstream areas.

It is important to note that pollution reduction is a primary objective for managing stormwater runoff from low intensity rainfall events and 'first flush' storm events. For stormwater flows from high intensity rainfall events, the primary objective remains to reduce flooding of buildings, infrastructure and other assets. 'First flush' describes situations when pollutants (e.g. sediments) that have accumulated on impervious surfaces are transported at the beginning of a rainfall event. This results in high pollution concentrations at the start of the runoff hydrograph, reducing to lower levels before the flood peak occurs (Argue, 2004). In particular, late dry/early wet season rains following long dry periods create high pollutant loads during runoff, where large volumes of materials such as litter, sediment and leaves that have accumulated on impervious surfaces are washed into the drainage system. This material can pollute receiving water bodies and result in impacts such as algal blooms and fish kills. Subsequent flow events effectively run off 'cleaned' impervious areas and generally do not carry high concentrations of pollutants.

Detailed information on the guiding principles, objectives and approaches for stormwater management is provided in Chapter 2.

## 2 What is retrofitting?

Retrofitting is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area. These techniques include increasing storage and infiltration areas to reduce peak flows and using vegetated systems to facilitate pollutant filtration. Retrofitting can include both structural<sup>5</sup> techniques, such as installing a soakwell, and non-structural<sup>6</sup> techniques, such as implementing erosion and sediment controls on building sites. The opportunity to improve on a traditional drainage system often arises during the redevelopment of older areas, or when the community initiates projects to improve the neighbourhood environment.

<sup>3</sup> Retention is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation. Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design Average Recurrence Interval event.

<sup>4</sup> Detention is defined as the process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design Average Recurrence Interval event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.

<sup>5</sup> Structural stormwater best management practices are permanent, engineered devices implemented to control, treat, or prevent stormwater pollution and/or to reduce the volume of stormwater requiring management. See Chapter 9 for more information.

<sup>6</sup> Non-structural stormwater best management practices are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments (Taylor and Wong, 2002). See Chapter 7 for more information.

Retrofitting includes techniques implemented at a variety of scales:

1. Lot scale, for example:
  - Maximising opportunities for capture and use of rainfall 'on-site' by techniques such as installing additional soakwells, rainwater tanks or garden bores.
  - Changing gardening practices, such as redesigning gardens to use catchment friendly techniques, e.g. soil amendment, minimising grassed areas and replacing high water and fertiliser using plant species with native (preferably local provenance) plants.
  - Replacing impervious paving with pervious paving.
  - Installing oil water separators in commercial carparks and petrol stations.
2. Block and neighbourhood scale, for example:
  - Removing kerbs from some sections of roads, such as where road runoff can flow into adjacent parkland.
  - Installing infiltration devices (e.g. 'leaky' sumps and gully / side entry pits) within roadways / road reserves.
  - Replacing impervious paving with pervious paving.
3. Catchment scale, for example:
  - Rehabilitating open urban drains or removing sections of sub-surface pipe and allowing surface flow through vegetated swales or 'living streams'.
  - Installing infiltration devices throughout the catchment.

### 3 What will retrofitting achieve?

Retrofitting is intended to maintain or add to the benefits of traditional drainage (i.e. flood protection). The multiple objectives of retrofitting are outlined below.

- ***Reduce flooding risk***

Retrofitting a catchment to increase infiltration and storage capacity, particularly higher in the catchment, prevents rapid collection downstream and results in reduced peak flows and better flood protection for residential areas.

Drain capacity needs to be considered when designing retrofit projects. There may be opportunities to reduce the required drain capacity by managing stormwater at or near source (see Chapters 7 and 9). Oversized open drains provide opportunity for implementing water quality and ecological restoration techniques, such as revegetation and habitat enhancement, without increasing the flood risk. Alternatively, increasing the size of the channel, where space is available, can offset the potential reduction in drain capacity due to revegetation. Regrading the typically steep banks of a trapezoidal drain through terracing or battering to create a gentle bank slope can increase the channel cross-sectional area. The gentle grade (maximum 1 vertical: 4 horizontal) will assist with plant establishment as well as reduce the bank erosion risk. Natural waterways and drains that have been rehabilitated to 'living streams' have floodways that are able to store and convey large flows. Broad, vegetated floodways result in increased storage volume, reduced flow velocities and greater area for infiltration, so that even larger rainfall events can be conveyed with little or no damage to the drainage system or receiving environments. For example, a large flood event that occurred in the retrofitted section of Bannister Creek, Lynwood, resulted in no damage to the restored waterway (see Figures 25a and b in Case Study 7.4).

Increased compensation, storage and infiltration throughout the catchment, as well as improved integration of the stormwater system within public open space, will reduce the flood risk and downstream stormwater capacity requirements. An example is the Town of Victoria Park's stormwater management system outlined in Example 1.

### **Example 1**

The Town of Victoria Park (located in Perth's southern metropolitan area) has developed an alternative method of stormwater management in response to a flooding problem in East Victoria Park. The flooding problem was caused by an existing sump (dry infiltration basin) on Patricia Street being too small for its catchment area. The problem was solved by installing five leach drain systems upstream of the sump to compensate flows. The stormwater is conveyed to a gross pollutant trap by pipes and then flows into the leach drain systems. The stormwater then infiltrates into the shallow aquifer. The Town has identified numerous sump sites within its boundaries with small to medium sized catchments that could be converted into other land uses such as public open space by using the above methodology. The existing sumps are unattractive, fenced-off blocks of land scattered throughout the Town's area.

#### **• *Improve public health and safety***

Steep sided drains present a potential safety risk, particularly to children who play near or attempt to climb into the drain and may fall down the bank. Retrofitting drains to 'living streams' involves reducing the grade of steep banks to a gentle slope and more natural waterway shape. A living stream has stable vegetated banks, diverse habitat and an ability to support a healthy ecosystem (see Section 6.2.9 and Case Study 7.4 for further information). Vegetation or fencing can be used in sections to form a barrier and discourage access to the water. Formalised access points, such as a crossing or riffle, can be used to allow public access to the stream at safer locations.

Retrofitting the drainage system can assist in the control of disease and nuisance vector insects (i.e. mosquitoes and midges) by reducing nutrient and pollution levels in stormwater and receiving water bodies. Shading cools the water, which reduces mosquito and midge numbers. Techniques that reduce the area of stagnant water, for example using flowing streams rather than stagnant pools, will also reduce the opportunity for mosquito breeding. Infiltrating or drawing down the water to prevent pooling for longer than four days will prevent completion of the mosquito larval life cycle. Refer to Chapter 9 for further detail on designing stormwater systems to reduce the risk of mosquitoes and midges.

#### **• *Improve water quality***

Retrofitting works can improve water quality by controlling pollutant inputs at source, reducing the mobilisation and conveyance of pollutants and treating stormwater by trapping or removing pollutants. The issue of water quality is not restricted to the main stormwater channels and receiving water bodies. Many minor tributaries and drains within the catchment can be a major source of pollutants. Historic sources of pollution, such as groundwater contamination seeping into stormwater channels, may continue to impact on water quality. Retrofitting projects need to be implemented in the context of a holistic approach to water management. Catchment management strategies, such as improved management of fertiliser use, are essential to address the problem at-source to improve water quality in the long term. For example, the Swan River Trust's Drainage Nutrient Intervention Program aims to implement on-ground works throughout the Swan-Canning Catchment to strip nutrients from known nutrient enriched drains before discharging into the rivers.

- ***Restore and conserve environmental condition***

One of the aims of retrofitting is to create a stormwater management system that also protects or restores environmental values. Retrofitting projects can incorporate revegetation and restoration of natural habitats (e.g. wetlands, waterways and bushland). Increasing the diversity of habitats in the urban landscape will result in improved biodiversity. Vegetated areas also improve stormwater treatment (e.g. nutrient removal) through increased stormwater filtration.

Retrofitting can increase stormwater infiltration, which recharges the groundwater system. This can help restore groundwater dependent ecosystems, such as some wetlands that are degrading due to declining groundwater levels in response to low rainfall and high groundwater abstraction rates. Many waterways are also degraded due to the installation of dams and reduction in flows. Redirecting clean stormwater to provide environmental flows can potentially improve waterway health.

Infiltration of stormwater and reuse through garden bores can help manage the local water balance, limiting consequential environmental impacts from urban developments. Maintaining the water cycle balance can prevent problems associated with acid sulphate soils, salinity and waterlogging.

Research has shown that waterway biodiversity is significantly impacted by the amount of impervious surfaces directly connected (i.e. through pipes and drains) to waterways and the subsequent poor quality stormwater runoff (Walsh, 2004). Therefore, retrofitting projects that improve stormwater quality and/or ‘disconnect’ impervious surfaces can have positive benefits on the biological health of water bodies. Disconnection can be achieved by ensuring that stormwater does not discharge directly into water bodies (see Figure 1 for an example of direct connection to a wetland). For example, flow could be directed into bioretention systems or soakwells. Retrofitting projects should also aim to remove or rationalise the number of pipe and constructed channel outlets to waterways and wetlands. Outlets should be relocated so that runoff flows overland through vegetation towards waterways and wetlands (see Figure 2).



*Figure 1. Stormwater pipes entering Lake Monger, Wembley. (Photograph: Department of Environment, 2006.)*



*Figure 2. Overland flow towards the Canning River, near Royal Street bridge, Thornlie. (Photograph: Department of Environment, 2006.)*

Techniques to improve storage and infiltration of stormwater in the catchment can reduce the velocity of water entering water bodies. Decreasing the ‘flashiness’ (where water levels rapidly peak and decline) and peak velocities of flows will decrease the potential for erosion of water bodies.

Improving water quality and removing lateral and longitudinal barriers to faunal movement, such as weirs, bunds and concrete banks, will also improve the health and biodiversity of waterways. Artificial drainage channels are often designed to convey large flood events (e.g. 10 year ARI<sup>7</sup> events), resulting in isolation of the floodplain from the waterway and rare floodplain inundation. Many fish species and other aquatic fauna rely on annual flooding of the floodplain for breeding purposes and as a food source.

- ***Create more attractive and liveable neighbourhoods***

Using water sensitive urban design (WSUD) principles to retrofit an area enhances the social and environmental amenity of the urban landscape. Incorporating stormwater systems in public open space, rather than installing them in fenced-off drain/basin reserves, can make developments more desirable and marketable and increase property values. Property values adjacent to retrofitted drainage features, such as living streams and landscaped stormwater features (such as sumps and swales), have been shown to increase due to the increased amenity of the area. Case Study 7.4 discusses restoration works at Bannister Creek (Lynwood) that improved the recreational and aesthetic value of the area. It was estimated that average property values adjacent to the restored creek increased 17% more than properties adjacent to unrestored sections of Bannister Creek (Robert, J., 2004, pers. comm.<sup>8</sup>). Linkages through the landscape can be formed through swales, waterways and riparian vegetation corridors, connecting communities through public open space. For more information, see the latest edition of Western Australian Planning Commission’s *Liveable Neighbourhoods*.

The visual amenity of the urban landscape can be enhanced by increasing the diversity of landforms (see Figure 3). For example, a meandering waterway or swale through parkland can create visual interest in an otherwise flat landscape. Restoring vegetation also improves the aesthetics of the stormwater system. Features of traditional drainage systems are often unaesthetic, consisting of uniform structures that provide little visual relief (such as straight line trapezoidal drains) and hard engineering (such as concrete erosion control mattresses, drop structures and poorly designed pipe outlets to waterways, wetlands and marine areas). These conflict with the natural environment and the landscaping undertaken to enhance public spaces. Retrofitting can result in the removal or enhancement of traditional artificial drainage structures, such as restoring weed infested trapezoidal drains to living streams with native (preferably local provenance) vegetation. Fenced basins / sumps are visually unappealing in public areas and can be enhanced through retrofitting; for example, by reshaping the banks to a gentle slope, revegetating with native (preferably local provenance) plant species and removing barrier fencing. Improving water quality also reduces the occurrence of unsightly and odorous algal blooms.



Figure 3. Ascot Waters ‘amphitheatre’ soakwell, Ascot. (Photograph: Department of Environment, 2003.)

<sup>7</sup>ARI (Average Recurrence Interval) is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration.

<sup>8</sup>Personal communication with Julie Robert, South East Regional Centre for Urban Landcare, 2004, citing information provided by the Real Estate Institute of WA.

- ***Enhance the cultural values of the urban water landscape***

WSUD aims to protect and enhance the cultural values of the urban water landscape. Water and the landscape features it creates are often of spiritual significance and heritage value to Aboriginal people (Water and Rivers Commission, 2002a). Aboriginal sites, protected under the *Aboriginal Heritage Act 1972*, are often associated with water bodies, or may encompass an entire natural feature of the landscape, such as a waterway. Removing artificial barriers to stream flow, such as weirs, and restoring the connectivity of water flow is important in protecting indigenous values associated with waterways. It is important to consult with Aboriginal people so that heritage values and cultural sites can be protected. In particular, works involving excavating or driving objects into the bed and banks of water bodies are a significant issue for Aboriginal people. Aboriginal people are often supportive of water body rehabilitation projects as they also wish to achieve the same outcome of restoring and protecting these systems and maintaining the heritage values of these areas for future generations (Water and Rivers Commission, 2002a).

The Western Australian Planning Commission's *Liveable Neighbourhoods* recommends preserving and enhancing areas of natural or cultural significance, as they contribute to the establishment of a positive sense of place or unique identity for an area. There may be opportunities for natural areas and cultural features to be incorporated into neighbourhood and district parks. Protection and restoration of stream corridors for their cultural values, as well as environmental and recreational values, is recommended (Western Australian Planning Commission, 2004).

- ***Improve use of open space and enhance recreational opportunities***

Multiple use corridors are a feature of WSUD and result in more efficient use of urban land by linking the stormwater management system into landscaped public open space. For example, playing fields can also act as temporary stormwater detention areas and parks can incorporate swales and living streams. Walkways can be integrated with waterways, swales and vegetation corridors to create a passive recreation network. Some traditional drainage systems (e.g. fenced-off drains and sumps such as the compensating basin shown in Figure 4a) can be retrofitted and incorporated into public open space, particularly if the systems are located adjacent to public open space (see Figure 4b).



*Figure 4a. Fenced compensating basin, Redgum Court, Kewdale. (Photograph: Swan River Trust, 2005.)*



*Figure 4b. Park located adjacent to the compensating basin, Redgum Court, Kewdale. (Photograph: Swan River Trust, 2005.)*

Improving water quality also improves the opportunity for water related recreation, such as canoeing and fishing, and decreases the occurrence of algal blooms that present a health risk. Areas like the lower Canning River catchment upstream of the Kent Street Weir (Perth) occasionally experience harmful blue green algal blooms shortly after late summer/early autumn rainfall events. These blooms often occur after long, dry periods when large loads of material and associated nutrients have accumulated on impervious surfaces and this material is then conveyed by stormwater into the Canning River (Swan River Trust and Department of Environment, 2005). Retrofitting the catchment to trap or treat these pollutants, in association with non-structural measures to reduce pollutant inputs at source, can result in decreasing the occurrence of these algal blooms.

- ***Improve community environmental awareness***

Retrofitting projects that improve the aesthetics and environmental values of a stormwater system can result in significant changes to community perception and awareness of the environmental issues associated with urban stormwater. Rather than seeing a drain as a disposal system and stormwater as a waste product, a restored waterway integrated with public open space is more likely to be considered by the community as an asset and stormwater valued as a resource. Littering or pollution of an aesthetically pleasing and valued waterway is more likely to attract the attention of the community than the pollution of a weed infested or unsightly artificial drain. Involving the community in the initial planning and design of the retrofit project, as well as planting days or litter collection days (e.g. Clean Up Australia Day activities), will increase ownership of the site and reduce littering of the waterway.

A Ribbons of Blue<sup>9</sup> program can be incorporated with a retrofit project. For example, a local school could undertake water quality and macroinvertebrate sampling to monitor the health of a retrofitted drain or sump. Community awareness can also be increased through media associated with the retrofit project, such as interpretative and explanatory signage at the site, local community newsletters and newspaper articles. The community or school group could also be involved in the maintenance and monitoring of a stormwater treatment device such as a gross pollutant trap, where safety issues can be addressed.

- ***Increase cost effectiveness***

By retrofitting a traditional drainage system with a range of BMP techniques, the size of the required structural stormwater system can be reduced (Victorian Stormwater Committee, 1999). Reducing peak flows and maintaining more natural stormwater systems can reduce capital and maintenance costs of stormwater infrastructure (Victorian Stormwater Committee, 1999). Using stormwater as a water source, for example, by using rainwater tanks or through recharging and using groundwater supplies, reduces stormwater infrastructure requirements as well as demands on potable supplies. Retrofitting to achieve multiple uses offers cost benefits where land can be used for integrated stormwater management and passive recreation and contributes towards the required public open space provision of developments.

- ***Demonstrate best management practices (BMPs)***

Retrofit projects can be used as demonstration sites for specific stormwater management practices. There is a community expectation that government agencies will lead by example. Trialling new techniques and demonstrating the benefits of best practice stormwater management will encourage broader adoption of the techniques by other government agencies and developers. There is a range of positive publicity opportunities and promotional activities that could be associated with a best practice retrofit project, for example newspaper articles. The project could also be nominated for an environment award or assist accreditation under an environmental program, to demonstrate to stakeholders the organisation's

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<sup>9</sup>Ribbons of Blue is a State-wide environmental education network aimed at increasing community awareness and understanding about the health of local waterways, wetlands and drains by involving school students and community groups in monitoring water quality. See Chapter 8 of the Manual for further information or visit <<http://www.wrc.wa.gov.au/ribbons>>.

commitments and achievements in environmental best practice. Examples of awards and programs include: Stormwater Industry Association's National Awards, Housing Industry Association's GreenSmart® Program, WA Environment Awards and the Water Corporation's Waterwise Village Program.

- ***Utilise stormwater as a valuable resource to reduce potable water use***

Maximising the recovery of stormwater as part of 'total water cycle management' and as a potential water source is one of the objectives of the *State Water Strategy* (Government of Western Australia, 2003). On-site water harvesting and reuse in new developments and when undertaking redevelopment presents a major opportunity to significantly reduce current and future demands for water (Government of Western Australia, 2003). Total water cycle management recognises that water supply, stormwater and sewage services are interrelated components of the whole water cycle. An integrated approach to managing these components can achieve many additional benefits, such as increased water conservation and reuse, compared to the traditional approach of managing them as separate entities.

Retrofitting projects can result in greater redirection of stormwater into the groundwater system, essentially making it available for use during drier periods through garden and council bores, while helping to conserve scheme water. Retrofitting projects can also include the installation of rainwater tanks that collect runoff from roofs, where the water can be used for non-potable purposes such as toilet flushing, washing machine use, vehicle washing and garden irrigation. In some circumstances, carpark runoff can be used for garden / reserve irrigation. However, rainfall patterns need to be considered when garden irrigation is planned because large runoff storage tanks or supplementary water supplies might be required. For example, approximately 80% of the average rainfall falls between May and September in Perth, while 90% of the external household water demand occurs during October to April (Water Corporation, 2005).

Further information about total water cycle management and the *State Water Strategy* is provided in Chapter 2. Section 2.5.2 of Chapter 7 also provides a guideline for managing the total water cycle. Information about stormwater tanks and aquifer storage and recovery is provided in Chapter 9.

## 4 When are retrofitting techniques suitable?

Ideally, WSUD should be implemented early in project planning, when land is initially being developed. Retrofitting should be considered in existing developed areas where the hydrologic, ecological and water quality requirements have not been adequately addressed. Planning in advance creates opportunities for retrofitting in areas reaching redevelopment potential. Urban renewal projects are becoming increasingly popular as a means to address the demands of population growth. Redevelopment of older residential, commercial and industrial areas provides an ideal opportunity to incorporate retrofitting measures into the redevelopment process. For more information on land use planning and development, see Chapter 3.

High density developments typically result in increased impervious areas. To reduce the risk of flooding downstream areas, stormwater runoff from high density developments should be minimised through the incorporation of measures such as pervious paving, soakwells, bioretention systems and 'rain gardens' (e.g. roof gardens and carpark garden beds). Refer to Argue (2004) for examples of how to retrofit high density developments at the lot, street and development scale.

The Department of Environment is encouraging the retention and detention of stormwater close to where it falls as rain to maximise infiltration and evapotranspiration opportunities, rather than collection and downstream conveyance. This is possible in many new (greenfield) areas. However, infiltration opportunities may be limited in already established built-up areas with restricted space and access,

especially in areas with clay, bedrock, high groundwater levels or steep slopes. Quantity management criteria are outlined in the *Decision Process for Stormwater Management in WA* (Department of Environment and Swan River Trust, 2005).

Source control<sup>10</sup> is the most effective method to reduce nutrients and contaminants discharging into water bodies. However, this is a long-term process that may take many years to produce a measurable change, due to contaminants already present in the drainage system. The recommendations outlined in this chapter should be undertaken in conjunction with source control measures, such as cleaner production and community education. Many source controls are non-structural and can easily be used in a retrofit context. In established urban areas where stormwater quality needs to be improved, installation of some types of structural controls can be difficult and/or expensive because of space constraints and existing infrastructure (e.g. sewer pipes). For example, the use of constructed wetlands for removal of fine sediment and nutrients from established urban areas requires large land areas. Additionally, unlike structural controls, many non-structural controls can be quickly modified to take advantage of new opportunities or to respond to new priorities. Soluble pollutants, which are often difficult to treat through structural techniques, can be addressed through non-structural techniques involving behavioural change to prevent pollutants entering the stormwater system. Chapter 7 provides further information on non-structural controls, which can be applied in retrofit projects in combination with structural techniques.

## 5 Costs and resourcing

The costs associated with retrofitting a system, particularly with structural techniques, can be large. There are costs associated with site selection, site investigations, design, approvals, construction (such as earthmoving, infrastructure and vegetation) and project management. There are also ongoing costs associated with maintenance, monitoring and, if necessary, the cost of decommissioning. These life cycle costs should be included in project budgets and plans. However, when distributed over the catchment, the cost of stormwater management per household can be small, as described in Example 2. More information about the costs of installing and maintaining non-structural and structural controls is provided in Chapters 7 and 9, respectively.

The costs associated with implementing non-structural techniques as part of a retrofit project can be relatively small and can result in savings or revenue in some cases. For example, techniques to reduce sediment pollution in stormwater may result in savings in terms of reduced loss of valuable topsoil and building/landscaping materials that may be washed off-site, as well as reduced maintenance costs to clean the stormwater system (refer to Section 2.1.1 of Chapter 7 for further information).

Limited data has been collected by Australian asset managers on life cycle costs of stormwater BMPs (Taylor, 2003), so a meaningful comparison of BMP costs compared with traditional drainage systems is difficult. Taylor (2003) provides a data recording sheet for collecting life cycle costs. In addition, very little information is available on triple bottom line assessment of stormwater BMPs. The Cooperative Research Centre for Catchment Hydrology (Australia) intends to develop an assessment process over the next few years (Taylor, 2003).

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<sup>10</sup> Source controls are non-structural or structural best management practices to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source and protect receiving environments.

### **Example 2**

The Town of Mosman Park (Perth) has calculated that the annual cost of cleaning sumps and traps that are distributed throughout the council is only \$10 per household and \$30,000 in total. Therefore, at-source controls are not necessarily too hard to clean and costly to maintain. Further cost information about installation and maintenance of stormwater management systems in the Town of Mosman Park is included in Case Study 7.1: Town of Mosman Park – Total Water Cycle Project.

## **5.1 Funding**

Establishing a dedicated and stable source of funding for stormwater management is a critical component of ensuring the long-term viability of programs and public support. Exploration of funding options should occur early in the development of a region's stormwater management program. Secure, long-term funding is required to continue to maintain and monitor the stormwater management devices and programs. Short-term funding can lead to poor outcomes, such as gross pollutant traps that become a source of nutrients and contaminants due to lack of maintenance. Successfully establishing a funding program often requires a community education component to clearly demonstrate the need for stormwater management projects. See Section 2.4.1 of Chapter 7 for further information about funding programs for stormwater management.

## **5.2 Incentives**

A good example of a funding system is the use of economic incentives that can operate under a property based stormwater fee/utility. For example, such a funding mechanism can be structured so that properties with a large amount of directly connected impervious area (e.g. a traditional carpark) pay a relatively high fee, while properties with a small amount of directly connected impervious area (e.g. a carpark with bioretention systems) pay a relatively low fee. Such an arrangement provides a strong, ongoing economic incentive for water sensitive urban design for both developing areas and existing areas. It is also consistent with the 'polluter pays' and 'user pays' principles.

Integration of stormwater management techniques with public open space could also offer incentives in terms of more efficiently using land and freeing up land traditionally allocated to drainage. See Chapter 3 for more information about stormwater and planning practices. Retrofitting can reduce the size of, or eliminate the need for, traditional drainage features, such as sumps, and create new opportunities for redevelopment in established areas.

Further information on funding, policy, regulatory and enforcement practices is provided in Section 2.4 of Chapter 7.

## 6 Retrofitting - how do you do it?

The *Decision Process for Stormwater Management in WA* (Department of Environment and Swan River Trust, 2005) should be referred to when planning retrofitting projects. A flow chart showing the simplified design process for retrofitting projects is provided in Figure 5.

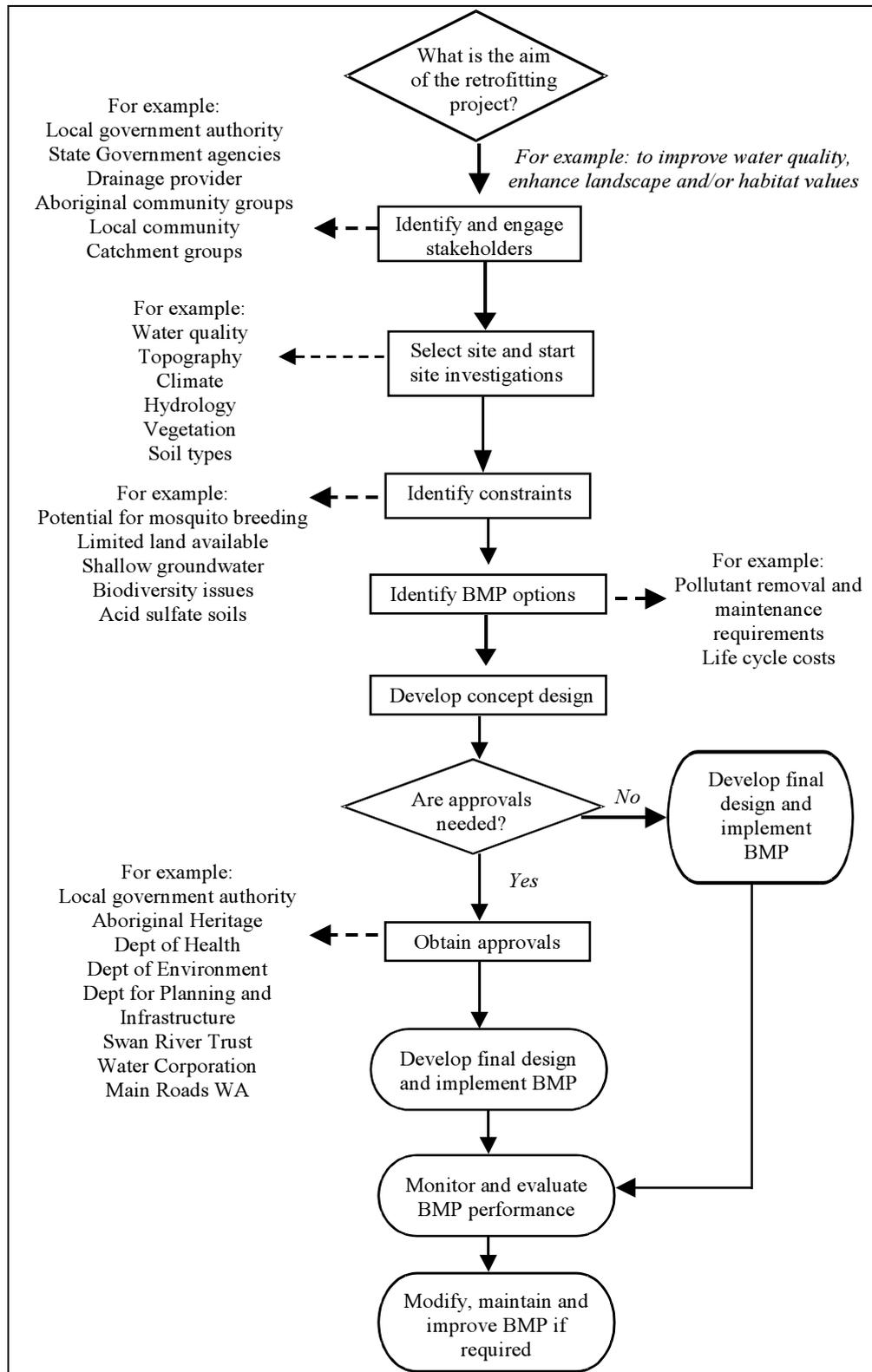


Figure 5. Flow chart showing the simplified design process for retrofitting projects.

## 6.1 Planning stages

Retrofitting should be part of an overall stormwater management plan. The primary role of a stormwater management plan is to facilitate the coordinated management of stormwater within a catchment or local government area, to maximise the environmental, social and economic benefits of stormwater management practices. It is a particularly useful tool for improving stormwater management in established urban areas, where the process of land use planning for individual redevelopment sites is often not sufficient to improve stormwater management. Part of the stormwater management plan process involves defining the problems and information requirements, including information on the catchment, stormwater system, receiving environments, land use patterns and activities, pollutants and stormwater threats. The process results in a list of recommended actions based on cost, effectiveness in protecting or enhancing the environmental, cultural and heritage values of the catchment and receiving environments, opportunities for implementation and capability of the stormwater manager to implement (Victorian Stormwater Committee, 1999). Chapter 5 outlines the process for preparing stormwater management plans.

### 6.1.1 Identify the main objectives

As stormwater management is so multi-faceted, the objectives of a retrofitting project should be clearly identified. Objectives can include environmental benefits (e.g. water quality improvements, hydrologic modification and erosion control), habitat value (biodiversity and conservation), or anthropocentric benefits (e.g. aesthetics and recreation). Good designs can also include many secondary objectives that do not compromise the primary aims.

### 6.1.2 Identify and engage stakeholders

The early stage of a retrofitting project requires the identification and involvement of all stakeholders. In many sites in urban areas, there are likely to be many stakeholders that have a direct interest in the project and will need to be consulted, such as the local government authority, relevant State government departments, catchment and community groups, nearby residents and industries, and local indigenous groups. See *Water Note 30: Safeguarding Aboriginal heritage* (Water and Rivers Commission, 2002a) and the Department of Indigenous Affairs' website <<http://www.dia.wa.gov.au/Heritage>> for more information on consulting with Aboriginal people and Aboriginal heritage sites and surveys. The identification of stakeholders and the development of a communications plan assist with streamlining the design and approvals processes. At this stage of the process, it is also good practice to identify long-term ownership and management responsibilities. About 20% of all drains in the Perth metropolitan area are owned and operated by the Water Corporation, whilst local government manage about 75% and other service providers, such as Main Roads Western Australia, manage the remaining 5%. Local government and other service providers (such as Main Roads Western Australia) own and manage urban stormwater infrastructure in the remainder of the State.

In developed areas, WSUD requires greater community support and is often more difficult to implement than in new developments. For example, it is essential to gain the support of people that live adjacent to drains and sumps that are proposed for retrofitting works. Any work needs to be acceptable to adjacent landholders and must minimise adverse effects. For example, tall vegetation on the banks can obscure landholders' views and make them feel more vulnerable to intruders. Vegetation may also increase fire risks and provide a habitat for pests. Some nearby residents may also be actively involved in the area and may be able to contribute to the development of a project with local knowledge of issues such as litter, sedimentation, erosion, flora and fauna species and hydrologic patterns. Therefore, the decision process must consider community issues, such as public health and safety impacts (e.g. the control of disease vector insects).

### 6.1.3 Legislative requirements

Before any structural retrofitting works are planned, the following Acts may need to be considered and the relevant approvals granted (Table 1).

**Table 1. Acts which may affect retrofitting proposals**

Agency	Relevant Acts	Requirements under the Acts
Department of Conservation and Land Management (CALM)	<i>Conservation and Land Management Act 1984</i>	Applies to projects undertaken within CALM managed lands.
	<i>Wildlife Conservation Act 1950</i>	This Act protects flora and fauna.
Environmental Protection Authority (EPA)	<i>Environmental Protection Act 1986</i>	An Environmental Impact Assessment may be required under Part IV of the <i>Environmental Protection Act 1986</i> .
Local Government	<i>Health Act 1911</i> <i>Local Government Act 1995</i> <i>Town Planning and Development Act 1928</i>	Development must be consistent with the Town Planning Scheme.
Department for Planning and Infrastructure (DPI)	<i>Metropolitan Region Town Planning Scheme Act 1959</i> <i>Town Planning and Development Act 1928</i> <i>Western Australia Planning Commission Act 1985</i>	Any development must be consistent with the Town Planning Scheme.
Swan River Trust (SRT)	<i>Swan River Trust Act 1988</i>	Under this Act, approval is required from the Trust to undertake any developments within the Swan River Trust Management Area.
Water Corporation	<i>Land Drainage Act 1925</i> <i>Water Corporation Act 1995</i> <i>Metropolitan Water Authority Act 1982</i>	It is an offence under the <i>Land Drainage Act 1925</i> and the <i>Metropolitan Water Authority Act 1982</i> to interfere with any drainage system vested in the Water Corporation without seeking prior approval.
Department of Indigenous Affairs (DIA)	<i>Aboriginal Heritage Act 1972</i>	Under this Act, approval is required for works that may impact on areas such as native vegetation or near water bodies, due to their association with Aboriginal heritage and culture.

Agency	Relevant Acts	Requirements under the Acts
		Aboriginal heritage values and cultural sites must be protected and disturbance minimised or avoided.
Department of Environment (DoE)	<i>Environmental Protection Act 1986</i> Environmental Protection (Clearing of Native Vegetation) Regulations 2004	A clearing permit may be required under Part V, Division 2 of the <i>Environmental Protection Act</i> , unless an exemption applies under either the <i>Environmental Protection Act</i> or the Regulations.
	<i>Waterways Conservation Act 1976</i>	Applies to development near prescribed waterway management areas.
	<i>Water Services Coordination Act 1995</i> <i>Water Services Licensing Act 1995</i> <i>Water Boards Act 1904</i> <i>Water Agencies (Powers) 1984</i>	Regulates and licenses water service providers.
	<i>Rights in Water and Irrigation Act 1914</i>  <i>Metropolitan Water Authority Act 1982</i>	A licence may be required to draw water from proclaimed Groundwater Areas or Surface Water Catchments. The Water and Rivers Commission has overall administrative responsibility for the Metropolitan Arterial Drainage Scheme. Redevelopment must be consistent with the Arterial Drainage Scheme.
	<i>Country Areas Water Supply Act 1947</i> <i>Metropolitan Water Supply, Sewerage and Drainage Act 1909</i>	Applies to development within proclaimed public drinking water source areas.

#### 6.1.4 Site investigations

Once stakeholder support has been achieved, the next stage is to start undertaking site investigations to determine the most appropriate BMP or suite of BMPs to use. The type and extent of investigations required will depend on the site and project. For the design of structural controls, topographical surveys, climate, hydrologic data (e.g. discharge ratings and groundwater levels), geotechnical data, monitoring for surface water and groundwater quality, fauna/flora assessment (including identification of weed species and fauna passage requirements) and testing for acid sulfate soils<sup>11</sup> should be minimum requirements.

<sup>11</sup>Acid sulfate soil 'high risk' areas are documented in *Planning Bulletin 64: Acid Sulfate Soils* (Western Australian Planning Commission, 2003).

Where non-structural controls are being implemented, additional information on the planning, regulatory, institutional and operational environment may also be required. For example, this may include community or industrial site surveys to collect information on people's awareness and behaviour in relation to stormwater management.

### 6.1.5 Identify opportunities and constraints

There may be constraints restricting implementation of structural controls, including shallow or polluted groundwater, disturbance of acid sulfate soils, bioaccumulation of metals and other contaminants, limited land availability and the potential for mosquito breeding. Proponents must also check cultural and heritage values, including Aboriginal heritage, impacts on flora and fauna, pests, weeds, fish passage, erosion control, groundwater protection and a range of potential impacts on the community, including public health and safety. Existing knowledge and perceptions can be a barrier to implementing BMPs, for example the preference for traditional practices and the reluctance to trial new techniques. As discussed in Section 5, life cycle costs must also be considered. Retrofitting projects may offer opportunities to enhance the social and environmental values of the area and provide additional benefits, as outlined in Section 3.

#### **Groundwater Issues**

Infiltration strategies should consider the risk to the quality of shallow groundwater aquifers. Stormwater from sites that have the potential to contain harmful pollutants and high nutrient concentrations must be pre-treated prior to infiltration or discharge off-site. Separation of stormwater streams at source to minimise interaction of poor and good quality water is a recommended practice.

If groundwater monitoring shows that there is already groundwater contamination, that is the groundwater is polluted with physical, chemical or microbiological matter that has the potential to present a risk of harm to human health or environmental values, management measures are required to contain the plume. Infiltration opportunities may be limited as direct infiltration may increase groundwater transport (by increasing groundwater gradients) and increase the risk of interception of historic shallow contaminant sources (e.g. seepage well and buried wastes). Build-ups in pollutant loading throughout drainage systems, due to past land uses or limited implementation of structural and non-structural control measures, will result in delayed benefits from retrofitting projects to the receiving water body. A site investigation is required in order to make an informed decision about the best management measures. The design may include techniques to trap and treat a groundwater plume, for example by installation of a cut-off trench and direction of nutrient rich groundwater through a bioretention system or constructed wetland. Conversely, the design may include raising the invert of existing drainage channels that convey contaminated base flow, so that the channel does not intercept and facilitate contaminated groundwater transport. The feasibility and potential impact of these options, including the impact on dependent ecological systems, would need to be examined.

Rising groundwater and perched water tables can cause the accumulation of sulfates, sulfides, iron oxides and salt. Resulting soils have poor productivity and have the potential to cause significant downstream environmental problems if affected areas are drained. The sediments of some groundwater dependent wetlands on the Swan Coastal Plain can acidify if the water table falls well below the base of the wetland due to dry weather, drainage or excessive groundwater pumping (Department of Environment, 2003).

If maximum groundwater levels are near the surface (within two metres), then runoff from impervious surfaces generally should not enter a piped system directly, rather it should be initially infiltrated. This is because most of the available separation to the maximum groundwater level, and therefore the opportunity to promote infiltration, is lost once runoff is directed into subterranean drainage systems. The runoff from

the initial part of rainfall events should be infiltrated at the ground surface (e.g. a swale, infiltration cell, pervious paving or bioretention area), before the runoff from (generally) greater than 1 year Average Recurrence Interval events enters a piped or overland flow system. Runoff should preferably flow through vegetation and soil to promote biological treatment and water uptake.

If groundwater levels are rising or have potential to cause waterlogging in a developed area, sub-soil drains may be used to prevent this waterlogging. These sub-soil drains should be set at the approved Controlled Groundwater Level. See *Decision Process for Stormwater Management in WA* (Department of Environment and Swan River Trust, 2005) for more information on Controlled Groundwater Level.

### **Flooding issues**

Open drains and sumps / compensating basins can be retrofitted where there is adequate space, or the systems are larger than the required capacity. The Water Corporation is the owner of the majority of the main drainage network in the Perth metropolitan area and has a responsibility to meet the requirements of their operating licence (administered by the Economic Regulation Authority) with respect to flood mitigation. Any works in the stormwater system cannot compromise the flood capacity or protection of property. Additionally, the trend of increased urban infill may also raise the demand on drainage systems. The requirement to meet future flood control and mitigation expectations needs to be considered.

### **6.1.6 Deciding on the best approach**

To effectively retrofit a system, it is necessary to match the selected BMP with the site characteristics, including target pollutants and their transport pathways, and groundwater levels. For this selection to be successful, the designer needs to know something about the catchment (land use, current stormwater management practices, soil types, hydrology) and something about the pollutants (typical components, dominant transport pathways). If one of the objectives of the project is to improve water quality, it is essential that the water quality of the stormwater is known (or estimated) beforehand, as this will influence the choice of BMPs. Different processes are required for removing different pollutants and their components. If litter is a large problem (i.e. from high traffic or commercial areas), then an at-source gross pollutant trap (GPT) may be useful, however its suitability for the catchment and expected in-flows still needs to be considered. If high concentrations of hydrocarbons from street runoff are expected, then an oil and grit trap may be the best solution. Stormwater with a high amount of sediment or nutrients attached to sediment can be treated by using open retention / detention areas, for example vegetated swales, which encourage sedimentation or filtration. Stormwater with a high amount of dissolved nutrients can be treated with BMPs that encourage biofilm growth, such as bioretention systems and ephemeral constructed wetlands. Dissolved nutrients and pollutants can also be removed by using amended material and pervious paving. Table 2 details structural BMPs to use to target specific water quality issues. To complement the selected structural BMPs, non-structural BMPs need to be implemented. For example, gross pollutants can be managed through implementing improved site management practices, litter bin provision, street sweeping, litter collection, plant selection and maintenance and regulation practices. See Chapter 7 for more information on the selection and design of non-structural controls.

The sequencing of BMPs in the treatment train is important in achieving best management of stormwater. For example, gross pollutants and sediment can clog and reduce the performance of infiltration systems, constructed wetlands, pervious paving and swale drains. Pre-screening devices such as buffer strips, gross pollutant traps and sediment trapping areas can be installed before discharging stormwater runoff to downstream treatment systems.

Many drains were built in the early 1900s and some are over-designed. Maintenance practices, such as clearing and removing accumulated sediment from drains, have resulted in some drains being much larger than their original design. Where drains are oversized, then retrofitting to increase compensation, enhance habitat, restore vegetation and improve water quality is an option. However, where space is restricted and

maximum facility capacity is required, the drain may be unsuitable for structural retrofitting. Where space is at a premium, alternatives such as retrofitting the catchment to reduce discharges to the constrained channel, or relocating infrastructure to widen the drainage reserve should be examined.

Basic principles for retrofitting to improve water quality in a built drainage system where space is limited have been investigated in the *Drainage improvement framework for the Mills Street Main Drain catchment* (Swan River Trust, 2003a). These recommendations include promoting a longer flow path between the inlet and outlet of basins, thereby increasing detention times of low and base flows (allowing for sedimentation and filtration), as well as revegetating the banks and in-stream sections. Plants are effective at nutrient removal by providing a good substrate for biofilm growth (for assimilation of dissolved nutrients) and encouraging sedimentation and filtration of nutrients (and other pollutants) attached to suspended matter, and to some degree by directly uptaking nutrients themselves when in the growth phase. Riffles promote oxygenation and can increase habitat.

**Table 2. Tools for targeting key parameters to improve water quality**

BMP	Provide habitat	Improve aesthetics	Improve Water Quality								Issues
			Reduce total suspended solids	Reduce litter	Reduce particulate total nitrogen, total phosphorus	Reduce dissolved nutrients	Increase oxygen	Reduce hydrocarbons	Reduce heavy metals	Reduce bacteria	
GPTs			✓	✓	~			~	~		✓
Trash racks etc.				✓							✓
Grass swales		✓	✓		✓	~		~	~		
Filter strips	~	✓	✓	✓	✓	~			~		
Sand filters			✓		✓						
Oil and grit traps								✓			
Riffles	✓	✓	✓				✓				
In-stream plants	✓	✓	✓		~	✓	✓				
Soil amendments						✓					
Permeable / Porous paving						✓			✓		
Bioretention systems	✓	✓	✓			✓					
Infiltration areas			✓		✓				✓		
Open water (UV exposure)	✓	✓								✓	✓
Constructed wetlands	✓	✓	✓		✓	✓	✓				✓
Sediment basins			✓	✓	✓			~	~		✓

✓ denotes parameter/issue is applicable to this BMP

~ denotes parameter/issue is applicable to some extent to this BMP

## 6.2 Implementation

Chapters 7 and 9 identify a number of techniques that are potentially applicable to retrofit projects and provide detailed BMP guidelines. Structural controls, such as stormwater infiltration systems, swales, 'living streams', bioretention systems, gross pollutant traps, oil water separators and constructed wetlands are outlined in Chapter 9. Brief descriptions of several BMPs that are particularly relevant in a retrofit context are provided below.

### 6.2.1 Rainwater storage systems

Rainwater tanks, enlarged-gutter storage or similar systems store water that is collected on a roof. They can be used at a lot scale or development scale for water capture and reuse, hence taking pressure off scheme water supply. However, these systems need to be maintained to ensure that they do not become breeding habitats for mosquitoes. The water quality is significantly impacted by the maintenance of the guttering and rainwater tank. A first flush system and gutter guards or screens over inlets should be installed and gutters cleaned regularly to reduce the amount of debris entering the tank. The Department of Health (Western Australia) supports the use of rainwater tanks in urban areas for non-potable uses. Roof runoff is suitable for toilet flushing and washing machine use (Water Corporation, 2005). It may also be suitable for some hot water systems. The Department of Health advises that unless adequately treated, rainwater is not reliably safe to drink. Further information is provided in the Department of Health's Environmental Health Guide: *Is the Water in your Rainwater Tank Safe to Drink?* (Department of Health, 1999) and *Urban Rainwater Collection* (Department of Health, 2003). The Water Corporation has produced a fact sheet *Rainwater Tanks*, which is available at: (<[http://www.watercorporation.com.au/owf/owf\\_factsheet\\_raintanks.cfm](http://www.watercorporation.com.au/owf/owf_factsheet_raintanks.cfm)>). More information about using rainwater tanks is provided in Chapter 9.

### 6.2.2 Infiltration systems

Infiltration systems include a number of devices, such as soakwells, soakage areas (e.g. basins and retention trenches), leaky gully / side entry pits, swales, pervious paving and bioretention systems, designed to promote stormwater permeation into the soil profile. A number of these techniques are discussed in more detail in subsequent sections. Correctly designed infiltration systems remove pollutants from stormwater through the processes of adsorption, filtration and microbial decomposition. Infiltration devices can be installed at source to maintain the local water balance and minimise the volume of runoff that can potentially carry pollutants from the site. This approach has a number of environmental and economic benefits, including reduced peak stormwater flows, reduced downstream flooding, reduced stormwater drainage capital costs, improved groundwater recharge and improved stormwater quality (Coombes, 2003).

Existing stormwater devices can be retrofitted to introduce more on-site infiltration. For example, solid base manholes, gullies and side entry pits can be modified (e.g. by coring out a hole in the base of the pit, as shown in Figure 6) to allow for infiltration, or existing devices can be supplemented with additional soakwells or infiltration cells / leach drains. This allows for on-site infiltration, while still maintaining a stormwater detention function, with larger runoff events accommodated by overflow systems. Figure 16 of Case Study 7.1 provides a concept design of a retrofitted gully with a soakwell added to the system. The base of the unit may need to be covered by a grate to prevent the permeable base material (e.g. blue metal) being sucked up by educting equipment and the unit being destabilised (Todd, B., 2005, pers. comm.<sup>12</sup>).

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<sup>12</sup> Personal communication with Bill Todd, Technical Engineering Officer, Town of Victoria Park, 2005.

The infiltration of roof runoff is widely practised in Western Australia, where the majority of urban development is located on the highly permeable, sandy soil of the coastal plains. Roof runoff is directed into soakwells, infiltration cells / leach drains or gravel-filled trenches, where the stormwater infiltrates into the ground. However, galvanised iron roofs have been identified as being a potential source of zinc and cadmium contamination of stormwater. Infiltration systems for treating runoff from more general areas such as streets and carparks can also be integrated into landscaping features.

The design of an infiltration system should consider the site conditions, particularly the soil hydraulic conductivity and groundwater quality and levels, as well as the pollutant types and rainfall characteristics of the catchment. Infiltration may be constrained in areas with high water tables, low permeability or steep sites such as scarp slopes, and may not be suitable in areas with waterlogged soils, contaminated groundwater or rising salinity. However, infiltration is particularly suitable in sandy areas with lower (greater than 2 metres to the annual maximum groundwater level) groundwater tables. The effectiveness of the system decreases dramatically if the soil infiltration rate or the system's permanent storage volume are incompatible with the rate and volume of inflow. Infiltration devices should be designed to accommodate low intensity rainfall events. The devices are not usually designed to infiltrate high intensity rainfall events or to provide the primary function of flood control (although decreased flooding can be a benefit). Lack of appropriate maintenance, resulting in clogging, is one of the main causes of reduced effectiveness over time. The appropriate positioning of infiltration systems within the stormwater treatment train is also important. Pre-screening devices to prevent gross pollutants and sediment clogging the infiltration system may be required. More information about infiltration systems is provided in Chapter 9.

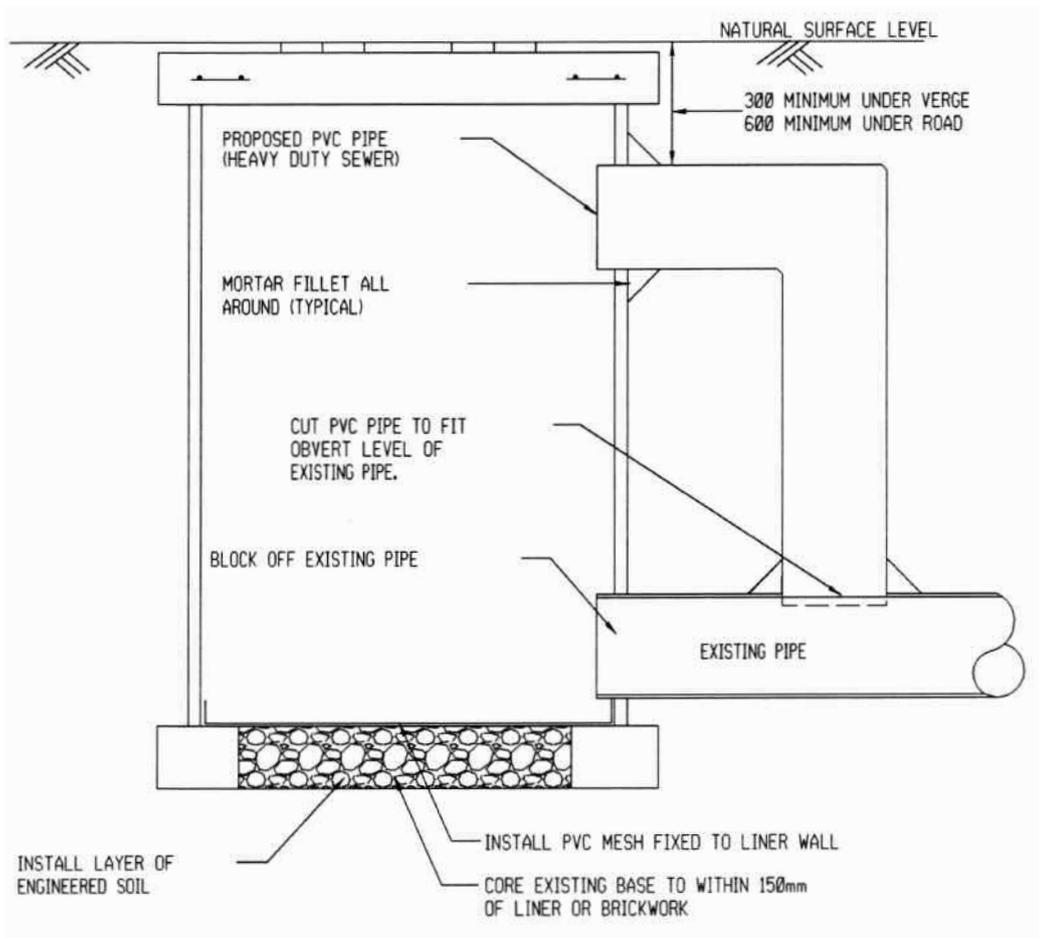


Figure 6. Retrofitting option for solid base pits. (Supplied by B. Todd, Town of Victoria Park.)

### 6.2.3 Pervious paving

Permeable / porous (collectively termed pervious) paving may be suitable in trafficable and non-trafficable areas where there is existing bitumen or concrete. Roads, carparks, footpaths and other hard surface areas (such as paving surrounding buildings) are typically impermeable and result in high runoff rates during a storm event. Pervious paving can either be produced by placing permeable material between widely spaced impermeable pavers, or by installing porous paving.

The use of pervious surfaces (e.g. porous paving or vegetation) is particularly important around buildings that do not have roof gutters (which is a common feature of buildings in the north of the State) (see Figure 7). The pervious surfaces will prevent soil erosion that can be caused by large volumes of water running directly off the roof onto the ground during intense rainfall events.



*Figure 7. Pervious surface underneath a gutterless roof, Shire of Broome offices, Broome. (Photograph: Allan Ralph, Shire of Broome, 2005.)*

Overseas experience in the use of pervious paving has shown that clogging can occur between 5 and 10 years after installation, so cleaning of the paving is essential (Dierkes *et al.*, 2002). The pervious paving not only allows for infiltration but can improve the water quality. Pervious pavement has been shown to be very effective at retaining dissolved metals (Dierkes *et al.*, 2002). More information is provided in Chapter 9 and in *Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater – A Handbook for Australian Practice* (Argue, 2004).

Australia's first street where traditional bitumen has been replaced with permeable pavement and permeable sub-base is in Manly, Sydney. The Manly Stormwater Treatment and Re-Use project involved permeable pavement, biological treatment and reuse of stormwater collected from parking areas along the North Steyne on Ocean Beach, Manly<sup>13</sup>. Gutters in the street were eliminated to attenuate flow, increase infiltration and reduce the transportation of pollutants. Treated stormwater was reused for irrigation.

<sup>13</sup> See <<http://www.manly.nsw.gov.au/star>>.

## 6.2.4 Gross pollutant traps

Gross pollutant traps (GPTs) are effective in removing gross pollutants such as litter, vegetation debris and sand that are typically found in urban catchments. Like any structural BMP, GPTs need to be well maintained otherwise they are at risk of becoming a source of poor water quality and may even impede water flow, causing flooding. A variety of GPTs are available and selection may depend on cost effectiveness, expected flow rates and maintenance requirements. More information about GPTs is provided in Chapter 9.

### Example 3

Various types of gross pollutant traps have been installed by the City of Belmont. A Rocla® Defender™ was installed in 1997 and has been successful in trapping solids in runoff from roads and stables near Epsom Ave, Ascot. The City has also installed a gross pollutant trap (prefabricated system with sedimentation and screening) near Mathieson Road/Ascot Racecourse, Ascot, to trap solids before discharge into a series of nutrient stripping ponds. A Geotrap pit was recently installed at Forbes Street, Ascot, near the Swan River foreshore. In 2003, the City installed a Wormall's Ecobite stormwater pollution pit at Faulkner Park off Wright Street to trap solids and hydrocarbons prior to the runoff entering the lakes in the park (Tan, P., 2003, pers. comm.<sup>14</sup>). Another Wormall's Ecobite stormwater pollution trap was installed on the pipe system at Ford Street to trap solids in the runoff prior to discharging into the river (Tan, P., 2003, pers. comm.).

### Example 4

In conjunction with the City of Bayswater, the North Metropolitan Catchment Group (NMCG)<sup>15</sup> installed a continuous deflective separator (CDS) unit at Wotton Street in the Bayswater industrial area in 1999. Continuous deflective separator units are reported to be very effective at removing litter and debris from stormwater to a particle size of 5 mm. In 2002, the Bayswater Integrated Catchment Management Group (now part of NMCG) analysed the proportions of solids trapped by the CDS (Warner, undated). The main component of the trapped waste was organic matter and sediment (>95%). Visual inspection found that the solids were trapping hydrocarbons and the report recommended that absorbent pillows be used to increase hydrocarbon removal. The CDS unit was maintained annually and the report recommended that the unit is emptied two or three times per year, as the unit contents were believed to be increasing the nitrogen and phosphorus contents in the stormwater via decomposition.

## 6.2.5 Swales

Swales can be part of the integrated stormwater treatment train, with their use matched to expected pollutant types and forms (Fletcher, 2002). An example of the integration of a grass swale within the grounds of Broome Senior High School is shown in Figure 8. Grass swales may be suitable for removal of particulate contaminants in lower flows and swales planted with sedges may be more suitable for higher flows (Fletcher, 2002). Vegetated swales should be planted with local native plant species to enhance biodiversity, reduce the need for fertiliser application or watering and reduce the spread of weed species to receiving environments via stormwater flows.

<sup>14</sup> Personal communication with Patrick Tan, City of Belmont, 2003.

<sup>15</sup> Previously the North East Corridor Committee (NECC).

Although some studies in Australia have shown that grassy and native vegetated filter strips are not generally very effective at trapping dissolved nutrients, they are generally more effective at removing sediment and nutrients attached to this sediment (Price and Lovett, 1999). Swale cross sections should be as uniform as possible to minimise scouring and maximise contact between water and vegetation. If slope is an issue, erosion can be prevented and the effectiveness of vegetated swales enhanced by installing riffles at intervals along the channel length. These riffles maximise the detention time within the swale, decrease the velocities and better promote particulate settling. As with road verges and median strips, swales also need to be maintained so they do not become a source of contamination from fertilisers, grass clippings, pesticides or other pollutants (see Section 2.2.7 of Chapter 7). More information about the design and effectiveness of swales is provided in Chapter 9.



Figure 8. Retrofitted grass swale, Broome Senior High School, Broome.  
(Photograph: Department of Environment, 2005.)

### 6.2.6 Bioretention systems

Bioretention systems are either grassed or landscaped swales promoting infiltration into specific treatment media. In clay soils, the bioretention system may include underground slotted pipes allowing for conveyance of the infiltrated water for further treatment downstream. Systems may also be lined with impervious material or geotextile, ensuring that there is no impact to groundwater, if that is the design objective.

#### Example 5

Bioretention systems used in Lynbrook Estate (Victoria) showed a 66% reduction in soluble phosphorus attributed to rapid adsorption of the phosphorus to the finely graded sediment in the bioretention systems (Lloyd *et al.*, 2002). Comparison of conventional piped stormwater systems with bioretention systems found that the bioretention systems out-performed the conventional systems with respect to water quality improvements (suspended solids, total nitrogen and phosphorus) due to flow reduction and filtration of the flow into the underlying soils (Lloyd *et al.*, 2002).

Lessons can be learnt from national experience where many systems fail to achieve design objectives due to damage caused during the development's construction phase. For example, bioretention systems should be protected from traffic to avoid compaction, which reduces the hydraulic conductivity and results in performance failure. Furthermore, systems should be protected from the high amounts of sediment produced during the construction phase of estates/subdivisions, which can clog the system. This can be done through sediment controls, such as silt fencing, or providing a protective 'cover' (such as a geofabric) over the bioretention system during the construction phase (Coombes, 2003). Alternatively, the bioretention system can be left to act as a sediment trap during the construction phase and then converted to a vegetated bioretention system after housing construction is complete. More information about bioretention systems is provided in Chapter 9.

### 6.2.7 Roads

Typical bitumen and other hardstand roads can be retrofitted to improve the quality and quantity of runoff. Rather than collecting and piping stormwater runoff from roads, the road drainage system can be 'disconnected' and on-site infiltration can be introduced. The road reserve can be used to restore or maintain the pre-development runoff characteristics of the site at a street scale for generally at least up to a 1 in 1 year ARI event. Retention and detention measures can be implemented in the road reserve, such as swales, soakwells and other controls to promote infiltration and evapotranspiration. For example, see Case Study 7.1: Town of Mosman Park – Total Water Cycle Project case study for information about retrofitting road drainage with combination gullies / soakwells. Kerbs can be replaced with flush kerbing (e.g. by grinding existing precast barrier kerbs down to the road level), allowing for infiltration of runoff into the road verge or into roadside or median strip vegetated swales (see Figures 9 and 10). If vehicular movement into the verge or swale area is not desirable, then traditional raised kerbs can be replaced with timber or concrete bollards (see Figure 9), or cuttings/openings can be made into the existing kerbing to allow water to pass through at specific locations. Retrofitting road verges or median strips to incorporate swales will not be possible in some situations, due to existing footpaths, above and below-ground services, and street trees.



*Figure 9. Example of flush kerbing and grass swales, Brisbane. (Photograph: Department of Environment, 2002.)*



*Figure 10. Example of a kerbless road and swale, Dampier Road, Karratha. (Photograph: Department of Environment, 2006.)*

Road design should include best management of vegetated road verges and median strips, particularly in regards to plant selection, fertiliser, pesticide and water application and mowing (see Section 2.2.7 of Chapter 7). Exotic deciduous trees on road verges and median strips should be replaced with native (preferably local provenance) plants. The bulk leaf drop in late autumn / early winter can block stormwater systems, increasing treatment and maintenance requirements (see Figure 11). These leaves are also delivered directly to water bodies via the stormwater system. See Section 6.2.8 *Revegetating options* for a discussion of some environmental problems caused by deciduous trees. Deciduous trees should be retained at sites where they are providing a passive solar design or heritage value function.



*Figure 11. Leaf litter entering stormwater network in Perth Central Business District. (Photograph: Department of Environment, May 2004.)*

Runoff from roads with high traffic flows may contain high levels of pollutants and may require some pre-treatment, such as incorporating overland flow through vegetated swales. In addition to traffic volume, the type of road surface and its condition, vehicle type, verge condition and surrounding land uses can all influence the amount of pollutant loading to stormwater runoff (Davies *et al.*, 2000). Road runoff can be a source of litter, sediment, nutrients, hydrocarbons and also heavy metals from brake and tyre wear and fuel combustion. Studies have shown that copper, lead and zinc are often highly concentrated at intersections with traffic lights where sudden braking can increase brake and tyre wear (reported in Davies *et al.*, 2000). More information on the maintenance of roads and pavements is provided in Sections 2.2.1 and 2.2.5 of Chapter 7.

### 6.2.8 Revegetating options

Introduced species (particularly weeds and exotic deciduous plants) within and next to inland water bodies should be replaced with native (preferably local provenance) plants. Exotic deciduous trees drop all of their leaves over a short period, delivering a bulk of organic material to water bodies in late autumn/early winter (see Figure 12). The large load and soft composition means that the leaves decompose too fast for many native macroinvertebrates to assimilate, compared to the more refractory nature of native leaves, resulting in a large release of nutrients (Water and Rivers Commission, 2002b). Additionally, the dense form provided by some deciduous trees in the spring and summer period can inhibit the growth of understorey plants (Water and Rivers Commission, 2002b).

Vegetated waterways and wetlands and their buffers help to attenuate stormwater flows and filter pollutants, as well as increase biodiversity values. Vegetated areas decrease runoff and increase stormwater use on site through increased infiltration, rainfall interception and evapotranspiration. Techniques include preserving trees during construction, revegetation with high water use native vegetation and urban forestry.



Figure 12. Leaf litter from exotic deciduous trees directly entering a pond. (Photograph: Department of Environment, May 2004.)

The *River Restoration Manual* (Water and Rivers Commission / Department of Environment, 1999-2003) and *A Guide to managing and restoring wetlands in Western Australia* (Department of Environment, Department of Conservation and Land Management and Department for Planning and Infrastructure, in preparation) provide information about revegetating natural waterways and wetlands, respectively. Section 2.2.7 of Chapter 7 provides more information about maintenance of gardens and reserves. Chapter 9 provides guidelines on using vegetation for surface and groundwater management and to offset potential changes to the local water balance through urbanisation.

#### Example 6

With assistance from the Two Rivers Catchment Group, the City of Belmont is undertaking stream restoration work on a 1km open section of the South Belmont Main Drain which was originally a natural creekline. This work has included removal of exotic species, re-establishment of native vegetation to help stabilise eroding embankments, and the construction of an artificial wetland and weir on the foreshore (Figure 13). This has been successful in preventing nutrient-laden sediments from discharging into the Swan River (King, J., 2004, pers. comm.<sup>16</sup>).



Figure 13. Adachi Park at outfall of South Belmont Main Drain. (Photograph: J. King, City of Belmont, September 2004.)

### 6.2.9 Living streams

The protection of existing waterways and the restoration of degraded waterways or drains are important techniques for improving stormwater management in our urban environments. When undertaking urbanisation of rural land or retrofitting in existing urban areas, this would mean the conversion of existing constructed drains into 'natural' meandering streams. Revegetation and reshaping of drains can restore the many values of a natural or 'living' stream. A living stream achieves multiple outcomes, including creating a healthy ecosystem, improving water quality, conveying floodwaters and creating an attractive landscape feature for the residential community (Water and Rivers Commission, 1998b).

<sup>16</sup> Personal communication with James King, City of Belmont, 2004.

In natural waterways, the shape and size of the channel and extent of vegetative growth in the channel are in balance with the discharge characteristics. In the 'living streams' approach, constructed channels are designed to mimic natural streams, with high flows accommodated along the vegetated streamline and its floodway. For example, the earthworks undertaken as part of the drain rehabilitation works at Bannister Creek initially resulted in an oversized channel (see Case Study 7.4). Vegetation growth then narrowed the low flow channel to be in balance with the typical annual flood flow. The aim of drain revegetation projects is to maximise channel 'roughness'<sup>17</sup> at low flows, while managing roughness at higher flows. Infiltration, detention and treatment of the stormwater through contact with vegetation are maximised at base flow and during low intensity rainfall events. During high rainfall events, flood protection is maintained by conveyance in the floodway. Flow velocities can be reduced and flood storage maximised for high flows by providing a broad vegetated floodway.

Healthy fringing vegetation provides wildlife habitat, ecological corridors, erosion control and biofiltering of pollutants, which is particularly important in WA where a high proportion of nutrients is in soluble form. A living stream is a complex ecosystem, supporting a wide range of plants and animals. It has stable vegetated banks with many plant species and provides habitats for animals such as frogs, fish and water birds. Plants that generate shade and have hard leaves are essential elements of healthy stream ecosystems.

Rock or log riffles can be installed along the stream to help stabilise the streambed and aerate flows. Unlike traditional weirs and drop structures, riffles do not block the migration of fish and other aquatic fauna and they enhance the habitat diversity of the waterway. Riffles create pools, which are a focus for fish and are typically a refuge for aquatic fauna during the dry season. In-stream large woody debris (logs and branches) are a feature of natural waterways and important for providing stable habitats, food sources and shelter for aquatic fauna. Figures 14a and b show Geegelup Brook, Bridgetown, which is a natural waterway that had been modified into an artificial stormwater drain. Low riffle structures were used to create pools and control the steep grade of the brook, the banks were reshaped and the brook and floodplain were revegetated.



*Figure 14a. Geegelup Brook, Bridgetown, before restoration works – a weed infested trapezoidal drain. (Photograph: Department of Environment, 2003.)*



*Figure 14b. Geegelup Brook, Bridgetown, after restoration works. (Photograph: Department of Environment, 2003.)*

<sup>17</sup> 'Roughness' refers to the channel resistance to flow created by the bed paving material and vegetation, logs, rocks, etc. in the channel. In hydraulic calculations, roughness is denoted as Manning's 'n'.

Design guidelines for living streams are provided in Chapter 9. Case studies in Sections 7.4 and 7.5 provide some information on living streams retrofitting projects.

### 6.2.10 Constructed wetlands

Where high concentrations of soluble material are expected, constructed wetlands or bioretention systems are recommended. This is especially relevant on sandy coastal plain sites where the proportion of dissolved nutrients is typically high. Appropriately designed and constructed wetlands can act as preliminary filters, stripping the water of nutrients and other pollutants, including micro-pollutants, before the water is released into natural wetlands, waterways or estuaries.

New constructed wetlands should be ephemeral. However, some constructed wetlands contain sections of permanent water, either due to year-round water supply from existing drains that intercept the groundwater and discharge into the wetland, or due to the retrofitting of drains or basins that intercept the groundwater.

Well-designed (and well-vegetated) constructed wetlands that mimic the ephemeral character of our natural wetlands are effective water pollution filters because in-stream and fringing aquatic vegetation provide an ideal structure for the growth of biofilm, which assimilates dissolved nutrients. Wetland plants can also improve water quality by encouraging sedimentation and filtration of nutrients and pollutants (through stems and leaves), oxygenating their root zone, providing shade and, to some extent, by using nutrients when in the growth phase.

A wetland designed with alternating deep and shallow zones, perpendicular to the water flow, can promote various chemical reactions, such as mineralisation, nitrification and denitrification processes, to transform and eventually remove nitrogen from the system.

Pre-treatment for removal of gross pollutants and sediment should be installed upstream of the constructed wetland. This ensures that the performance of the vegetated system is not reduced by clogging. A pre-treatment or entry control device, such as a bubble-up or deeper wetland zone, can buffer high flows that could result in erosion, damage to vegetation and biofilms, or re-suspension of sediment.

Constructed ephemeral wetlands can provide flora and fauna habitat in areas where many natural wetlands have been cleared, drained or filled. Case Study 7.6 provides information on a constructed wetland retrofitting project. More information about ephemeral systems is provided in Chapter 9.

### Example 7

In 2001, the City of Canning constructed the Black Creek Wetland (Station Street wetland) on a previously linear trapezoidal section of the Black Creek Branch Drain at Station Street, Cannington. The project was undertaken in partnership with Main Roads, Water Corporation, Rotary Club of Welshpool, Friends of Queens Park Bushland and the community, with assistance from environmental consultant Karl Karu. The wetland was designed to cater for the increased stormwater runoff from the extension of Orrong Road. Its dual purpose was to provide an area for sedimentation of particulate material from the Black Creek Branch Drain and to provide improved habitat, with water depths and island heights especially built to cater for the needs of various water birds. The site was heavily infested with watsonia, with 100% coverage at some locations. The watsonia was removed by 'peeling' the weeds off the surface with machinery, which was very successful. Some problems were experienced early in the construction phase after it was discovered that the soil pH necessitated soil amendment and a re-consideration of plant species. Macroinvertebrate monitoring has shown that a number of sensitive insects are present, which are indicative of improved water quality. The City of Canning received a grant from Nestlé to install interpretive signage at the site that will explain aspects of this ecological system. In addition, Park Engineers Pty Ltd were supplying resources to construct a viewing platform.

## 6.2.11 Detention and retention basins

Detention and retention basins were developed principally for stormwater quantity control. It is only in recent times that many of these basins have been designed and retrofitted for use close to runoff sources, for both stormwater quantity and quality management (Water and Rivers Commission, 1998a). Detention basins retard flows by holding water and releasing it to the downstream system over a longer period, whereas retention basins are an end point for stormwater flow, which infiltrates and evaporates from the basin.

Regional detention and retention basins have been used extensively in urban development to attenuate urban runoff peaks for flood protection of downstream areas. They generally fall into the category of in-transit control measures. The attenuation of stormwater runoff has the environmental benefit of reducing erosion of natural creeks by controlling discharge rates. There are opportunities for retrofitting basins to provide water quality and habitat enhancement functions. For example, the banks of basins can be reshaped and graded to a gentle slope, the basin revegetated with local native plant species, and logs or ceramic pipes installed to provide habitat for frogs. Guidelines for building frog-friendly habitat are provided by the WA Museum's Alcoa Frog Watch Program (<<http://www.museum.wa.gov.au/frogwatch>>). To provide a suitable grade for revegetation, it is recommended that banks be graded to a maximum slope of 1:4. Limited space constrains opportunities for providing gentle slopes. However, steep slopes can be retrofitted through the use of techniques such as terracing or by combining the battering with organic matting or other soil reinforcement materials that assist vegetation establishment. For public safety, it is recommended that banks of water bodies be graded to no steeper than 1:6.

More information about basins is provided in Chapter 9.

### Example 8

The Burges Street sump in Geraldton was a fenced-off block filled with weeds, typical of other stormwater sumps in the region. Remediation works were undertaken at the Burges Street sump to establish a demonstration site for future sump developments within the City of Geraldton and the Shire of Greenough. In addition, it was also intended to improve the quality of the stormwater that entered the groundwater. Ribbons of Blue Water Watch coordinated the project, which involved various groups from the community. Mission Employment Work for the Dole crew removed plants that impacted negatively on the sump (such as tamarisk and sunflowers) and posed health risks to the wider community (such as peppers and bulrushes). The City of Geraldton provided machinery and crew to remove and replace the contaminated soil that was further analysed by the Department of Environment. The sump was landscaped with rocks and recycled timber in terraces and a pool safety fence was erected to replace the existing chain mesh fence, thus improving the aesthetics of the area. Beachlands Primary School students planted 'sump friendly' trees and sedges. A floating sedge raft was installed, which provides habitat for frogs and filters nutrients from the stormwater. When water levels rise in the sump, the raft rises with the water, which ensures that the sedges remain in the water column no matter what the water level is. The result is a clean sump that provides a healthy environment for aquatic life such as tadpoles and water beetles. It provides an educational resource for water monitoring and environmental studies to be used by schools and it promotes community awareness about the Ribbons of Blue Water Watch Clean Drains Project.



*Figure 15a. Burges Street sump, Geraldton, before rehabilitation works. (Photograph: Department of Environment, 2003.)*



*Figure 15b. Burges Street sump, Geraldton, after rehabilitation works. (Photograph: Department of Environment, 2003.)*

### 6.2.12 Retrofitting existing permanent water bodies

Permanent water bodies are often constructed due to the public's attraction to views of open water. However, construction of permanent water bodies, such as artificial ponds and lakes and modified natural wetlands, is generally not recommended due to the commonly associated water supply, water quality and public health issues. Ponds and lakes can become breeding grounds for mosquitoes and midges or become infested with algae. These problems may be a result of poorly designed systems or high nutrient inputs from the catchment to the water body. Poor design can create stagnant, shallow, warm water, which provides ideal conditions for breeding of disease vector insects. Construction and modification of permanent water bodies may disturb acid sulfate soils, generating large amounts of sulfuric acid and leaching contaminants naturally occurring in the soils, such as arsenic, aluminium and heavy metals. The water level of some permanent water bodies is artificially maintained during the dry season by topping up with groundwater, which is an inefficient use of water resources. If the groundwater pumped into these

lakes and ponds is nutrient rich or contaminated with other pollutants, it can cause further water quality problems.

A number of in-system management measures are available to improve the water quality, health and environmental value of existing permanent water bodies, including artificial and modified natural systems. A commonly used intervention method is flow modification, for example topping up lakes, transferring water between lakes or periodically drying out lakes. Other methods include altering the shape or depth of the water body, excavating sediment deposits and planting or harvesting vegetation. Aerators, amended soils, oxygenation, ultrasonic devices and bioremediation methods have been trialled to treat water bodies that have poor water quality. These remediation techniques should be part of an integrated approach that determines the causes of the water quality problems, and then seeks to remove these causes.

It is important to identify pollutant sources to select the best approaches to managing the water body. Different approaches are required depending on whether the pollutants are derived from the catchment or if there is an internal supply of pollutants from the sediments. Processes such as mixing and stratification also need to be considered. Good data collection helps to correctly identify the causes of water quality problems, as well as assess the effectiveness of any remedial action taken. Remedial actions can have negative effects if they are applied incorrectly or without a good knowledge of the overall system, for example:

- Topping up lakes with bore water that is high in nutrients can result in further water quality problems.
- Changing water levels or water salinity can be detrimental to existing vegetation.
- Removing aquatic vegetation can create conditions suitable for serious algal blooms.

Priorities and measures for catchment management and treatment train approaches to pollutant loads can be addressed through the development of stormwater management plans. See Chapter 5 for information on the development of stormwater management plans. Non-structural measures to reduce pollutant sources throughout a catchment are provided in Chapter 7. Controlling fertiliser inputs, which commonly enter lakes and ponds through runoff from surrounding parks and gardens, is essential in reducing the occurrence of algal blooms. For information on best management of parks and gardens, see Section 2.2.7 of Chapter 7. Structural measures to reduce pollutant loads at-source, in-system and end-of-pipe are discussed in Chapter 9.

Modification of natural wetlands must comply with the wetland management category objectives, relevant legislation (including the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* and the environmental harm and unauthorised land clearing provisions of the *Environmental Protection Act 1986*) and any approved wetland management plans. Information about the management of natural wetlands is provided in *A Guide to managing and restoring wetlands in Western Australia* (Department of Environment, Department of Conservation and Land Management and Department for Planning and Infrastructure, in preparation), available at <<http://wetlands.environment.wa.gov.au>>. Information about the management of natural waterways is provided in the *River Restoration Manual* (Water and Rivers Commission / Department of Environment, 1999-2003), available at <<http://waterways.environment.wa.gov.au>>.

**Physical modification** of an artificial or previously modified water body can help improve its health. The system can be changed to an ephemeral system by removing impermeable lining, ceasing additions of water during the dry season, or raising the basin invert so that it does not intersect the groundwater table. By allowing the water body to dry out, as occurs with many natural wetland systems, algal and nuisance insect problems can be reduced. Direct stormwater discharges (i.e. via pipes or constructed channels) into the water body should be avoided and runoff overflow should only enter water bodies by overland flow paths across vegetated surfaces, to filter out much of the organic matter and nutrients before it reaches the

main water body. More information about vegetated filter strips and swales is provided in Chapter 9.

Most aquatic fauna and most important bio-chemical processes that promote healthy nutrient cycling depend on the presence of sufficient dissolved oxygen concentrations in the water column. When dissolved oxygen levels are high, aerobic decomposition and recycling processes can function efficiently to break down organic matter and remove nutrients from the system. Under low oxygen conditions, nutrients are released from the sediments, which can fuel phytoplankton blooms.

Water bodies may become deficient in oxygen through incomplete mixing, such as stratification caused by temperature gradients, which reduces the transfer of oxygen from the air-water interface to deeper waters. Another common cause of poor oxygen concentrations is high biological or chemical oxygen demand, such as respiration of an algal bloom at night. The simultaneous combination of these two conditions is often responsible for the worst cases of hypoxia.

**Aeration and oxygenation** devices seek to address this lack of oxygen in two ways: directly increasing oxygen concentrations of the water, or encouraging transfer of oxygen from the atmosphere. An example of the former is hypolimnetic oxygenation, which is currently used in the Canning River above the Kent Street Weir (see Example 9). The second process is much more commonly used and can be performed by passive structures, such as riffles, cascades and waterfalls, or by mechanical devices (see Example 10). Mechanical devices can use a variety of ways to encourage mixing, such as: specially designed paddles or rotors; jets of water; curtains of bubbles rising from the bottom to encourage destratification; and spraying water into the air. Each situation needs to be assessed to ensure the selected device is appropriate and can achieve the desired goals. Additionally, aerators that encourage mixing can minimise still water that provides ideal conditions for mosquito and midge breeding, and which may favour the rapid growth of blue-green algae. The presence of sulfidic sediment such as iron monosulfide should be investigated prior to undertaking an aeration or oxygenation project due to the potential acidification that can occur when these sediments are exposed to oxygen.

#### **Example 9**

Oxygenation trials were undertaken on the Swan and Canning Rivers with the aim of modifying the river conditions so that the occurrence of phytoplankton blooms was reduced (Swan River Trust and Water and Rivers Commission, 2000). These systems have sediment derived nutrients (as well as nutrients from drainage inputs). Salinity stratification occurs in the Swan River, whereas temperature stratification occurs in the Canning River, which is a freshwater system above the Kent Street Weir. Stratification reduces mixing of oxygen from the surface layer to the deeper layer of the water column, which can result in low oxygen or anoxic conditions in the bottom waters. The two oxygenation plants installed on the bank of the Canning River and the mobile barge unit used on the Swan River worked by pumping low oxygen water out of the river, adding pure oxygen and then returning the high oxygen water to the bottom of the river. The advantage of this approach was that it minimised disturbance to bottom sediments or stratification, and allowed the oxygenated water to be directed to the river bottom where it is most required. The Canning project site was initially the pilot plant to research the technique and assess its potential application to the Swan River. Oxygenation in the Canning River Kent Street Weir pool achieved significant increases in oxygen concentrations, reduced nutrient concentrations and positively impacted aquatic fauna, but did not prevent algal blooms (Swan River Trust, 2003b). Further information on the Swan-Canning Cleanup Program oxygenation trials is provided in River Science Issues 13, 14, 15 and 18, available at <<http://www.swanrivertrust.wa.gov.au>>.

### Example 10

Tomato Lake is a seven-hectare former natural wetland situated in Kewdale, City of Belmont, which has been highly modified for stormwater management purposes. It is surrounded by nine hectares of parks and recreation reserve. The City of Belmont has been trialling two new aeration systems in Tomato Lake over a two-year period between the summers of 2003 and 2005 to improve water quality. The aerators operate for 12 hours per day in winter and 24 hours per day in spring, summer and autumn. The aerators replaced an original agitator unit that was installed in the lake in 1999, as the aerators were more cost effective.

Within four weeks of installation of the aerators, visibility in the water improved from almost zero, to being able to see the bottom of the lake in shallow areas. The night time dissolved oxygen levels also increased from 3.6 to 10.3 mg/L. Some of the benefits to be gained from installing the aerators include:

- Circulation of the lake water
- Increased oxygen in the water for aquatic organisms
- Reduced anaerobic (low oxygen) decomposition and therefore reduced odour
- Reduced water temperature and reduced evaporation
- Reduced potential for Botulism bacteria, which thrive in warm temperature and low oxygen conditions
- Reduced incidence and severity of blue-green algae
- Improved water clarity
- Removal of some excess nutrients (primarily nitrates)

The effectiveness of the aeration systems in Tomato Lake will be monitored through the City of Belmont's Tomato Lake Water Quality Monitoring Program. Data has been collected since 1998 to determine the effectiveness of water quality improvement initiatives such as the installation of aerators, bacterial application for nutrient reduction and foreshore revegetation.

**Absorbent materials** can be used to bind dissolved nutrients, reducing their availability to phytoplankton. Rare earth modified clays (such as Phoslock™, see Example 11) and hydrotalcites (which may be synthesised from industrial waste materials such as red mud and fly ash) are the most suitable materials for removing phosphorus from lakes or impounded rivers (Douglas *et al.*, 2004). However, it would have to be demonstrated that there would be no significant human health or ecotoxicological effects from its intended application. The cost of this method of treatment may be high, depending on the scale of application and selected absorbent, so the causes of water quality problems need to be well understood to ensure that this is the most appropriate method of treatment.

Zeolite clays are known for their capacity to bind nitrogen in the form of ammonium. Factors that have been demonstrated to determine the uptake capacity of ammonium by zeolite include the physical and chemical properties of zeolite, such as grain size, porosity, pH, the presence of competing species and the exchangeable ion within the zeolite. The main advantage is their porous structure that allows colonisation by bacteria, which in the right environment assist in the conversion of ammonium to nitrogen as gas that is released to the atmosphere.

### Example 11

Phoslock™ was developed to prevent the release of sediment derived phosphorus. A slurry of Phoslock™ was sprayed on the water surface of an 800 metre reach of the Canning River during January 2000. The trial demonstrated that Phoslock™ was effective in removing dissolved phosphorus from the water column and sediments (Swan River Trust and Water and Rivers Commission, 2001). The clay particles bind dissolved phosphorus as they settle through the water column and form a reactive layer on the sediment that continues to bind phosphorus. Further information on the Phoslock™ trials undertaken as part of Swan-Canning Cleanup Program is available in River Science No. 17 at <<http://www.swanrivertrust.wa.gov.au>>. Phoslock™ has not been tested in natural wetlands, so the potential impacts, such as modification of the benthic environment through blanketing and changing the physio-chemical environment and habitat, have not been assessed. Therefore, Phoslock™ currently is not recommended for use in natural wetlands.

**Bioremediation** (or bio-augmentation) involves either creating conditions that encourage the growth of natural (in-situ) bacteria or adding high concentrations of bacteria to a water body in order to consume nutrients and out-compete algae for their food source. The natural bacterial population in a water body can be severely reduced by a number of factors such as competition for their food sources by excessive algal growth or deoxygenation during algal decomposition. The conditions contributing to high algal concentrations need to be well understood prior to selecting bioremediation as a management tool.

Broadcasting bacteria into the natural environment may be ineffective if the conditions causing their depletion are not addressed. Additionally, adding large amounts of bacteria would substantially increase the oxygen demand and is not a suitable approach if there are already problems in the water body associated with low dissolved oxygen levels. Bacteria is already present in water bodies and some enhancement of their growth conditions is usually all that is required in order to restore a healthy population. For example, low aerobic bacterial numbers may be due to low oxygen concentrations associated with excessive nutrient loading. Aerobic bacterial numbers should naturally increase, without additives, if the nutrient supply is addressed. In some cases where toxic compounds that are difficult to break down are present, for example due to industrial pollution, specialised bacteria can be added that have been developed to treat these compounds. Research into the long-term effectiveness and maintenance requirements of bioremediation to improve the quality of water bodies is required. (Robb, M., 2005, pers. comm.<sup>18</sup>)

### Example 12

A bioremediation trial was undertaken at Tomato Lake by the City of Belmont to address toxic blue-green algal blooms at the lake, which were common occurrences. The lake was fed with high concentrations of nutrient-consuming bacteria four days per week every summer and aerated from 1999 to 2003. A report on water and soil quality at Tomato Lake is prepared every six months. Significant reductions in total nitrogen concentrations have been measured during this period. Monitoring through visual observation found that the severity and duration of blue-green algal blooms were significantly reduced and the abundance of aquatic fauna increased. Water clarity improved dramatically, from black water with virtually no visibility to clear water with the bottom of the lake visible. The bacterial mix applied to the lake was also able to break down hydrocarbons that washed into the lake from road drains. Bacteria application ceased in 2003 and was replaced with a more cost effective enzyme product that boosts naturally occurring bacteria.

<sup>18</sup> Personal communication with Malcolm Robb, Principal Environmental Officer, Department of Environment, 2005.

## 6.3 Performance monitoring and maintenance

### Monitoring

The pollutant removal effectiveness and performance of structural controls is not well understood in Western Australia, particularly on the Swan Coastal Plain. This is because most research has been conducted in the eastern states, where the climate and hydrogeology is very different to that of the Swan Coastal Plain. The highly permeable sands, high amount of dissolved nutrients and pollutants, and shallow groundwater experienced in many parts of the Swan Coastal Plain are very different to the conditions experienced in the eastern states. Therefore, the performance curves that have been developed in the eastern states cannot be directly applied to the majority of urban development in Western Australia.

The Cooperative Research Centre for Catchment Hydrology has developed a *Model for Urban Stormwater Improvement Conceptualisation* (MUSIC), which is based on this eastern states research, to assess the performance of a treatment train in an urban context. However, the researched performance curves embedded in this model focus on physical processes that primarily remove particulates. Further research and development is required for consideration of dissolved nutrients, where biological processes are likely to be more relevant (Fletcher *et al.*, 2001; Taylor *et al.*, 2005). The hydrological component of the model is based on a hill slope process description that cannot be applied on the Swan Coastal Plain, which is characterised by a dual groundwater system (one perched ephemeral system and a deeper perennial system). Modifications to the model are being developed by the Department of Environment, in conjunction with the Cooperative Research Centre for Catchment Hydrology, to better reflect the characteristics of the Swan Coastal Plain.

The evaluation of the performance of stormwater management measures, especially those implemented as retrofits, should account for occurrences upstream of the system that could overload the system and make it appear to fail. For example, sediment removal systems should be installed before infiltration systems, to reduce the likelihood of blockage of the infiltration systems. These risks should be understood and not become deterrents. They highlight the importance of also undertaking source controls. Monitoring of stormwater treatment measures will also need to consider the impact of groundwater quality on the performance results.

Not only will many structural controls have a direct effect on water quality improvement, but they can also add value to a system, for example by improving the aesthetics of an area. This can increase the value of the system to the community and result in indirect benefits, such as reduced littering and increased protection of the area by local environmental groups. These indirect benefits could also be monitored, for example by monitoring changes to property values or conducting surveys of local residents and community groups.

Given that retrofitting in Western Australian has been limited to date, a performance monitoring and evaluation plan should be developed for all projects during the planning stages. Performance monitoring will not only assist the project team in determining whether their desired project outcomes have been met, but it will also be useful for other stormwater managers when preparing their own retrofitting projects. Chapter 10 provides a process for determining how to monitor and evaluate structural and non-structural controls.

### Maintenance

Maintenance requirements, from the construction phase through to the expected lifetime of the technique/s, need to be factored into the design phase of a retrofit project.

Stormwater treatment measures must be managed over the implementation phase, particularly at development sites where building activities can result in overloading of the system with sediment and

other pollutants. For example, experience from the eastern states shows that the installation and planting of swales should not be completed until after properties have been developed and building construction completed.

A management plan that details maintenance issues and associated timelines, costs and responsibilities, such as plant replacement, weed control and litter and sediment removal, needs to be prepared. Where applicable, a weed management program, from site preparation to follow-up targeted weed eradication, is strongly recommended. Refer to Chapter 7 for information on maintenance of gardens and reserves (Section 2.2.7), litter management (Sections 2.2.3 and 2.2.4) and sediment management (Section 2.1.1).

### **Example 13**

Maintenance is a controversial issue with some local governments and asset managers. The uncertainty about ongoing maintenance costs is a deterrent to many developers and local councils in WA to implement WSUD. The Cooperative Research Centre for Catchment Hydrology has produced a report on the costs of maintenance and community acceptance of WSUD from experience in Lynbrook Estate (Victoria). Costs of maintaining vegetated swales reduce as the system becomes more self-sustaining. For example, the maintenance costs associated with a vegetated swale dropped from \$9.00/m<sup>2</sup>/year to \$1.50/m<sup>2</sup>/year<sup>19</sup>, with a similar pattern of reduction in costs being expected for the vegetated sections of constructed wetlands (Lloyd *et al.*, 2002). Some maintenance costs can remain constant over time, such as the costs of maintaining a grassed swale at \$2.50/m<sup>2</sup>/year<sup>20</sup>. Community surveys in Victoria showed that 90% of the community were supportive of the integration of landscaped and grassed bioretention systems into the landscape for stormwater purposes (Lloyd *et al.*, 2002). Furthermore, surveys have shown that 60% of the community would be willing to pay extra for WSUD implementation, such as a fee of \$25/year (Lloyd, 2002).

Structural techniques, such as side entry pits and gross pollutant traps, require regular inspection and monitoring to determine the optimal frequency and timing of cleaning. Maintenance is essential to ensure the device does not become a source of pollutants. For example, nutrients in an organic form can be converted to a bioavailable form in the anoxic environment of an unmaintained trap. Remobilisation of trapped pollutants or bypassing due to a lack of storage volume in an unmaintained trap could also result in the supply of pollutants to the stormwater system. Disposal of effluent / wastes from cleaning activities also needs to be considered. Such wastes should be assessed to determine the correct form of disposal, in consultation with operators of liquid and soil waste disposal facilities. Wastewater from maintenance activities should not be discharged to the stormwater system.

### **Example 14**

The City of Canning reviewed its gully educting program. Its study found that the educted liquid that was returned to the gullies (standard practice in Australia) was often concentrated with nutrients, metals and hydrocarbons. The City of Canning (through contractors) now disposes all produced solid and liquid wastes to landfill (Morrison, P., 2003, pers. comm.<sup>21</sup>). The City also commissioned a report for its entire catchment, compiling a rating matrix and prioritising sub-catchments for gross pollutant production.

<sup>19</sup> From Lloyd *et al.* (2002), from maintenance costs records from Kinfauns Estate, Victoria.

<sup>20</sup> From Lloyd *et al.* (2002), based on figures from VicRoads.

<sup>21</sup> Personal communication with Peter Morrison, Senior Environmental Health Officer, City of Canning, 2003.

Some pollutant traps may be at risk of filling with tree roots. Access to clean and maintain the device should be considered when evaluating treatment options. If you cannot clean and maintain a device, then it may not be suitable for installation. However, alternatives that provide pre-treatment can reduce the need for maintenance, such as a gross pollutant and sediment trap installed before the entry to an infiltration system. Alternatively, the device may require periodic removal and replacement.

Wetlands and infiltration systems (such as detention basins) need regular inspection for sediment build-up and, if necessary, removal of this sediment. On-line vegetated systems (i.e. systems that are part of the main stormwater conveyance network) need to be periodically inspected to ensure that prolific growth of plants does not block the channel or choke the system. Branches or plants that are dislodged during high flows and transported downstream may need to be cleared if they become trapped and form a debris dam or block a culvert.

Maintenance activities present an opportunity for community education, such as involving school or community groups in cleaning gross pollutant traps (where safety concerns can be addressed), or publicising the statistics of materials removed from the trap.

See Section 2.2.2 of Chapter 7 for more information on maintenance of the stormwater network. Maintenance requirements of structural controls are outlined in Chapter 9.

### **Limit the use of lawn and avoid using fertilisers and pesticides around water bodies**

It is essential that water bodies are not surrounded by highly fertilised lawns grown to the water's edge. Green lawn often requires large amounts of fertiliser to maintain aesthetic appeal. Fertiliser use may result in the direct application of nutrients to the water body by either being washed directly into the water from lawn surface runoff or by being inadvertently applied within the fringe area, potentially exacerbating nutrient problems. Other lawn maintenance requirements such as mowing can result in grass clippings entering the water, which subsequently decay and add further nutrients to the system. Local native plants are a cost effective, aesthetically pleasing and sustainable alternative to lawn around the perimeter of the water body. Most native plants require very little extra nutrients in the form of fertilisers, little extra watering (except in initial establishment phases) and will provide habitat for native fauna. If lawn is an essential feature of the surrounds of a waterway or water body, it is recommended that a Nutrient Management Plan be written. It is also important to limit pesticide use near water bodies. See *Herbicide use in wetlands* (Water and Rivers Commission, 2001), which outlines acceptable pesticide use near waterways and wetlands. See Section 2.2.7 of Chapter 7 for more information about maintenance of gardens and reserves.

## **7 Case studies**

### **7.1 Town of Mosman Park - Total Water Cycle Project**

#### **Project description**

A number of projects were undertaken by the Town of Mosman Park to address decreasing groundwater quality due to salt water intrusion and flooding problems due to inadequate stormwater management. The objectives of the projects were to maximise infiltration across the superficial aquifer, reduce demand on the aquifer, minimise local flooding and minimise pollution of groundwater and the Swan River. These projects were supported by policy statements and local laws to provide the regulatory framework for adopting the Council's approach to water resource management.

The Town of Mosman Park is located on the Leighton Peninsula between the Indian Ocean to the west and the Swan River to the south and east. The Town has a total area of 4.5 square kilometres. One square

kilometre is public land vested for the purposes of recreation and much of this land is irrigated for recreational activities, such as the Mosman Park Golf Course at Chidley Point. It is predominantly residential with a density of R20 or less, with a commercial area along Stirling Highway.

The Town is located on highly permeable sands of the Cottesloe Soils. Alluvial soils are found along foreshore areas and are generally grey sandy deposits.

There are 39 sub-catchments within the council and a series of natural surface water channels that travel along the original dune valleys. These channels have been the cause of most local flooding problems because designated flood paths were not established. The superficial freshwater aquifer is perched above a saltwater lens. The freshwater source is rainwater that has infiltrated through the sandy soils or has traversed along the peninsula from the north, while the salt water connects the Swan River and the Indian Ocean beneath the peninsula. There is a thin layer of sedimentary clays on the eastern side of the peninsula, which provides an interlayer between the lenses, however most of the fresh water floats directly on the saltwater lens. The aquifer varies in thickness from 16 metres in the area beneath Memorial Park, to less than 2 metres adjacent to the river and ocean. The freshwater superficial aquifer at Leighton Peninsula is a unique and finite resource. If too much water is withdrawn from the superficial aquifer, salt water will intrude from the ocean and river into the groundwater.

The Council also wanted to ensure that any water entering the aquifer remains clean and unpolluted. Pollution sources could potentially include fertiliser runoff from golf courses, parks, gardens and domestic use. Other pollutant sources may include past industrial land uses, landfill, runoff from road pavements and leakage from underground pipes and tanks.

The stormwater was previously collected and directed into stormwater pipes leading to outfalls into the Swan River. The infrastructure was limited to grated gullies, undersized pipe networks and traditional sumps. A number of the sumps had been filled in due to development pressure. There were pipe networks under private property without sufficient protection by easement and little consideration for design criteria such as hydraulic gradelines, etc. There were 16 river outlets and 22 infiltration basins and compensating basins. There were no gross pollutant traps, but there were many soakwells within verges and carparks. The major problem for the community was the resultant localised flooding due to the insufficient capacity of the stormwater management system.

### **Approaches implemented**

The implemented strategies were:

- Conduct an audit and create a database of all drainage and irrigation assets. This information was also placed on the Council's Geographic Information System.
- Reduce water use by monitoring irrigation systems to optimise the efficiency of turf watering regimes and replacing inefficient irrigation systems.
- Maximise stormwater infiltration to increase aquifer recharge by installing retrofit infiltration devices across the municipality.
- Seek alternative water supplies, including investigating wastewater reuse.
- Decrease local flooding by retrofitting or replacing traditional drainage structures.
- Maximise pollutant capture by utilising both at-source and in-system controls and end-of-pipe methods.

### Maximising infiltration:

The new strategy adopted by the Council was to infiltrate stormwater at as many sites as possible. On-site infiltration was included in the Town of Mosman Park local laws. A specially designed combination grate and side entry gully placed over a deep soak well was installed in the highest priority catchments with respect to incidence of local flooding (see Figure 16). The combination gully/soakwells continue to be installed as the road network is resurfaced. These systems were designed to meet the requirements of a one in five year storm event of ten-minute duration. This accommodates the soakage requirements for 1 m<sup>3</sup> of soakage volume per 80 m<sup>2</sup> of pavement area, assuming 100% runoff. The combination gully/soakwell allows capacity to be retrofitted into the catchment within existing pavements. This minimises service clashes and ensures that discharge from a full unit does not escape from the pavement area flood path.

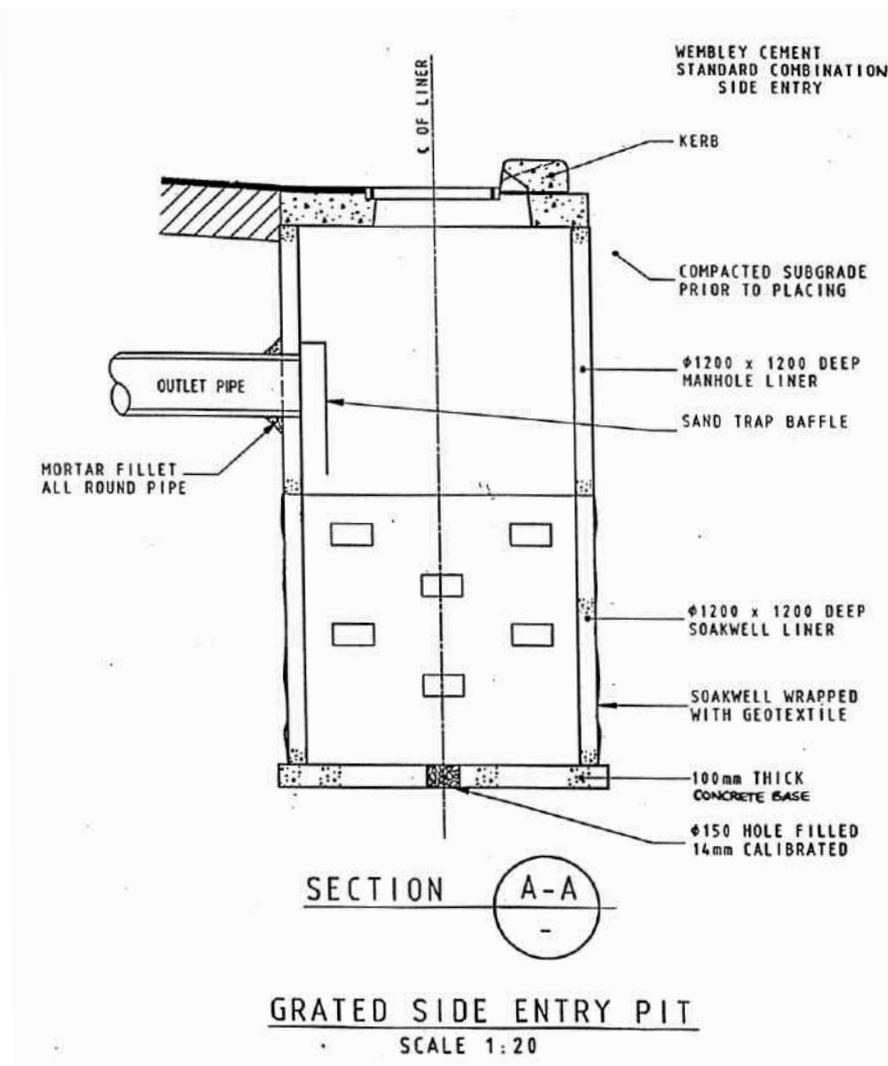


Figure 16. Standard combination gully / soakwell.

In addition to the combination gully/soakwells, either traditional sumps, subterranean infiltration buffer banks, or shallow swale infiltration basins were installed in parks, reserves and wide road verges to maximise infiltration across the council. Combinations of the above systems were sometimes used. For example, a subterranean infiltration facility was installed at Centenary Park, Mosman Park (see Figures 17 a and b) and a shallow swale recharge bore was constructed in Stringfellow Park (see Figure 18).



Figure 17a. Original sump, Centenary Park, Mosman Park. (Photograph: Martyn Glover, Town of Mosman Park.)



Figure 17b. Completed subterranean infiltration facility, Centenary Park, Mosman Park. (Photograph: Martyn Glover, Town of Mosman Park.)



Figure 18. Shallow swale, Stringfellow Park, Mosman Park. (Photograph: Martyn Glover, Town of Mosman Park.)

Other related projects include:

- a gross pollutant trap trial,
- a catchment pollution discharge trial, and
- installation of pollutant traps on all river outlets.

Additionally, the Town of Mosman Park was involved in the development of the *Regional Strategy for Management of Stormwater Quality*. The Strategy was developed by the Western Suburbs Regional Organisation of Councils (WESROC), comprising the Cities of Nedlands and Subiaco, Towns of Claremont, Cottesloe and Mosman Park, and the Shire of Peppermint Grove. In 2001, WESROC and Town of Cambridge identified the need for better management of stormwater quality and a need to address the associated strategic issues on a broad catchment basis across traditional local authority boundaries. A regional strategy for stormwater quality management was developed to draw together issues concerning the collection and management of stormwater over a 6400 hectare area of Perth's established western suburbs, with the aim of managing the quality of stormwater discharging to the Swan River, Indian Ocean, local wetlands and the groundwater system.

The strategy made two key recommendations. The first key recommendation was the implementation of an integrated monitoring program targeting identified priority catchments, to establish baseline stormwater quality data from which suitable water quality criteria and targets could be established. The second key recommendation was the implementation of a regional community water quality education program.

### **Results / achievements**

The projects resulted in:

- A 10-30% reduction in turf irrigation over the summer months.
- Infiltration of 95% of all stormwater in the municipality. Infiltration is now evenly spread across the peninsula and discharge to the Swan River has been minimised.
- Decreased incidents of local flooding. There were twenty-one local flooding sites shortly after the January 2000 storms. This was reduced to only five local flooding sites in March 2003. By March 2005, all of the flooding issues had been resolved.
- Achievement of the target to decrease direct stormwater discharge to the Swan River to less than 5%. All river outfalls are now serviced by pollutant traps. Recent monitoring in Mosman Bay has indicated that the pollutant levels in the discharge have been reduced by more than 90% for all pollutants. Results from the Caporn Street catchment trial has indicated that the Council's treatment train of street sweeping, interceptor gully / soakwells and end-of-pipe gross pollutant traps removes 99.5% of particle bound pollutants from the stormwater.
- Longer term monitoring will be required to determine the project's impacts on stormwater and groundwater quality. It is anticipated that the completion of the WESROC stormwater/groundwater study in 2006 will provide the base information to establish water quality criteria.

### **Challenges**

The three major challenges were to:

- Improve the groundwater quality, to secure the future quality of Council parks and reserves.
- Provide sufficient retrofitted infiltration facilities, to minimise local flooding.
- Convince the community that the work was necessary and needed their input to succeed.

## Resources

The costs of the project to date are included in Table 3.

**Table 3: Construction and maintenance costs of works undertaken under the Town of Mosman Park Total Water Cycle Project**

Year	1995/96	1996/97	1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	Average
<b>Maintenance</b>									
<b>Drainage</b>	\$10,353	\$12,694	\$21,666	\$15,027	\$33,620	\$30,557	\$47,272	\$37,887	<b>\$26,135</b>
<b>Gully Cleaning</b>	\$6,717	\$4,459	\$4,282	\$11,214	\$26,766	\$13,485	\$22,221	\$20,490	<b>\$13,704</b>
<b>Sumps</b>	\$11,713	\$6,004	\$6,327	\$2,129	\$24,349	\$13,635	\$22,311	\$20,020	<b>\$13,311</b>
<b>Road Sweeping</b>	\$20,868	\$19,727	\$21,985	\$24,282	\$24,931	\$23,491	\$26,806	\$19,268	<b>\$22,670</b>
<b>Bores</b>	\$163	\$0	\$640	\$6,868	\$15,269	\$9,117	\$11,257	\$7,468	<b>\$6,348</b>
<b>Sub Total</b>	\$49,814	\$42,884	\$54,900	\$59,520	\$124,935	\$90,285	\$129,867	\$105,133	<b>\$82,167</b>
<b>Construction</b>									
<b>Drainage</b>	\$33,722	\$47,875	\$49,994	\$19,684	\$37,471	\$56,590	\$29,188	\$50,750	<b>\$40,659</b>
<b>Sumps</b>	\$9,275	\$0	\$15,598	\$159,555	\$83,229	\$55,707	\$35,318	\$17,305	<b>\$46,998</b>
<b>Bores/Irrigation</b>	\$38,478	\$18,184	\$197,473	\$211,025	\$24,120	\$34,342	\$206,326	\$35,000	<b>\$95,619</b>
<b>Sub Total</b>	\$81,475	\$66,059	\$263,065	\$390,264	\$144,820	\$146,639	\$270,832	\$103,055	<b>\$183,276</b>
<b>Total</b>	<b>\$131,289</b>	<b>\$108,943</b>	<b>\$317,965</b>	<b>\$449,784</b>	<b>\$269,755</b>	<b>\$236,924</b>	<b>\$400,699</b>	<b>\$208,188</b>	<b>\$265,443</b>

Note: This chart does not include upgrades that were part of roadworks. It is estimated that this was an additional \$370,000 of expenditure for associated gullies, manholes and pipework.

The individual maintenance interval and costs per unit are:

- Sweeping – monthly - \$150/km/year
- Gully eduction – bi-annually - \$28/gully/year
- Sump cleaning – annually - \$300/sump/year
- Infiltration facilities – annually - \$250 to \$1200/year, dependent on size of facility

## References / further information

- Glover, M. 2001, *Battling Salinity: The Holistic Approach – A case study at the Town of Mosman Park*.
- Glover, M. and Chalmers, L. 2003, *Town of Mosman Park – A total water cycle approach to reduce water use and improve stormwater management*.
- Highman, S. 2004, *Caporn Street, Mosman Park – A Total Catchment Review*, Final Year Thesis, Faculty of Engineering and Computing, Curtin University of Technology.
- JDA Consultant Hydrologists 2002, *Regional Strategy for Management of Stormwater Quality for Western Suburbs Regional Organisation of Councils*, Report to WESROC.
- Martens, S., Davies, J., O'Donnell, M. and Zuvela, P. 2005, 'Monitoring for Total Water Cycle Management: The WESROC Experience', Paper presented to the *2005 Public Works Engineering State Conference*, Perth, Western Australia.

## 7.2 Busselton Stormwater Management

### Project description

The Lower Vasse River and the Vasse-Wonnerup wetland system near Busselton experience very poor water quality. The Lower Vasse River has been greatly changed from its original state through alterations to flow, widening of the channel, removal of native vegetation and development in the catchment. Most of the rivers in the Geographe catchment once flowed through the Lower Vasse River and the Vasse-Wonnerup wetland system, but many have been diverted via drains directly to Geographe Bay. Floodgates were also installed to prevent flooding. River diversion and construction of floodgates has decreased flushing, resulting in an accumulation of nutrients. A Geographe Catchment Management Strategy was developed to address problems in the catchment (see Geographe Catchment Council, 2000).

Nutrient enrichment is the major issue for these systems, with the occurrence of severe algal blooms during the warmer months. The impacts of contaminants on waterways from urban areas is also an issue of concern for the local community. As part of the concentrated effort to address the cause of the water quality problems in the Vasse Estuary and River, the Shire of Busselton and GeoCatch upgraded the existing stormwater system to improve treatment of stormwater prior to discharging into waterways. The project focussed on implementation of best practice stormwater management techniques on stormwater drains in urban areas of Busselton (see Figure 19).

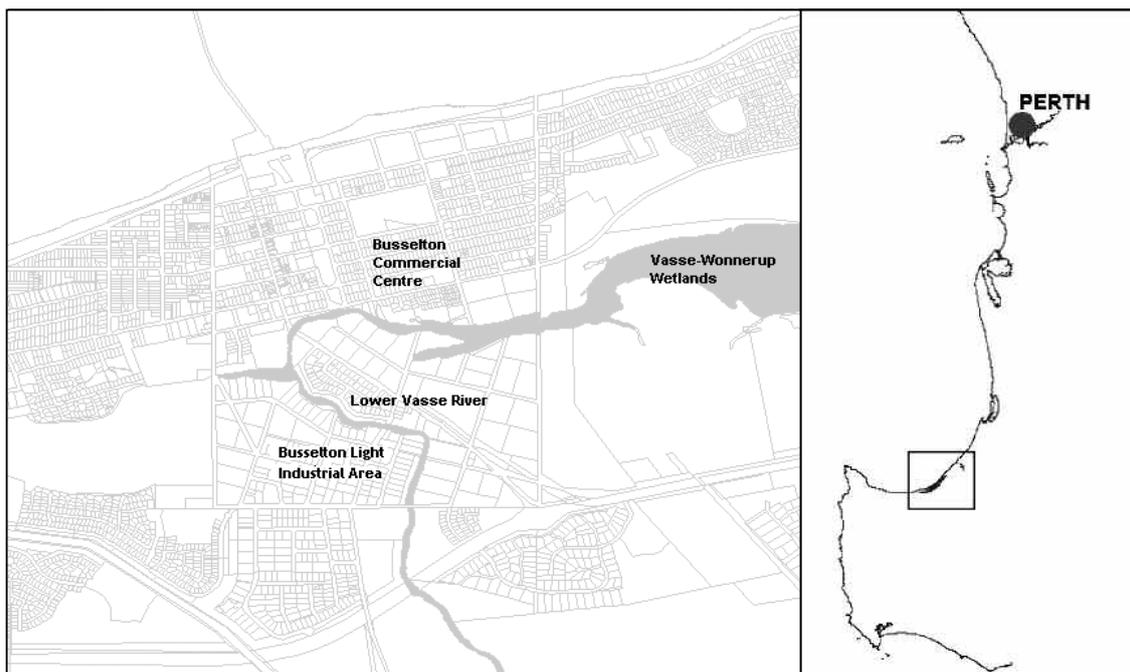


Figure 19. Busselton Stormwater Management Project Area.

The project area is on the Swan Coastal Plain where deep sands are the dominant soil type. The area is very flat, with groundwater generally close to the surface and most wetlands are expressions of the groundwater. The hydrology of the area has been greatly modified to allow the town of Busselton to develop on previously flood-prone land.

### Approaches implemented

Structural control devices were installed at 24 sites on stormwater drains that discharge to the Vasse River and Estuary system and out to Geographe Bay. The major structural control type implemented was construction of vegetated stormwater detention basins, which aimed to slow water movement, filter

nutrients and facilitate sediment deposition. Other structural controls included interceptor devices and separators to remove oils and grit from stormwater before it enters the river, vegetated swales, gross pollutant traps and river foreshore revegetation to intercept runoff from parkland. Upgrades and alterations to the stormwater network were also required to improve efficiency of the network and to divert stormwater through structural controls.

Raising community awareness of the impacts of stormwater on local waterways and how they can contribute to stormwater management was an important part of this project. Based on a successful project in the neighbouring Leschenault catchment, a Clean Drains campaign is being coordinated through the GeoCatch Ribbons of Blue Program. The aim of the project is to increase student and community awareness about street runoff and household drains that carry a range of pollutants into the rivers, wetlands and Geographe Bay. Through the use of a display and distribution of educational materials, greater recognition of the potential impacts of everyday activities is being promoted. Promotional material for the Clean Drains awareness campaign includes T-shirts, stickers, posters and fridge magnets with the slogans 'Don't let your Bay go down the drain' and 'Keep our Bay healthy – take care in the catchment'.

Stormwater information sessions and tours are available to all school classes in the catchment. Students learn about the difference between water movement in a naturally vegetated area and an urban area, and about the different types of pollutants carried in stormwater. They also learn about what they can do to help keep stormwater as clean as possible, and visit sites where structural controls have been installed. Students take home the messages to their families and friends.

Students also paint colourful designs including the words 'Drains to the Bay' or 'Clean Water Only' around drains. The bright, eye-catching designs draw people's attention to the stormwater issue and increase the students' awareness and ownership of the problem.

### **Results / achievements**

This project has become a demonstration initiative, providing many learning outcomes that can be shared with others. It has improved the capacity of the Shire of Busselton to manage stormwater throughout the shire, and to make improved recommendations to developers.

The major structural control type implemented was construction of stormwater detention basins. These basins were revegetated and are now well established, providing additional habitat for water birds in the local area.

Water quality monitoring of drains and basins was undertaken in 2002 to investigate the effectiveness of stormwater detention basins and to determine the levels of pollutants in stormwater. Monitoring of drains in 2003 aimed to determine levels of pollutants in drains without any structural controls installed, with the aim of guiding future management, and to further investigate the effectiveness of the Fairlawn Street detention basin. Year 11 Biology students from McKillop Catholic College assist with monitoring through the Ribbons of Blue Program to improve understanding of stormwater management issues.

Only the Fairlawn Street detention basin indicated significant pollutant removal effectiveness, with output concentrations of nitrogen, phosphorus and suspended solids generally lower than input concentrations. This was most evident for total nitrogen, where all samples in outflows were lower than those in inflows. Table 4 shows a comparison of average concentrations of total nitrogen, total phosphorus and total suspended solids in inflows and outflows for this detention basin. The Fairlawn Street detention basin differs from the others as it has an elongated shape and has more established in-stream vegetation. The pollutant removal effectiveness of the other detention basins cannot be fully assessed due to limitations of the monitoring program.

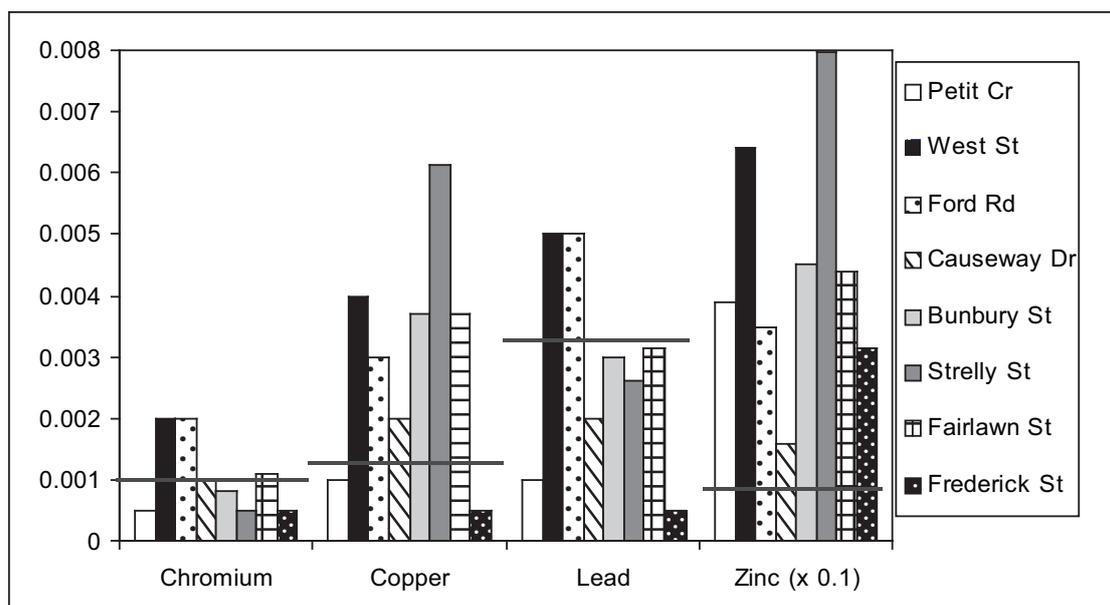
**Table 4. Comparison of nutrients and suspended solids in inflows and outflows for Fairlawn Street Detention Basin, Busselton**

Indicator	Average Inflow Concentration (mg/L)	Average Outflow Concentration (mg/L)	% Reduction
Total Nitrogen	2.5	1.3	48%
Total Phosphorus	0.09	0.07	22%
Total Suspended Solids	14.0	10.0	29%

The monitoring suggests that the desired shape for stormwater treatment basins is a widened drain with minimal permanent storage of water and maximum perennial in-stream vegetation, that is an ephemeral living stream. Retrofitting drains into living streams may therefore be preferable to building more detention basins in the Busselton area. The most effective systems for improving water quality entering Geographe Bay are probably the natural wetlands in the Busselton area. It may be a more efficient management option to protect and enhance the natural functions of the Busselton wetlands as the town expands, rather than constructing detention basins, for example, by re-establishing a well-vegetated wetland buffer.

Although nutrient levels were sometimes elevated during storm event sampling, overall nutrient concentrations were low to moderate for stormwater drains in the Busselton area. Stormwater contained undetectable or acceptable concentrations for most toxicants, including hydrocarbons, pesticides, volatile organic compounds and arsenic. Surfactants were detected in Frederick Street and Strelly Street drains, but no guideline is available for this parameter. While hydrocarbons were not detected, a distinct petroleum smell was noted at Fairlawn Street drain on several sampling occasions, which discharges opposite a service station. Hydrocarbons are very volatile and difficult to monitor, but it is important to continue to monitor their presence at this site.

Some heavy metal concentrations were of concern, particularly chromium, copper, lead and zinc (Figure 20). Most drains significantly exceeded the ANZECC and ARMCANZ (2000) copper guideline of 0.014 mg/L. West Street and Ford Road drains had elevated levels of chromium and lead. All monitored drains had zinc levels much higher than the ANZECC and ARMCANZ (2000) guideline of 0.008 mg/L. Targeting more awareness-raising efforts at businesses may be beneficial in managing this problem.



*Figure 20. Average heavy metal concentrations found in Busselton stormwater drains in 2002-03. Lines indicate guidelines for protection of aquatic ecosystems (ANZECC and ARMCANZ, 2000).*

## Challenges

The high water table in the Busselton area restricted the construction period for on-ground works to two months in late summer. It was difficult for the Shire of Busselton to complete all of the works in this short period, which increased the duration of the project. The high water table and space constraints in the existing developed areas also restricted the range of improvements that could be implemented.

## Resources

Under an agreement with the Water and Rivers Commission, the Federal Government's Coasts and Clean Seas program committed \$250,000 towards implementing the Busselton Stormwater Management Project. The Shire of Busselton managed the design and construction works, utilising \$170,000 of the funding. GeoCatch were responsible for project coordination, monitoring, revegetation activities and community promotional activities. Initially, this project did not include a budget for maintenance of the structural controls, which is a necessary project component. These funds were subsequently clearly allocated in the work plan.

This project received a WA Coastal Award in 2002 in the category of Outstanding Coastal Project.

## References / further information

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

Geographe Catchment Council 2000, *Geographe Catchment Management Strategy*, GeoCatch, Natural Heritage Trust and Water and Rivers Commission, Perth, Western Australia.

For further information, please contact the GeoCatch Network Centre, 1A/72 Duchess Street, Busselton, telephone (08) 9781 0111, or visit the Geocatch website <<http://geocatch.asn.au/>>.

## 7.3 Bayswater Main Drain Catchment

The North Metropolitan Catchment Group (NMCG)<sup>22</sup> has undertaken in-drain measures in the Bayswater Main Drain catchment with the aim of improving stormwater quality and creating habitat. The group has undertaken works at various sites throughout the catchment, including revegetating the banks and in-stream sections of the Bayswater Main Drain at Paterson Street, Bayswater, and realigning the drain to create a meandering flow path (see Figures 21a to 21c). The aims of the project were to restore indigenous vegetation, create habitat for local fauna and reduce stormwater nutrient levels. The drain was bound by the backs of residential properties on the southern side and parkland on the northern side. The drain consisted of numerous weed species that were sprayed annually, which resulted in bare banks. The parkland consisted of a large expanse of grass, bordered by (non-indigenous) Ficus trees.

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<sup>22</sup>The Bayswater Integrated Catchment Management Group merged with Bennet Brook Catchment Group in 2002 to form the North East Catchment Committee (NECC). The NECC was then re-named the North Metropolitan Catchment Group.



*Figure 21a. Paterson Street drain, Bayswater, after earthworks. (Photograph: Rosemary Glass, formerly of Bayswater Integrated Catchment Management Group.)*



*Figure 21b. Revegetated drain, Paterson Street drain, Bayswater. (Photograph: Debbie Besch, NMCG.)*



*Figure 21c. Revegetated area and parkland, Paterson Street Drain, Bayswater: (Photograph: Debbie Besch, NMCG.)*

The proximity of residential properties limited the extent of earthworks and the choice of vegetation. There was only a narrow 3 m strip between residential properties and the top of the bank. It was not possible to alter the slope on this side, so it remains at 1:1. To ensure public safety on the bank bordering the park, the slope was contoured to 1:3. Local residents were extensively consulted on the suitable types of vegetation. The selected species had to be colourful, have visual appeal and be less than 1 m tall or medium sized with single stem trees to allay fears of providing concealing areas for intruders. Trees were planted so that there would be no overhang of branches over residents' properties. The base of the drain was planted with wetland plants that would not spread rapidly and block the channel. The channel was also planted to block child access to the water, at the request of local residents. One lesson learnt from the project was that, due to the lack of shade for young seedlings (as larger plants were not present), ground covering species are needed early in rehabilitation to shade the ground, minimise weeds and maximise plant survival.

Involvement and support from the local community was found to be very important, particularly with respect to preventing and reporting vandalism. A wide diversity of macroinvertebrates have been found every year in the water body during the Ribbons of Blue ‘Snapshots’ sampling events conducted with local schools, which is indicative of a healthy water body. Numerous native frog and bird species have also been observed. Work will be undertaken at the site to monitor the success of the wetland plant species in removing pollutants from stormwater. Their affect on the hydraulic capacity of the drain will also be assessed (Besch, D., 2003, pers. comm.<sup>23</sup>).

Other work in the Bayswater Main Drain catchment has included the creation of wetland habitats at the Russell Street compensating basin in a commercial area of Morley (Figure 22) and the Mooney Street compensating basin in an industrial zone of Bayswater. A continuous deflective separator was also installed in an industrial zone in Bayswater (see Example 4).



*Figure 22. Straight drain converted to a vegetated compensating basin, Russell Street, Morley. (Photograph: Debbie Besch, NMCG.)*

## 7.4 Bannister Creek Drain to Living Stream Project

### **Project description**

A drain retrofit project was undertaken on an approximately 350 metre reach of Bannister Creek, adjacent to Bywood Way in Lynwood, Perth’s southern metropolitan region (Figure 23). The Bannister Creek catchment area is 23 square kilometres and includes the suburbs of Canning Vale, Lynwood, Ferndale and Parkwood. The creek is one of the main tributaries of the Canning River and was originally a series of wetlands, but was modified to a main drain in 1979. The soils of the Bannister Creek catchment are predominantly Bassendean Sands. However, the lower reach of the creek, where the rehabilitation reach is located, consists of sandy soils overlaying clayey swamp flats.

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<sup>23</sup> Personal communication with Debbie Besch, North East Catchment Committee, May 2003.



Figure 23. Location of Bannister Creek Living Stream Project.

Urbanisation in the Bannister Creek catchment has resulted in a high proportion of impervious surfaces and a traditional drainage system designed to quickly remove stormwater runoff. The increased volume and velocity of waters draining to the creek has resulted in erosion problems and pollution of the waterway. Pollution sources include fertiliser runoff from golf courses, parks and gardens; domestic pet faeces; industrial waste discharge; motor vehicle residues; domestic pesticide and chemical use; landfill; and leakage from underground pipes and tanks (Fisher, 1999). The hydrology and structure of Bannister Creek has been greatly altered. The loss of wetland systems and riparian vegetation has resulted in decreased habitat, the loss of plant and animal communities and a decrease in the natural capacity of the waterway to buffer floods and pollutants.

In response to community concern over pollution of the waterway, the Bannister Creek Catchment Group (BCCG) was formed in 1996 to ‘coordinate integrated natural resource management over the whole of the Bannister Creek catchment’. Rehabilitation of the creek was one of the projects initiated by the BCCG.

The aim of the project was to transform a straight section of drain (Figure 24a) into a living stream, while maintaining the function of the waterway to convey stormwater from the urban and industrial catchment into the Canning River. As the creek is within a recreational reserve, enhancement of the creek aesthetics was also an objective.

## Approaches implemented

In November 2000, large volumes of soil previously imported in the 1970s as part of urban development were removed from the site to create a 'meandering' creek and to reshape the steep banks to a gentler slope suitable for planting (Figure 24b). Riffles were built to aerate flows and create habitat. Erosion control matting was used to stabilise sections of the stream banks and the area was revegetated.



*Figure 24a. Bannister Creek before restoration works (1999) – a straight trapezoidal drain with steep grassed banks and high velocity flows. (Photograph: Department of Environment.)*



*Figure 24b. Bannister Creek post-engineering (restoration) works summer 2001. The channel was realigned to create a winding creek and the banks reshaped to a gentle slope and stabilised. (Photograph: Department of Environment.)*

The BCCG have undertaken numerous source control activities to reduce pollution of the creek. These activities have included:

- Development of a Turf Nutrient Management Plan and monitoring of soil nutrient requirements to determine appropriate fertiliser application regimes (Fisher, 1999).
- A survey of residents adjacent to Bannister Creek, as part of the 1997 BCCG Phosphorus Reduction Campaign to determine community awareness of the impact of their actions and attitudes to change their actions to improve the water quality of Bannister Creek.

The City of Canning also undertook an industrial audit of light industrial premises in 1997 to determine levels of awareness of stormwater risks, washdown and drainage practices and emergency clean-up procedures.

Other community education and awareness raising activities have included:

- Mapping, aerial photos, macroinvertebrate monitoring, flora and fauna surveys, foreshore surveys and reports completed to evaluate and report the project results;
- Tours of the rehabilitation reach as a demonstration site of stormwater management;
- Bus tours, forums and workshops to educate stakeholders and the community;
- Pamphlets about stormwater management and drains distributed in the catchment;
- Awareness raising by visiting over 600 businesses and industries in the catchment;
- Nine schools have been involved in the rehabilitation project, including four schools undertaking Ribbons of Blue monitoring;
- Pollution response education;
- Cleaner production training;

- Articles in local and State newspapers and on television; and
- Production of the quarterly BCCG newsletter.

The BCCG has reached a wide audience - approximately 4000 people have had some level of involvement in the project.

### Results / achievements

The channel realignment and bank stabilisation works have been very successful. A storm event in winter 2001 caused severe damage to the main drain structure upstream of the demonstration site (Figure 25a), while the newly rehabilitated 'living stream' section of the channel carried the increased flow without any significant damage (Figure 25b).



*Figure 25a. Flood damage of the trapezoidal drain upstream of the rehabilitation reach of Bannister Creek. (Photograph: Department of Environment.)*



*Figure 25b. Bannister Creek 2004. Revegetation was undertaken to reduce water velocity, control erosion and rehabilitate the drain into a living stream. Flooding resulted in no significant damage to the creek. (Photograph: Georgia Davies, BCCG.)*

Macroinvertebrate sampling was carried out in spring 1999 prior to the restoration works and in spring 2001 post-restoration works. The sampling was a snap shot and replicate sampling has not been undertaken. Habitat diversity at the site was significantly increased by the restoration works, including the creation of pools, riffles, macrophyte zones and runs. Increased habitat diversity is linked to increased species diversity. There was a greater abundance and diversity of taxa present post-restoration than pre-restoration. A 55% increase in the number of taxa present was found post-restoration works (17 taxa compared to 11 pre-works). There was an increase in the number of macroinvertebrates that are indicators of healthy waterways, such as damselflies, dragonflies and caddis flies. Additionally, a significant increase in bird life, turtles and other wildlife in the area has been observed since the restoration works.

The retrofitting project at Bannister Creek is part of a broader program to improve the health of the catchment. Other activities include extensive areas of weed eradication, revegetation and remnant bush and creekline restoration, as well as establishment of a local community herbarium. The Bannister Creek Management Plan (November 1998) was prepared as a guideline for all stakeholders. The project has been successful due to the high investment in partnership building with various stakeholders and the high level of community involvement and skill development.

The recreational and aesthetic value of the area has been improved, including construction of a pathway and viewing platform that have resulted in less vandalism and foot traffic in the restoration area. It was estimated that average property values adjacent to the creek increased 17% more than properties adjacent to unrestored sections of Bannister Creek (Robert, J., 2004, pers. comm.<sup>24</sup>).

<sup>24</sup> Personal communication with Julie Robert, South East Regional Centre for Urban Landcare, 2004, citing information provided by the Real Estate Institute of WA.

This project helped the Bannister Creek Catchment Group win the River Rats Living Stream Award in 2001 and be runner up in the NHT Rivercare Award for 2001. The success of this project has led to an extension of the site. Stage 2 of the living stream project, involving enhancement of a 120 metre reach immediately downstream of initial works, commenced in March 2004.

### Challenges

As the site forms part of the main drainage network, concerns were raised that the selected rehabilitation techniques would increase flooding on Bannister Creek. Other challenges to implementing the project arose from traditional drain management practices, reluctance to trial new techniques and a focus on conveyance rather than water quality or ecosystem values.

An advantage of this site was the wide drainage reserve that enabled the channel to be widened to reduce the bank slopes and offset any decreased flood capacity due to revegetation. Some drains have a narrow reserve and this limits the scope to undertake restoration works. However, where drainage is integrated with public open space, there are often opportunities to achieve multiple benefits by rehabilitating the drain.

### Resources

The BCCG has received nearly \$1 million dollars in funding since its formation in 1996. This funding has been used for a variety of projects within the Bannister Creek catchment and includes salaries and administration costs, as well as all on-ground works and education programs. The engineering works cost \$110,000 to remove 13,000 m<sup>3</sup> of fill and \$2,500 to build the riffles (see Table 5). The City of Canning undertook the works in-house and used the fill for other projects, for example road building. The cost is relative to traditional drainage practices. For example, drop structures can cost in excess of \$100,000. It is far cheaper and easier to implement best practice stormwater management in the planning and design phase of a project, rather than retrofit a poorly designed or traditional system.

The following table shows the costs for various engineering items. This includes all earthworks, bulk mulching, retaining walls and balustrades. Volunteer labour and items of a landscaping nature, such as jute matting and planting, are not included.

**Table 5. Cost of engineering works for Bannister Creek Drain to Living Stream Project (Leek, 2001)**

Activity	Quantity	Cost
Cut to fill	1,200 BCM	\$110,000
Excavate and cart surplus	13,000 BCM	
Strip top cover		\$8,500
Drainage alterations		\$73,000
Supply mulch and spread		\$12,000
Construct riffles		\$2,500
Retaining walls and balustrades		\$32,000
<b>Total</b>		<b>\$238,000</b>

The quantity of soil carted from the site was approximately 13,000 BCM (Bank Cubic Metres) which approximates 22,000 tonnes or 1,000 semi-trailer loads of material.

The Bannister Creek Catchment Group (BCCG) and the City of Canning have undertaken the project with support from the Department of Environment, Water Corporation, Swan Catchment Urban Landcare Program, Alcoa, the Natural Heritage Trust and the local community. The project is part of the broader Swan-Canning Cleanup Program and Swan Region Natural Resource Management Strategy.

### References / further information

Fisher, J. 1999, *Bannister Creek Reserve Management Plan*, prepared for the City of Canning, Western Australia.

Leek, C. 2001, *Bannister Creek Costs*, Engineering and Technical Services Division of the City of Canning, Memorandum to Julie Robert, Coordinator of Bannister Creek Catchment Group, dated 23 May 2001.

Water and Rivers Commission 2002, *A simple assessment of the changes in macroinvertebrates in a restoration project at Bannister Creek*, Water and Rivers Commission, Perth, Western Australia.

## 7.5 Coolgardie Drain to Living Stream Project

### Project description

As part of a collaborative project, the Two Rivers Catchment Group<sup>25</sup>, City of Belmont, Department of Environment, Garvey Park Friends Group and Boral Resources WA have restored the Coolgardie Drain in Garvey Park, Ascot (Figures 26 a and b). The main objective of the project was to create a 'living stream' to enhance the habitat value of the site.

This work involved stream realignment, bank revegetation and riffle construction to create two distinct habitats – one for fresh water from the drain and one that has a tidal (saline) influence.



Figure 26a. Coolgardie Drain before living stream project. (Photograph: J. King, City of Belmont.)



Figure 26b. Coolgardie Drain in April 2004, two years after the earthworks. (Photograph: J. King, City of Belmont.)

### Approaches implemented

The project was first conceived in late 1999 when the concept to turn the Coolgardie Drain into a living stream was proposed to the City of Belmont. The concept was first put forward in the *Garvey Park and Swan River Foreshore Restoration and Concept Plan* (Ecoscape, 1999). The 500 m stretch of drain was previously linear and narrow, with limited habitat value. The 24-hectare catchment is a mixture of residential and light industrial.

<sup>25</sup> Then known as the Belmont-Victoria Park Catchment Group, prior to the merger with the Canning Plain Catchment Group.

The project commenced in 2000 with planning, collection of baseline information on fauna, weed management and seeking funding from SALP<sup>26</sup> and corporate sponsorship from Boral Resources WA. The earthworks and riffle were designed by the Department of Environment and earthworks commenced in April 2002.

The drain has now been modified by sculpting and battering the banks to create a meandering stream with some open water areas and stands of native shrubs and sedges. A riffle has also been constructed to separate the freshwater habitat from tidally influenced habitat. Approximately 22,000 native plants were planted in 2002 and a further 18,000 in 2003. An additional 5,000 plants have been planted since 2003 to increase diversity and fill in gaps. The revegetation area has been extended during 2003 to 2005 to cover the floodplain area and link the living stream with remnant wetland vegetation to the south. The City of Belmont, with assistance from the Two Rivers Catchment Group, continues to maintain the area by eradicating weeds (mainly by spraying) and planting native plants.

Further work will involve restoring the vegetation on the island in front of the drain inlet pipe and additional stream infill and buffer planting to increase plant density and improve habitat.

### **Results / achievements**

Approximately 45,000 wetland and dryland trees, shrubs, sedges and rushes have been planted and 4,500 tonnes (or 3000 m<sup>3</sup>) of clay has been removed to create the living stream.

The project has been successful in encouraging local government, State government, industry and community groups to work together in creating a valuable environmental asset. The project has involved a considerable number of volunteers, been a focus of a number of Swan River Trust Corporate Care Days and has received good publicity in the local media.

Macroinvertebrate and water quality monitoring has commenced, with an aim to determine the type and amount of pollutants entering the Swan River from the Coolgardie Drain and to assess the impacts of the restoration and revegetation techniques.

### **Challenges**

One particular sedge species (*Carex* species) did not have a high success rate, possibly due to site acidity, but all other revegetation works were successful. The planting survival rate has been excellent, at approximately 90%. Controlling the weed Wild Gladiolus (*Gladiolus undulatus*) has been a major challenge.

The Coolgardie Drain retrofit project was undertaken prior to recent awareness of acid sulfate soils (ASS) issues. The drainage realignment caused ASS oxidation within the channel and banks at a few locations in the upper section of the drain, resulting in acidic soil conditions. The City of Belmont initially had problems stabilising the banks, which had excessive soil acidity, however these areas have now been stabilised using hardier sedge species (*Juncus kraussii* and *Isolepis nodosa*). The project site highlights the need to assess the risk of ASS disturbance, particularly in those areas identified as susceptible to ASS. Acidity issues can be managed if acid sulfate soils are first identified and disturbed soils neutralised prior to reuse.

### **Resources**

This project is a collaborative effort between the City of Belmont, the Two Rivers Catchment Group, Garvey Park Friends Group and the Department of Environment. The City of Belmont provided

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<sup>26</sup> Swan Alcoa Landcare Program (SALP) – a joint initiative between Alcoa World Alumina Australia and the Swan River Trust.

approximately 50% of the project funding, with the remainder primarily originating from SALP funding. There was also considerable assistance from Boral Resources WA and contributions from the other project partners.

### **References / further information**

Ecoscape 1999, *Garvey Park and Swan River Foreshore Restoration and Concept Plan*, City of Belmont, Western Australia.

For further information visit SERCUL's website at <<http://www.sercul.org.au>>.

Alternatively, contact the City of Belmont on 9277 7222 or at <[belmont@belmont.wa.gov.au](mailto:belmont@belmont.wa.gov.au)>.

## **7.6 Liege Street Wetland**

### **Project description**

The Swan River Trust in partnership with the City of Canning, Department of Conservation and Land Management, Water Corporation and the South East Regional Centre for Urban Landcare (SERCUL) constructed the Liege Street Wetland in Cannington. The main aim of the constructed wetland is to treat nutrient enriched stormwater and groundwater from two main drains (and one local council drain) before it is discharged into the Canning River. Improvements to the habitat and aesthetics of the area are also objectives of the wetland.

The Liege Street Main Drain catchment is approximately 530 hectares. The catchment is covered by the City of Canning and includes the suburbs of Cannington, East Cannington, Queens Park and a small portion of Welshpool. The upper portion of the catchment is mainly set aside for residential land use whilst the lower portion is dominated by a commercial area including the large Westfield Carousel Shopping Centre. The catchment is dissected by the Perth to Armadale railway line and some major roads including Albany Highway at the lower end of the catchment and Welshpool Road towards the top of the catchment.

The Liege Street drain outfall is an artificial system, which was constructed in 1992/93. The drain lies within the Canning River Regional Park, which is managed by the Department of Conservation and Land Management.

Water quality monitoring of both Liege Street and Cockram Street drain outfalls shows that the drains have elevated levels of nitrogen and phosphorus. The two drains meet upstream of the existing dual use pathway (which was retained) before delivery into the Canning River, just over 2 kilometres upstream of the Kent Street Weir. This area of the river frequently experiences algal blooms, so reducing nutrient delivery into this section of the river is a key objective of the Swan-Canning Cleanup Program.

### **Approaches implemented**

The Swan River Trust received \$750,000 in 2003 to implement on-ground works in the Canning Plain catchment, with the aim to immediately reduce the amount of nutrients being discharged into the Canning River, whilst catchment management activities were taking effect. In mid 2003, discussions with the land and drainage service managers identified that the area defined by the outfalls of the Liege Street and Cockram Street main drains and the dual use footpath had sufficient capacity for restoration works. Water quality monitoring since 1999 had shown that these two drains were nutrient enriched and although located in the Canning River Regional Park, the area was also of poor habitat and aesthetic value (see Figure 27a).

In late 2003, a stakeholder workshop was held to discuss concept designs and by early 2004 a Project Steering Committee had been formed to oversee the project management, design, construction and maintenance phase of the wetland. The consultants Syrinx Environmental Pty Ltd designed the wetland in consultation with the project partners.

Earthworks began in April 2004, restoring a total of 350 metres of linear drainage line into a 3 hectare wetland consisting of a combination of sumplands, pools, islands and floodplain. The first phase of revegetation commenced in July 2004, with over 50,000 plants being planted into both the wetland and uplands areas by the end of spring 2004.

The design includes a sediment forebay for collecting sediment, a series of clay lined ponds and densely vegetated sumplands, a raised weir to create the former floodplain and the trial of a sub-surface flow filter bed.

The project has now moved into the short-term maintenance phase, with all project partners committing to a Maintenance Plan and Memorandum of Understanding. It was recognised that an education and communication component is also important to encourage land use changes throughout the catchment, so preparation of an Education Plan commenced in 2005.

### **Results / achievements**

The site has already received recognition in the media and has been the focus of a number of Corporate Care planting and weeding activities. There has also been successful collaboration between local and State government working with the community towards a common goal of water quality and habitat improvement.

An extensive monitoring and evaluation program has commenced that will fill vital knowledge gaps in the performance of constructed wetlands in improving water quality. The site has already seen the return of a variety of fauna, including swans, native ducks, egrets, ibis, pelicans and long neck turtles (see Figure 27b).



*Figure 27a. Pre-works - outlet with floating plant, azolla. (Photograph: Department of Environment, March 2004.)*



*Figure 27b. Constructed wetland. (Photograph: Tom Atkinson, SERCUL, April 2005.)*

### **Challenges**

Due to the variety of partners with diverse interests, some changes in design were required during the construction phase. This resulted in construction delays whilst all project partners reached agreement to the proposed changes. Due to these delays, a substantial amount of earthworks were undertaken after the winter rains had commenced. This resulted in some extra earthwork expenses but produced a wetland that is valuable to all project partners.

## Resources

The wetland planning, design, construction and planting cost approximately \$550,000, with the majority of funding coming from the Swan River Trust's Drainage Nutrient Intervention Program. However, the City of Canning also contributed an additional amount of nearly \$300,000 in drain sediment disposal costs, restoration of the local council drain and works supervision. Other project partners also contributed a considerable amount of in-kind contribution to the project.

## References / further information

For further information, go to the Swan River Trust's website at <<http://www.swanrivertrust.wa.gov.au>>, or visit SERCUL's website at <<http://www.sercul.org.au>>.

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## 9 Useful internet sites

<<http://www.bmpdatabase.org/>>

National Stormwater Best Management Practices (BMP) Database. An American website that provides access to BMP performance data in a standardised format for over 190 BMPs.

<[http://www.cwp.org/retrofit\\_article.htm](http://www.cwp.org/retrofit_article.htm)>

Retrofitting information from the USA Centre for Watershed Protection.

<<http://www.ecosystemvaluation.org/>>

A website explaining how economists value ecosystems – for non-economists, including ecosystem benefit indicators.

<<http://www.eng.newcastle.edu.au/~ncwe/ncweARQ/arqSummary.htm>>

On-line versions of the Draft Australian Runoff Quality manual, which is a companion document to the Institution of Engineer's Australian Rainfall and Runoff.

<<http://www.stormwater.asn.au/>>

Stormwater Industry Association website.

<<http://www.wsud.org/>>

Provides some case studies and examples of WSUD from subdivision to lot scale, including retrofitting, in New South Wales, Victoria and Queensland.

## 10 Acronyms

ARI	Average Recurrence Interval
BMP	Best management practice
CDS	Continuous deflective system
EMRC	Eastern Metropolitan Regional Council
GPT	Gross pollutant trap
NMCG	North Metropolitan Catchment Group
SCCP	Swan-Canning Cleanup Program
SRT	Swan River Trust
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
WSUD	Water sensitive urban design

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Stormwater  
Management  
Manual for  
Western Australia

7  
Non-structural  
controls



Department of  
Environment



*Cover photograph: Native Plant Domestic Garden (Source: Sally Cousans)*

# Stormwater Management Manual for Western Australia

## 7 Non-structural controls

Prepared by André Taylor, Ecological Engineering, and Emma Monk,  
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Consultation and guidance from the Stormwater Working Team



Department of  
Environment



April 2005

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## Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the *State Water Strategy* (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Catchment Management Branch of the Department of Environment.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

The aims of this chapter are to:

- Describe non-structural controls, as well as provide an overview of their benefits, use, effectiveness and evaluation.
- Provide advice on how to select and implement non-structural controls.
- Provide technical guidelines on some of the most important non-structural controls to improve stormwater quality that can be applied at the citywide, regional, estate or allotment scale.

Non-structural controls are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments.

Non-structural controls can be defined into five principal categories:

1. **Town planning controls** - such as the use of town planning instruments to promote water sensitive urban design features in new developments.
2. **Strategic planning and institutional controls** - such as the use of strategic, regional or citywide urban stormwater management plans.
3. **Pollution prevention procedures** - such as maintenance practices, operational procedures and staff training at government, commercial and industrial sites to minimise the risk of stormwater pollution.
4. **Education and participation programs** - such as training programs and involving the community in the development and implementation of stormwater management plans.
5. **Regulatory controls** - such as enforcement of local laws to improve erosion and sediment control on building sites, the use of environmental licences to help manage premises likely to contaminate stormwater or groundwater, and programs to minimise illicit discharges to stormwater management systems.

Non-structural controls should be used in combination with structural controls (i.e. the ‘treatment train approach’) to achieve a balanced mix of stormwater management measures. The potential benefits from using non-structural controls include:

- **Cost:** Some non-structural controls are relatively inexpensive to run, particularly when compared with structural alternatives.
- **Coverage:** Some non-structural controls cover broad areas compared with structural alternatives.
- **Can be used in existing developed areas:** Some types of structural controls can be difficult and/or expensive to install because of space constraints and existing infrastructure in established areas, whereas, non-structural controls generally do not have space/land requirements.
- **Can target specific pollutants of concern.**
- **The polluter pays principle and economic incentives/disincentives** can be applied through regulation and/or enforcement programs, unlike large regional structural controls, where the bulk of the life cycle costs are often borne by the wider community.
- **The high potential effectiveness of some measures.** For example, planning controls can change practices over large areas.
- **Community participation:** Interactive and participatory programs can provide an opportunity for the community to accept greater responsibility for stormwater pollution and be involved in developing management strategies.

- Flexibility: Unlike structural controls, many non-structural controls can be quickly modified to take advantage of new opportunities or to respond to new priorities.
- Secondary benefits: Such as helping build a mandate for increased political support, stable funding mechanisms and new organisational institutions.

Non-structural controls can be highly valuable, and in some cases essential, for urban stormwater management. The non-structural controls that have been demonstrated to have the most potential value are:

- Town planning controls involving the implementation of stormwater policy in town planning schemes, requiring stormwater to be addressed in development proposals, and applying development approval/permit conditions.
- Development of stormwater management plans for a city, shire or catchment to improve stormwater management and the protection of aquatic ecosystems.
- Illicit discharge elimination programs.
- Sustained construction site management programs that have strong enforcement elements and address both public and private sector works.
- Point source regulation of stormwater discharges (e.g. licensing and inspecting/auditing industry and enforcement activities).
- Targeted, intensive and interactive community and stormwater management industry education and participation programs (e.g. community training workshops on good gardening practice).
- The use of a wide variety of citywide maintenance operations to improve stormwater quality, typically undertaken by local government authorities or other drainage service providers (e.g. maintenance of the stormwater drainage network and manual litter collections).
- Business/industry programs (e.g. targeted campaigns involving education, incentives, site assessments and/or enforcement to improve procedures and practices relating to stormwater management on commercial or industrial sites).

This chapter also provides advice on how to implement non-structural controls. These include:

- Seek a complementary balance of structural and non-structural controls.
- Ensure organisational arrangements are conducive to non-structural controls.
- Undertake research and use expertise in their design and evaluation.
- Develop a contingency plan in case of failure to achieve the desired outcome.
- Clearly state and document the objectives at the start of the project.
- Be patient and plan for the long term.
- Look for synergies.
- Develop a sound monitoring and evaluation plan at the start of the project.
- Report honestly and openly, regardless of success.
- Recognise that non-structural controls also require maintenance.
- Do not get distracted by the ‘feel good factor’.

There are a wide variety of non-structural controls for managing stormwater. This chapter focuses on the practices that are most effective and applicable to Western Australia. A summary of each non-structural control addressed in this chapter is provided at the beginning of Section 2.

# 1 Introduction

## 1.1 Aims of the non-structural controls chapter

The aims of the non-structural controls chapter are to:

- Describe non-structural controls, as well as provide an overview of their benefits, use, effectiveness and evaluation.
- Provide basic information on the selection of non-structural controls and the use of relevant technical guidelines.
- Provide technical guidelines on some of the most important non-structural controls to improve stormwater quality that can be applied at the citywide, regional, estate or allotment scale.

## 1.2 Scope of the chapter

This chapter focuses on *non-structural* approaches to stormwater management. Non-structural best management practices (BMPs) are one type of ‘source control’, the other being structural controls that can be applied at the source (e.g. porous paving, rain gardens, bioretention systems). Structural controls are addressed in Chapter 9.

There are a wide variety of non-structural approaches for managing stormwater (see Appendix A for a list that includes references to sections of this chapter or to other information/reference sources). This chapter focuses on those practices that are most effective and applicable to Western Australia (see Table 1, Section 1.7).

With time, it is envisaged that guidelines will be provided in this Manual for the vast majority of measures listed in Appendix A. In the interim, Section 1.12 and the links/references column in Appendix A provide additional references that can be used to locate guidelines and case studies on non-structural BMPs not specifically addressed in this chapter.

## 1.3 Terminology and key definitions

**Non-structural stormwater best management practices** (non-structural BMPs) are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management (US EPA, 1999). They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments (Taylor and Wong, 2002a).

Taylor and Wong (2002a) defined non-structural BMPs for stormwater management into five principal categories:

1. **Town planning controls** - such as the use of town planning instruments to promote water sensitive urban design features in new developments, e.g. promoting infiltration and biofiltration.
2. **Strategic planning and institutional controls** - such as the use of strategic, regional or citywide urban stormwater management plans and stable funding arrangements to support the implementation of these plans.
3. **Pollution prevention procedures** - such as maintenance practices (e.g. maintenance of the stormwater drainage network) and elements of environmental management systems (e.g. procedures on material storage and staff training on stormwater management at government, commercial and industrial sites).

4. **Education and participation programs** - such as training programs and involving the community in the development and implementation of stormwater management plans.
5. **Regulatory controls** - such as enforcement of local laws to improve erosion and sediment control on building sites, the use of regulatory instruments such as environmental licences to help manage premises likely to contaminate stormwater or groundwater, and programs to minimise illicit discharges to stormwater management systems (e.g. drains).

Note that this chapter includes temporary erosion and sediment controls (e.g. mulching and sediment fences) in the definition of non-structural BMPs, as they do not involve the construction of fixed or permanent assets.

**Structural stormwater best management practices** are permanent, engineered devices implemented to control, treat, or prevent stormwater pollution and/or reduce the volume of stormwater requiring management.

**Best management practices** are devices, practices or methods for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters (Taylor and Wong, 2002a). Within the context of this chapter, BMPs primarily seek to manage stormwater *quality* to minimise impacts on the health of water bodies.

**Source controls** are non-structural or structural best management practices to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source (NSW EPA, 1998) and protect receiving environments, including groundwater, estuaries, waterways and wetlands.

## 1.4 The target audiences

This chapter has been written primarily for four audiences:

- Stormwater management agencies (such as local governments, Department of Environment, Water Corporation, Main Roads and Department for Planning and Infrastructure) who may develop citywide or regional management strategies, or site-based management plans to minimise stormwater pollution and protect the health of receiving environments.
- Developers and their consultants who may develop stormwater management plans for new developments at the estate to allotment scale.
- Managers of commercial or industrial sites who may require guidance on the on-site management of stormwater.
- Community groups or community members who may require guidance on better ways to manage stormwater at the catchment to allotment scale.

## 1.5 Why implement non-structural best management practices?

### 1.5.1 Potential benefits of non-structural best management practices

Potential benefits from using non-structural BMPs in a balanced catchment or citywide urban stormwater management program have been summarised by Taylor (2000) and Taylor and Wong (2002a). They include:

- **Cost:** Some non-structural BMPs are relatively inexpensive to run, particularly when compared with structural alternatives. For example, where major educational and enforcement campaigns aimed at erosion and sediment control have been conducted in Australia, the revenue gained from enforcement has usually resourced the campaign's total operational expenses. Changes to environmental protection

legislation in Western Australia are increasing local government powers to issue infringements and collect fines for pollution offences, such as discharges of pollutants into the stormwater system.

- **Coverage:** Some non-structural BMPs cover broad areas compared with structural alternatives (e.g. citywide town planning controls).
- Can be used in **existing developed areas:** In established residential, rural-residential, commercial and/or industrial areas where stormwater management needs to be improved, installation of some types of structural BMPs can be difficult and/or expensive because of space constraints and existing infrastructure (e.g. sewer pipes and underground power). Non-structural BMPs generally do not have space requirements.
- Can target **specific pollutants** of concern: For example, in Perth's established residential areas located on sandy soils, nutrients and pesticides from lawns and gardens threaten the quality of shallow groundwater, stormwater and receiving waters. Such pollution is managed through non-structural means (e.g. encouraging the use of waterwise/fertilise wise gardens).
- The polluter pays principle and **economic incentives/disincentives** can be applied through regulation and/or enforcement programs. Unlike large regional structural BMPs, where the bulk of the life cycle costs are often borne by the wider community, regulation and/or enforcement campaigns allow the cost of pollution management to be borne by individuals or sectors of the community that are polluting (e.g. those found to be illegally discharging pollutants to stormwater).
- The high **potential effectiveness** of some measures: For example, the use of mandatory town planning controls to promote the widespread adoption of water sensitive urban design in new developments.
- **Community participation:** Interactive and participatory programs, such as the Green Stamp Programs that include participation techniques such as site assessments and training, can provide an opportunity for the community to accept greater responsibility for stormwater pollution, help develop innovative management strategies and participate in the implementation of these strategies. Such participatory and deliberative<sup>1</sup> processes can have intrinsic value (i.e. they help build 'social and natural capital'), as well as produce tangible outcomes (i.e. improvement in 'natural capital').
- **Flexibility:** Unlike structural BMPs, many non-structural BMPs can be *quickly* modified to take advantage of new opportunities or to respond to new priorities. For example, ongoing small business/industry education programs involving stormwater management can be continually modified to promote practices that incorporate new technology or knowledge (e.g. targeting problem areas that have been identified through annual compliance auditing).
- **Secondary benefits:** A strong argument for using some non-structural BMPs in a balanced catchment or citywide stormwater management program is their secondary benefits, such as helping build a mandate for increased political support, stable funding mechanisms, new organisational institutions, bolder initiatives and broader catchment management results. For example, the use of high profile, citywide stormwater awareness programs may help a stormwater management agency obtain support for ongoing funding for stormwater management. North American researchers have surveyed communities and found the establishment of a dedicated funding mechanism and investment in educational activities are essential ingredients for success in urban stormwater management (Lehner *et al.*, 1999; Schueler, 2000b).

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<sup>1</sup> The term 'deliberative' means involving deliberation or consideration. Public participation methods such as citizen juries and consensus conferences involve a strong deliberative element, where participants have the opportunity to digest information, formulate views and discuss them.

## 1.5.2 Trends in the use of non-structural best management practices

Stormwater managers commonly use a mix of structural and non-structural BMPs to achieve their stormwater management objectives, particularly at the catchment or citywide scale. These managers have the challenging task of finding the optimal combination of BMPs using limited funds (Schueler, 2000a; Taylor, 2000). After reviewing 100 stormwater case studies from the US, Lehner *et al.* (1999) also stressed the value of a balanced, multi-faceted approach, stating that ‘...stormwater management efforts build synergistically off each other; the most successful municipal strategies cover all program elements effectively’ (pp. 5-16).

During the 1990s, most expenditure on urban stormwater management in Australia was on large, regional, end-of-pipe structural BMPs (e.g. gross pollutant traps, ponds and wetlands) (Taylor, 2000). Since the late 1990s, the funding has increasingly shifted toward *source controls* for managing stormwater quality and quantity and achieving a more balanced mix of structural and non-structural stormwater strategies (Taylor and McManus, 2002). Such controls include more water sensitive urban design elements in new developments (e.g. the use of stormwater recycling and infiltration at the allotment or streetscape scale) and non-structural BMPs that can be applied on a citywide scale (e.g. town planning controls, education and participation programs, and enforcement programs).

A survey of urban stormwater managers conducted in 2001-02 by Taylor and Wong (2002b) found that non-structural BMPs in Australia:

- are already playing a major role in urban stormwater quality improvement;
- are increasing in use; and
- will continue to increase in use if Australian stormwater programs mature in a similar way to those developed in the United States of America (US) and New Zealand (NZ).

These trends are consistent with the current national and State policy direction for the management of urban stormwater through the publication of this Manual and similar policies and guidelines by the State Government. Chapter 2 of this Manual: *Understanding the context* recommends the following hierarchy be applied to stormwater management in Western Australia:

1. **Retain and restore natural drainage lines:** retain and restore existing valuable elements of the natural drainage system, including waterway, wetland and groundwater features and processes.
2. **Implement non-structural source controls:** minimise pollutant inputs principally via planning, organisational and behavioural techniques, to minimise the amount of pollution entering the drainage system.
3. **Minimise runoff:** infiltrate or reuse rainfall as high in the catchment as possible. Install structural controls at or near the source to minimise pollutant inputs and the volume of stormwater.
4. **Use of ‘in-system’ management measures:** includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps.

## 1.5.3 The most effective non-structural best management practices

The CRC for Catchment Hydrology (Victoria) broadly evaluated the potential effectiveness of non-structural measures through the use of a literature review and a survey of 36 urban stormwater managers from Australia, NZ and the US (Taylor and Wong, 2002b & 2002c). The overall finding from this research was that non-structural BMPs can be highly valuable, and in some cases essential, for urban stormwater management. The non-structural BMPs that had been demonstrated to have the most potential value are:

- Town planning controls involving the implementation of stormwater policy in town planning schemes, requiring stormwater to be addressed in development proposals, and applying development approval/permit conditions (such measures can result in *widespread* adoption of best practice environmental management on construction sites and water sensitive urban design).
- Development of stormwater management plans for a city, shire or catchment to improve stormwater management and the protection of aquatic ecosystems.
- Illicit discharge elimination programs.
- Sustained construction site management programs that have strong enforcement elements and address both public and private sector works.
- Point source regulation of stormwater discharges (e.g. licensing and inspecting/auditing industry and enforcement activities).
- Targeted, intensive and interactive community and stormwater management industry education and participation programs (e.g. community training workshops on good gardening practice).
- The use of a wide variety of citywide maintenance operations to improve stormwater quality, typically undertaken by local government authorities or other drainage service providers (such as the Water Corporation) (e.g. maintenance of the stormwater drainage network and manual litter collections).
- Business/industry programs (e.g. targeted campaigns involving education, incentives, site assessments and/or enforcement to improve procedures and practices relating to stormwater management on commercial or industrial sites).<sup>2</sup>

## 1.6 How to use the BMP guidelines in this chapter

Section 2 of this chapter includes a lot of information on various non-structural BMPs. A brief summary of all 22 BMP guidelines is provided on pages 21-28.

The technical BMPs in Section 2 contain summarised background information, recommended practices, factors to consider and additional references for a number of non-structural BMPs. Like a dictionary, it is not necessary to read all of the information in Section 2 in order to use it. The detailed content of Section 2 should be selectively accessed as needed, to gather information on how to apply specific non-structural BMPs (e.g. Section 2.2.1 provides specific advice on street sweeping).

## 1.7 Non-structural control best management practices addressed in this chapter

Table 1 is a ‘BMP matrix’ that lists all of the non-structural control BMPs that are addressed in this chapter and highlights the relevance of each BMP to each of the four target audiences listed in Section 1.4. Some of these BMPs are addressed in other chapters, so chapter references are also provided for each BMP. This chapter addresses the most effective and applicable BMPs for Western Australia. Appendix A provides a comprehensive list of non-structural control BMPs with relevant references.

Non-structural BMPs can operate at two levels according to Taylor and McManus (2002):

- as *discrete BMPs* (e.g. educational programs), that can be applied at the citywide, regional, estate and/or allotment scale; and

<sup>2</sup> It should be noted that the BMPs listed here are those associated with some evidence of higher levels of effectiveness. Other non-structural BMPs may also be effective, but have not been demonstrated as such.

- as *facilitating practices or frameworks* that result in discrete structural and non-structural BMPs (e.g. town planning controls are non-structural measures, but they *produce* new developments that incorporate both structural and non-structural BMPs).

Most of the non-structural BMPs provided in this chapter are *discrete* BMPs (e.g. soil amendment, illicit discharge elimination programs), as BMPs of this type are more numerous. However, the non-structural BMPs that play a *facilitation* role could be regarded more important, as agencies seek to establish a strong stormwater management program. For example, BMPs that relate to the establishment of sustainable funding mechanisms, mandatory town planning controls, environmental management systems, and a total water cycle management philosophy are highlighted as being particularly important.

**Table 1. BMP Matrix – Relevance to Target Audiences**

Non-structural Control BMPs Covered in this Manual	Relevance to the Target Audiences				Section/Chapter Reference
	Government stormwater management agencies	Developers	Commercial or industrial premises managers	Individuals, landholders or community groups	
<b>Construction practices</b>					
Land development and construction sites: • Drainage controls • Erosion controls • Sediment controls • Housekeeping controls • Dust control	✓	✓	~ (during construction)	~ (during major landscaping)	2.1.1
Soil amendment undertaken to minimise the export of nutrients from gardens and lawns	✓	✓	~	✓	2.1.2
<b>Maintenance practices</b>					
• Street sweeping/cleansing	✓	~	✓	✗	2.2.1
• Maintenance of the stormwater network (incl. desilting)	✓	✓(during construction and maintenance period <sup>3</sup> )	~	✗	2.2.2
• Manual litter collections (e.g. roadside collections)	✓	✗	✗	✗	2.2.3
• Litter bin design, positioning and cleaning	✓	✗	✗	✗	2.2.4
• Road / pavement repairs / resurfacing and road runoff	✓	✓(during construction and maintenance period)	✗	✗	2.2.5
• Maintenance of premises typically operated by local government (e.g. parks, cemeteries, sports fields, nurseries, depots, buildings, road reserves, etc.)	✓	✗	✗	✗	2.2.6

<sup>3</sup> The period that developers are responsible for maintenance post-construction is usually 12 months, but can be longer depending on the size and staging of the development.

Non-structural Control BMPs Covered in this Manual	Relevance to the Target Audiences				Section/Chapter Reference
	Government stormwater management agencies	Developers	Commercial or industrial premises managers	Individuals, landholders or community groups	
• Maintenance of gardens and reserves with respect to plant selection, pest management, irrigation, lawn maintenance and nutrient management	✓	✓ (during construction and maintenance period)	✗	~	2.2.7
• Maintenance of vehicles, plant and equipment (incl. washing)	✓	✗	✓	✗	2.2.8
• Building maintenance (incl. graffiti removal and building washing)	✓	✓	✓	~	2.2.9
Stormwater management on industrial and commercial sites, such as: <ul style="list-style-type: none"> <li>• Storage of hazardous and dangerous goods, etc.</li> <li>• Housekeeping</li> <li>• Loading/unloading</li> <li>• Waste management</li> <li>• Stormwater management plans</li> <li>• Wastewater management</li> <li>• Emergency management and response</li> <li>• Vehicle and equipment wash-down areas</li> </ul>	~	~	✓	~	2.2.10
<b>Education and participation programs</b>					
Building capacity for local government and stormwater management industry professionals	✓	~	~	~	2.3.1
Intensive training of landowners on aspects of stormwater management	✓	✗	✗	✓	2.3.2
Encouraging participation by the community in all aspects of stormwater management	✓	✗	✗	✓	2.3.3 Chapter 8
Education and participation campaigns for commercial and/or industrial premises	✓	✗	✓	~	2.3.4 Chapter 8
Focused stormwater education involving new estates.	✓	✓	✗	~	2.3.5

Non-structural Control BMPs Covered in this Manual	Relevance to the Target Audiences				Section/Chapter Reference
	Government stormwater management agencies	Developers	Commercial or industrial premises managers	Individuals, landholders or community groups	
<b>Funding, policy, regulatory and enforcement practices</b>					
Self-sustaining stormwater funding mechanisms	✓	✗	✗	✗	2.4.1
Point source regulation of stormwater discharges and enforcement activities (e.g. licensing and inspecting/auditing industry, enforcement of State or local laws for sources of stormwater pollution)	✓	✗	✗	✗	2.4.2
Illicit discharge elimination programs	✓	✗	~	✗	2.4.3
<b>Catchment planning practices</b>					
Use of risk assessments and environmental management systems by local authorities, State government departments and businesses to strategically assess and manage risks to stormwater	✓	~ (major projects)	✓	✗	2.5.1
Integrating the organisational management of stormwater with other aspects of the total water cycle	✓	✓	✓	✗	2.5.2

**Key:** ✓ = Highly relevant. ~ = Some relevance. ✗ = Not relevant.

## 1.8 How to select best management practices

The question ‘How do I know what BMP to design and use?’ is often asked. An overview of the seven steps *typically* used when undertaking any stormwater and/or groundwater management strategy/plan, whether it is in the context of a new development, catchment or a local government area, is provided below. More detail on the development of Stormwater Management Plans is provided in Chapter 5.

### 1. Identify relevant water quality-related objectives

For any plan or strategy to succeed, it must have clear objectives. For example, a ‘water management plan’ for a new development may set *quantitative* water quality-related design objectives to assist the conceptual design of the stormwater drainage network. These objectives may relate to the quality of stormwater and/or groundwater that may be discharged from the site. Such objectives should be set by or developed in conjunction with regulatory authorities responsible for managing the quality of the area’s receiving water bodies.

### 2. Clearly understand the ‘management environment’ in which the BMPs will be applied

Those preparing the strategy or plan must clearly understand the resources, constraints and opportunities that are relevant to the project. These may relate to finances, people, skills, timing, politics, land availability, market forces, etc.

### ***3. Undertake a process to select a suitable suite of BMPs***

There are *many* different types of BMPs from which to choose. A process is needed to select a set of BMPs that meet the project's objectives and are compatible with the local physical and 'management environment'. Possible methodologies include:

- Undertaking a 'Delphi study' approach, where a group of experts draw on their knowledge of the study area, available resources and BMPs to quickly develop a suitable suite of BMPs<sup>4</sup>.
- Undertaking a risk assessment process to screen and prioritise possible BMPs to meet local water management needs and to identify and address pollutant 'hotspots'. An example of such a process is the methodology adapted from the Victoria Stormwater Committee for developing a stormwater management plan in 'Section 3.1: Stormwater Best Management Practice Guidelines', *Local Government Natural Resource Management Policy Manual* (EMRC, 2002).
- Undertaking a 'triple-bottom-line' assessment process using multi-criteria analysis (MCA) to evaluate the economic, social and environmental costs and benefits of possible BMPs. Such a process can be used to highlight which BMPs have greatest overall 'value', and can be linked with public participation processes (e.g. to help determine the weight that should be placed on each criterion in the MCA). An example of such a process is the desk-top screening exercise that was used to evaluate the potential value of a range of non-structural and structural BMPs if applied to a sub-catchment of the Swan Coastal Plain (see Parsons Brinckerhoff and Ecological Engineering, 2004).
- Undertaking pollutant export modelling, where the effect of a suite of BMPs is modelled to determine the *approximate* reduction of pollutant loads and concentrations in stormwater. Modelling runs are usually undertaken on various conceptual stormwater management designs until the quantitative water quality-related design objectives are achieved. Modelling is still evolving as a stormwater management tool. See the Cooperative Research Centre for Catchment Hydrology's website for more information on modelling (<[www.catchment.crc.org.au](http://www.catchment.crc.org.au)>).

Regardless of the chosen assessment methodology, expertise is needed at some point to select a set of possible BMPs that may meet the needs of the study area. People undertaking this role must be broadly familiar with the benefits and constraints of all possible BMPs. As this is a major challenge for one person, a multi-disciplinary team approach is recommended. More information on the decision-making process for selecting BMPs is provided in Chapter 5.

### ***4. Develop a Plan or Strategy***

Once the BMPs have been chosen for the study area, a document should be prepared to set out the characteristics of the BMPs (e.g. location, size, type), the timing of their implementation, who is responsible for their implementation and how they will be monitored and evaluated. For a proposed development, such a document may be a Water Management Plan that is required as part of development approval. For a catchment or local government area, such a document may be part of a Catchment Management Plan that is regularly updated.

### ***5. Design the BMPs***

Structural and non-structural BMPs need careful design prior to implementation. For example, if an industrial education and enforcement campaign is to be implemented, careful planning will be needed to ensure that the educational content and strategy is best practice, and that all of the necessary elements are

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<sup>4</sup> For more information on how to run a 'Delphi study', see the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management's Citizen Science Toolbox at <[www.coastal.crc.org.au/toolbox/index.asp](http://www.coastal.crc.org.au/toolbox/index.asp)>.

in place for the enforcement component (e.g. regulations, delegated powers, training of enforcement officers, dispute resolution procedures, etc.).

## **6. Implement the BMPs**

This should occur in accordance with the Plan or Strategy developed in Step 4.

## **1.9 Advice on implementing non-structural best management practices**

The following guidance on using non-structural best management practices is intended to maximise their value and help stormwater managers avoid mistakes.

### ***a) Seek a complementary balance of structural and non-structural controls***

All BMPs, whether they are structural or non-structural, or whether they are source controls, in-transit controls or end-of-pipe controls, have potential benefits and limitations. The key is finding the *best combination* of these measures to suit local circumstances.

A common finding of successful case studies involving stormwater management is that non-structural BMPs often work synergistically with other BMPs, or are needed to deliver structural BMPs. For example, a complementary enforcement and education program may work synergistically to alter people's littering behaviour across a large municipal area. Maintenance of stormwater infrastructure (e.g. sludge removal) will improve the performance of that structural control and of downstream structural controls.

### ***b) Ensure organisational arrangements are conducive to non-structural controls***

Delivering a comprehensive stormwater management plan depends on a sound institutional and administrative framework (Taylor and Wong, 2002c). Finnemore and Lynard (1982) emphasised the importance of such frameworks, stating 'the most promising non-structural control measures include institutional control agencies organised to adopt and enforce ordinances, conduct area wide control projects and levy stable and equitable sources of funding' (p.1098). This perspective is supported by Lehner, *et al.* (1999), who nominated six keys to success based on their review of 100 stormwater management case studies in the US. Three of these keys were administrative (i.e. a dedicated source of funding<sup>5</sup>, strong leadership and effective administration). See Section 2.4 for more information.

One of the potential institutional impediments to effective use of non-structural measures in a balanced stormwater management plan/program is that they require a broad range of skills that are not usually found in those sections of traditionally structured organisations that manage stormwater (e.g. traditional 'works departments'). Ideally, the section managing the organisation's stormwater program would be in a position to draw upon a wide range of skills to implement the program, including skills in town planning, law, civil engineering, community consultation, marketing, environmental management, psychology and statistics.

There is an increasing trend towards engaging the community via deliberative participation methods to identify issues to be managed, priorities and management strategies. Techniques such as citizen juries are now being used that greatly enhance the community's role in stormwater management. Where new approaches are being used, it is important to ensure that the organisational structure and culture and key staff are amenable to such strategies, to increase the chances of success.

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<sup>5</sup> In this context, a dedicated source of funding means a sustainable, secure funding mechanism (such as a local 'environmental levy' or stormwater-related fee on all properties), rather than short-term government grants or year-to-year budget bids.

Another organisational challenge is to address the fact that some non-structural BMPs have an increased risk of failure compared to more established structural measures. Using the philosophy of ‘adaptive environmental management’, stormwater managers need to be prepared to engage in responsible risk-taking, leading to improved understanding, program modification and ultimately better outcomes. This philosophy requires a culture of responsible risk-taking within the organisation, which typically requires strong leadership and continual reinforcement.

***c) Undertake research and use expertise in their design and evaluation***

Non-structural BMPs can be difficult to design and evaluate, primarily because most of these BMPs work by altering people's behaviour. How people will behave in a particular context is difficult to predict because behaviour can be affected by many variables. Similarly, determining with a reasonable level of confidence whether behaviour change has occurred, stormwater quality has improved, or the health of water bodies has improved can be challenging.

When designing a non-structural BMP and/or a plan to evaluate its effectiveness, spend time to undertake research into how effective such BMPs have been in other contexts, how similar BMPs have operated, the features of successful case studies and lessons learnt from other case studies. For example, case studies from similar contexts may demonstrate that it typically takes five years to see on-the-ground outcomes from new town planning controls for stormwater management. Such knowledge is important, as it may be inconsistent with stakeholder expectations or BMP funding timeframes. The guidelines and references presented in this chapter and a literature review undertaken by the Cooperative Research Centre (CRC) for Catchment Hydrology (Taylor and Wong, 2002c) provide a good starting point for such research.

***d) Develop a contingency plan in case of failure to achieve the desired outcome***

As explained previously, there are many potential benefits of using non-structural BMPs. However, one disadvantage is that there is often a risk of failure associated with them. This is because of uncertainty regarding their effectiveness and/or their effectiveness is context dependent. Consequently, stormwater managers should develop contingency plans in case evaluation demonstrates that the BMP fails to achieve the desired outcome. For example, a behaviour change campaign may be prepared to encourage residents to minimise the use of fertilisers. If an evaluation finds this campaign is not successful, contingency options could include:

- altering the messages, products, method of delivery, coverage, intensity, etc.;
- implementing supporting regulatory measures (e.g. local laws) and enforcing these measures; and/or
- implementing supporting economic instruments (e.g. subsidised slow-release fertiliser).

***e) Clearly state and document the objectives at the start of the project***

It is a common mistake to poorly define the objectives of the BMP, to allow these objectives to evolve as the project is implemented, or define objectives that are impractical to measure. Like all projects that need to demonstrate success (or otherwise), the objectives should be specific, measurable, achievable, relevant and linked to a timeframe.

For example, an education program's objectives could be: implement the program in accordance with the project plan; raise awareness within a target audience; change their values; change their self-reported and actual behaviour; improve stormwater quality (in terms of pollutant loads and/or concentrations); or improve the health of receiving waters. The choice of program objectives has significant implications for the effort required for evaluating the BMP.

#### ***f) Be patient and plan for the long term***

Some non-structural BMPs take many years to operate at peak efficiency. For example, it is estimated that it takes approximately a decade for citywide erosion and sediment control programs that have strong, sustained enforcement elements to produce compliance levels of approximately 90 per cent<sup>6</sup> (Taylor and Wong, 2002c).

Two of the consequences of such long timeframes are that:

- the expectations of stakeholders (e.g. local government councillors and community groups) may need to be adjusted, as they may be expecting outcomes within a shorter timeframe; and
- the organisation's funding and evaluation arrangements for the BMP may need to be reviewed, so that they can be sustained over the BMP's entire life cycle.

#### ***g) Look for synergies***

Non-structural BMPs can be used to add value to structural BMPs. For example, interpretive signage around stormwater management devices in parks can perform a valuable educational role for the local community.

In addition, some non-structural BMPs can help to manage other parts of the 'total water cycle'<sup>7</sup> (refer to Chapter 2: *Understanding the context*). For example, town planning controls, educational programs, local laws and/or economic instruments can be used to promote catchment friendly gardening. Resulting benefits may include reduced stormwater and groundwater pollution (e.g. from nutrients), reduced runoff, reduced use of mains water (for irrigation) and ecological benefits from the increased use of native plants.

#### ***h) Develop a sound monitoring and evaluation plan at the start of the project***

Monitoring and evaluation of non-structural BMPs is often not done, or is done poorly. To better utilise limited funds to improve the state of water bodies, monitoring and evaluation is needed because the effectiveness of many BMPs is either unknown or uncertain.

The CRC for Catchment Hydrology has recently developed monitoring and evaluation guidelines aimed specifically at non-structural measures for stormwater management (Taylor and Wong, 2003). These guidelines outline a conceptual evaluation framework that involves seven possible styles of evaluation to allow stakeholders to choose a style (or styles) that meets their objectives and available resources. These styles involve monitoring:

1. BMP implementation (i.e. simple evaluation of whether the BMP has been fully implemented and the quality of that implementation).
2. Changes in people's awareness and/or knowledge (i.e. evaluation of whether the BMP has increased levels of awareness and/or knowledge of a specific stormwater issue within a segment of the community).
3. Changes in people's *self-reported* attitude (i.e. evaluation of whether the BMP has changed people's attitudes, either towards the goal of the BMP or towards implementing the BMP itself, as indicated through self-reporting).

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<sup>6</sup> That is, approximately 90% of randomly audited construction sites would be complying with the region's erosion and sediment control requirements.

<sup>7</sup> Total water cycle management recognises that water supply, stormwater and sewage services are interrelated components of catchment systems, and therefore must be dealt with using a holistic water management approach.

4. Changes in people's *self-reported* behaviour (i.e. evaluation of whether the BMP has changed people's behaviour, as indicated through self-reporting).
5. Changes in people's *actual* behaviour (i.e. evaluation of whether the BMP has changed people's behaviour, as indicated through direct measurement).
6. Changes in stormwater quality (i.e. evaluation of whether the BMP, or set of BMPs, has improved stormwater quality in terms of loads and/or concentrations of pollutants).
7. Changes in the health of water bodies (i.e. evaluation of whether the BMP, or set of BMPs, has improved the health of receiving waters).

As a general rule, the results become more meaningful moving from style 1 to 7, but the evaluation becomes increasingly complex and expensive.

Where monitoring and evaluation has been undertaken for non-structural best management practices for stormwater management, an electronic copy of the final report should be sent to the Department of Environment, to help disseminate the resulting knowledge to other stakeholders.

***i) Report honestly and openly, regardless of success***

The failure of a BMP can teach as much and sometimes more than the success of a BMP. Knowledge gained from evaluating non-structural BMPs that have failed to meet their objectives should be communicated within the stormwater industry, so that mistakes can be avoided in future and subsequent funds can be used more wisely. Consequently, any substantial monitoring and evaluation report should be impartial, preferably peer reviewed and communicated to the industry.

***j) Recognise that non-structural controls also require maintenance***

Concern over the cost of maintaining structural BMPs, such as gross pollutant traps and constructed wetlands, has been one of the drivers for an increased focus on source controls and in particular non-structural BMPs (Taylor, 2000). However, non-structural BMPs also require maintenance.

Common non-structural BMPs such as educational programs, stormwater management plans, town planning controls and enforcement programs all require some work over their life cycle to ensure that they remain effective. Long-term educational programs are perhaps the most difficult to maintain, as messages and strategies need to be regularly refreshed to effectively engage the target audience. In addition, funding may become harder to obtain as the campaign begins to age.

***k) Do not get distracted by the 'feel good factor'***

Some non-structural BMPs might be perceived to be effective due to support from some sectors of the community. However, if the initial objective of the BMP is to change people's behaviour and/or improve stormwater quality, the level of community support should not be used as the principal measure of success. This is particularly the case for educational programs.

A good example of a BMP where this *could* occur is the use of stormwater road gully drain stencilling programs. Such programs are commonly used as mechanisms to engage the community, raise awareness of stormwater issues, foster positive attitudes towards stormwater management, help change people's behaviour with respect to stormwater management and reduce stormwater pollution. A recent literature review by Taylor and Wong (2002c) found that some evaluation exercises have reported a positive correlation between seeing the stencils and levels of stormwater awareness/knowledge (e.g. Morison and Hargans, 2002), but no studies were identified that demonstrated stormwater drain stencilling induces behavioural change. However, if the drain stencilling program includes associated activities such as

shopping centre/library displays, postcards/pamphlets in residents' letterboxes and one-on-one discussions, this may increase the possibility of raising awareness levels and changing behaviour.

## 1.10 Additional information

A short set of references is provided at the end of each non-structural BMP addressed in this chapter. In addition, the following general sources of information on non-structural BMPs are recommended:

### ***Australian guidelines (available as a hardcopy only):***

- *Urban Stormwater: Best Practice Environmental Management Guidelines* (Victorian Stormwater Committee, 1999).
- *Managing Urban Stormwater - Source Controls* (Draft guidelines prepared for the State Stormwater Coordinating Committee, NSW EPA, 1998).

### ***North American documents (available on the internet):***

- *National Menu of Best Management Practices for Storm Water Phase II* (US EPA, 2001).
- *Non-structural Urban BMP Handbook – A Guide to Non-point Source Pollution Prevention and Control Through Non-structural Measures* (Northern Virginia Planning District Commission, 1996).
- *Stormwater Strategies: Community Responses to Run-off Pollution* (Numerous American case studies investigated by the Natural Resource Defence Council and reported by Lehner *et al.*, 1999).
- *Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters* (US EPA, 1997).

### ***Australian websites:***

- The New South Wales Environmental Protection Authority's 'Urban Stormwater Program': <[www.epa.nsw.gov.au/stormwater/index.asp](http://www.epa.nsw.gov.au/stormwater/index.asp)>. (Provides information aimed at local government authorities designing stormwater-related education/media campaigns.)
- Melbourne Water's Stormwater program: <[www.stormwater.melbournewater.com.au](http://www.stormwater.melbournewater.com.au)> and Water Sensitive Urban Design guidelines: <[www.wsud.melbournewater.com.au](http://www.wsud.melbournewater.com.au)>.
- Clearwater: a joint initiative of the Municipal Association of Victoria (MAV) and the Stormwater Industry Association of Victoria (SIAV): <[www.clearwater.asn.au](http://www.clearwater.asn.au)>. (Includes an information exchange of case studies, tools, resources, contacts and research.)

### ***American websites:***

- The US Environmental Protection Agency's 'Storm Water Phase II Menu of Best Management Practices': <[www.epa.gov/npdes/menuofbmps/menu.htm](http://www.epa.gov/npdes/menuofbmps/menu.htm)>. (A highly valuable source of information on a wide variety of non-structural BMPs. Presented in a simple to use, fact-sheet format.)
- The US Environmental Protection Agency's 'Non-point Source Program': <[www.epa.gov/OWOW/NPS/index.html](http://www.epa.gov/OWOW/NPS/index.html)>. (Also see their 'Publications and Information Resources' page for a wide range of useful American sites and on-line documents.)
- The 'Stormwater Manager's Resource Center': <[www.stormwatercenter.net](http://www.stormwatercenter.net)>. (Aimed at local government authorities developing strategic urban stormwater management plans and programs.)

- The American ‘National Stormwater Best Management Practices Database’: <[www.bmpdatabase.org](http://www.bmpdatabase.org)>. (Provides access to BMP performance data in a standardised format for numerous BMP studies conducted over the past fifteen years. Currently however, structural BMPs dominate the database.)

## 1.11 Acknowledgment

Several of the introductory sections for this chapter have drawn heavily from Taylor and Wong (2002a & 2002c).

## 1.12 References

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# Appendix A

## Commonly Applied Non-structural Measures for Stormwater Management

Non-structural Measures	Links & Manual Reference
<b>Town Planning Controls</b>	
<ul style="list-style-type: none"> <li>Stormwater planning controls that promote water sensitive urban design.</li> </ul>	Chapter 3; WAPC (Draft) Water Resources SPP No. 2.9 and Liveable Neighbourhoods.
<ul style="list-style-type: none"> <li>Stormwater planning controls that promote best practice stormwater management on construction sites (including erosion and sediment control).</li> </ul>	WAPC (Draft) Water Resources SPP No. 2.9.
<ul style="list-style-type: none"> <li>Non-structural, site-based, water sensitive urban design (WSUD) measures for new residential developments:               <ul style="list-style-type: none"> <li>WSUD applied to public open space networks;</li> <li>WSUD applied to the layout of residential housing lots;</li> <li>WSUD applied to the road layout for residential areas (e.g. narrower residential streets and alternative turnarounds);</li> <li>WSUD applied to streetscaping layout of residential areas;</li> <li>Conservation easements;</li> <li>Development density manipulated to minimise inputs of key pollutants;</li> <li>Open space design (also known as cluster or conservation development).</li> </ul> </li> </ul>	WAPC Liveable Neighbourhoods and (Draft) Water Resources SPP No. 2.9.
<ul style="list-style-type: none"> <li>Non-structural, site-based, water sensitive urban design (WSUD) measures for new commercial/industrial areas:               <ul style="list-style-type: none"> <li>WSUD applied to commercial/industrial parking areas (e.g. green parking lot design);</li> <li>WSUD applied to on-site detention for large commercial/industrial areas.</li> </ul> </li> </ul>	WAPC (Draft) Water Resources SPP No. 2.9; Detention and infiltration systems in Chapter 9.
<b>Strategic Planning and Institutional Controls</b>	
<ul style="list-style-type: none"> <li>Development of stormwater management plans for a local government area or catchment for the improvement of stormwater quality and protection of aquatic ecosystems.</li> </ul>	Chapter 5.
<ul style="list-style-type: none"> <li>Self-sustaining stormwater funding mechanisms.</li> </ul>	Section 2.4.1.
<ul style="list-style-type: none"> <li>Use of risk assessments and environmental management systems by local authorities, State government departments and businesses to strategically assess and manage stormwater risks.</li> </ul>	Section 2.5.1.
<ul style="list-style-type: none"> <li>Integrating the organisational management of stormwater with other aspects of the total water cycle.</li> </ul>	Section 2.5.2.
<ul style="list-style-type: none"> <li>Identifying and fostering champions for stormwater management.</li> </ul>	Chapter 11.
<ul style="list-style-type: none"> <li>Building capacity of elected members, government staff, consultants, developers and residents or the community to improve the management of stormwater.</li> </ul>	Section 2.3.1; Chapters 8 and 11.

Non-structural Measures	Links & Manual Reference
<b>Pollution Prevention Procedures</b>	
<ul style="list-style-type: none"> <li>• Non-structural, site-based measures for land development and construction sites:               <ul style="list-style-type: none"> <li>- Drainage controls;</li> <li>- Erosion and sediment controls;</li> <li>- Dust control;</li> <li>- Housekeeping / pollution prevention / waste management controls (e.g. chemical storage and litter prevention);</li> <li>- Soil amendment undertaken to minimise the export of nutrients.</li> </ul> </li> </ul>	<p>Section 2.1.1. Section 2.1.1. Section 2.1.1. Sections 2.1.1 and 2.2.10. Section 2.1.2.</p>
<ul style="list-style-type: none"> <li>• Stormwater management addressed in infrastructure/assets maintenance operations, for example:               <ul style="list-style-type: none"> <li>- Street cleansing/sweeping;</li> <li>- Stormwater management device maintenance (includes desilting);</li> <li>- Road / pavement repairs / resurfacing and road runoff;</li> <li>- Maintenance of cemeteries, nurseries, depots, parks/reserves activities and road reserves;</li> <li>- Maintenance of gardens and reserves with respect to plant selection, pest management, watering, bore management, lawn maintenance and the application of fertiliser (includes xeriscaping);</li> <li>- Vehicle, plant and equipment maintenance (including storage and washing);</li> <li>- Building maintenance;</li> <li>- Graffiti removal and building wash-down;</li> <li>- Industrial and commercial site practices;</li> <li>- Maintenance of loading and unloading areas;</li> <li>- Storage of hazardous and dangerous goods, food containers, etc;</li> <li>- Sewerage maintenance (including prevention of overflows);</li> <li>- Management of septic systems;</li> <li>- Management of discharges from swimming pools;</li> <li>- Water main maintenance and construction.</li> </ul> </li> </ul>	<p>Section 2.2.1. Section 2.2.2. Section 2.2.5. Section 2.2.6. Section 2.2.7. Section 2.2.8. Section 2.2.9. Section 2.2.9. Section 2.2.10. Section 2.2.10. Section 2.2.10. Department of Health Environmental Health Guide.</p>
<ul style="list-style-type: none"> <li>• Waste management practices:               <ul style="list-style-type: none"> <li>- Domestic waste and recycling collection;</li> <li>- Manual litter collections and ‘clean-up days’;</li> <li>- Bin design, positioning and cleaning;</li> <li>- Management of pet/animal wastes in public open space;</li> <li>- Management of illegal dumping;</li> <li>- Collection programs for hazardous household chemicals, batteries, etc.</li> </ul> </li> </ul>	<p>Waste Wise WA: &lt;<a href="http://www.wastewise.wa.gov.au">www.wastewise.wa.gov.au</a>&gt; or (08) 9278 0300. Section 2.2.3. Section 2.2.4. Phosphorus Action Group: (08) 9458 5664. Metropolitan Illegal Dumping Taskforce: (08) 9278 0300. Contact the relevant local government authority.</p>

<b>Non-structural Measures</b>	<b>Links &amp; Manual Reference</b>
<ul style="list-style-type: none"> <li>• Emergency response procedures.</li> </ul>	<p>&lt;<a href="http://emergency.environment.wa.gov.au">http://emergency.environment.wa.gov.au</a>&gt;</p>
<ul style="list-style-type: none"> <li>• Management of washwaters from: <ul style="list-style-type: none"> <li>- Boats;</li> <li>- Mobile industries (e.g. carpet cleaning, dog washing), etc.</li> </ul> </li> </ul>	<p>Victorian Environmental Protection Authority’s Cleaner Marinas – EPA Guidelines for Protecting Victoria’s Marinas (Oct 1998) &lt;<a href="http://epanote2.epa.vic.gov.au/">http://epanote2.epa.vic.gov.au/</a>&gt;. SCCP Environmental Management and Cleaner Production Directory for Small and Medium Businesses, Section 3.26.</p>
<b>Using/Managing Stormwater</b>	
<ul style="list-style-type: none"> <li>• Stormwater and shallow groundwater recycling.</li> </ul>	<p>Chapter 6; Chapter 9; Search for Water Advice Series: &lt;<a href="http://www.environment.wa.gov.au">www.environment.wa.gov.au</a>&gt;.</p>
<ul style="list-style-type: none"> <li>• Urban forestry.</li> </ul>	<p>Chapter 9.</p>
<ul style="list-style-type: none"> <li>• Eliminating kerbs and gutters.</li> </ul>	<p>Chapters 6 and 9.</p>
<b>Education and Participation Programs</b>	
<ul style="list-style-type: none"> <li>• Source control measures - education programs (general): <ul style="list-style-type: none"> <li>- Printed material (e.g. posters, pamphlets, etc.);</li> <li>- Media campaigns (e.g. radio, TV);</li> <li>- Signs (including gully trap stencilling);</li> <li>- Community programs;</li> <li>- Displays (e.g. at major events);</li> <li>- Community water quality monitoring programs;</li> <li>- Launches (e.g. of a new stormwater initiative);</li> <li>- Local action committees and groups;</li> <li>- Consumer programs (e.g. stormwater awareness at the point of sale);</li> <li>- Business programs (e.g. surveys, targeted workshops);</li> <li>- School education programs.</li> </ul> </li> </ul>	<p>Chapter 8.</p>
<ul style="list-style-type: none"> <li>• Intensive training on aspects of stormwater management.</li> </ul>	<p>Section 2.3.2.</p>
<ul style="list-style-type: none"> <li>• Encouraging citizen participation by the community in all aspects of stormwater management.</li> </ul>	<p>Section 2.3.4.</p>
<ul style="list-style-type: none"> <li>• Regional/citywide stormwater awareness/education programs.</li> </ul>	<p>Section 2.3.3; Chapter 8.</p>
<ul style="list-style-type: none"> <li>• Education and participation programs involving lawn and garden care practices.</li> </ul>	<p>Section 2.3.2.</p>
<ul style="list-style-type: none"> <li>• Education campaigns for commercial or industrial premises.</li> </ul>	<p>Section 2.3.4.</p>
<ul style="list-style-type: none"> <li>• Education and participation campaigns for commercial shopping centres.</li> </ul>	<p>Section 2.3.4.</p>

<b>Non-structural Measures</b>	<b>Links &amp; Manual Reference</b>
• Technical education on water sensitive urban design/low impact development.	Section 2.3.1.
• Focused stormwater education involving new estates.	Section 2.3.5.
<b>Regulatory Controls</b>	
• Enforcement of State or local laws for point and diffuse sources of stormwater pollution (e.g. for erosion and sediment control).	Section 2.4.2.
• Point source regulation of stormwater discharges (e.g. licensing and inspecting/auditing industry).	Section 2.4.2.
• Illicit discharge elimination programs.	Section 2.4.3.
• Vegetated buffer areas.	Chapters 6 and 9.

**Note:**

- Where a specific reference has not been given in the above table, consult the general guideline references given in Section 1.10.

## 2 Guidelines for the use of specific non-structural best management practices

This section contains guidelines for a wide variety of non-structural best management practices. They have been grouped under the following headings:

- Construction practices
- Maintenance practices
- Educational and participatory practices
- Funding, policy, regulatory and enforcement practices
- Catchment planning practices

A summary of the guidelines is provided below. Detailed ‘stand-alone’, lift-out BMP guidelines are provided in the next section (green pages).

Each best management practice has the following sub-headings:

- Description
- Applicability
- Recommended Practices
- Benefits and Effectiveness
- Challenges
- Cost
- Additional Information
- Examples / Case Studies
- References and Further Information

### Summary of non-structural best management practices

#### 2.1 Construction practices

##### 2.1.1 Land development and construction sites

This guideline provides information on *management practices* that may be applied at construction sites to improve stormwater management and environmental performance. These guidelines may also be applicable to land developers and land development government agencies. Land development and construction sites have the potential to be a major source of stormwater pollution, including litter, chemicals, sediment and harmful pollutants absorbed to sediment particles (e.g. heavy metals, nutrients and pesticides). The guideline recommends best management practices, including hazardous and non-hazardous waste management measures, and how to prepare an erosion and sediment control plan to control drainage, erosion, sediment loss and dust, and improve housekeeping practices (e.g. the washing of buildings and equipment, and litter control).

##### 2.1.2 Soil amendment for urban gardens and lawns

Urban development usually diminishes the capacity of soil to support plant growth through processes such as the removal of topsoil and soil compaction. Many areas in Western Australia have sandy soils with low ability to retain moisture, nutrients and trace elements. Soil amendment is a technique used to create fertile topsoil by increasing the soil’s ability to retain moisture and nutrients, and filter some contaminants, such as heavy metals, before they infiltrate into groundwater. Soil amendment involves adding an agent, such as clay or crushed limestone, to the soil to improve its structure, porosity, water holding capacity and nutrient recycling capacity. Soil amendment in urban areas is still an experimental technique in Western Australia, but shows great potential.

## 2.2 Maintenance practices

### 2.2.1 Street sweeping/cleansing

Street sweeping is widely used in urban areas to reduce the accumulation of litter, leaves and coarse sediment from roads and footpaths. It is undertaken to improve aesthetics, public safety and stormwater quality. Street sweeping as a stormwater quality BMP is an attractive option for many local authorities, as it is already in use, and roads, car parks and footpaths account for approximately 70% of impervious urban areas. There are many types of sweeping equipment, with new technologies recently emerging that have the potential to collect a high proportion of fine sediments, unlike their predecessors. Street sweeping has most benefit in specific circumstances, such as focusing on pollution ‘hot spots’ rather than routinely sweeping all streets, and coordinating street sweeping with other maintenance activities and events, such as after a street parade.

### 2.2.2 Maintenance of the stormwater network

Maintenance of the stormwater drainage network includes inspection, cleaning and repair of open and piped drains, pits, treatment devices, detention basins and outfall structures. This network needs to be regularly cleaned to maintain its performance. Drainage features such as infiltration pits/soak wells and detention basins can provide ‘hot spots’ for accumulation of gross pollutants and contaminated sediments with high concentrations of heavy metals, hydrocarbons and nutrients. Regular cleaning of the stormwater drainage network provides an opportunity to remove pollutant loads that would otherwise enter receiving water bodies after heavy rainfall. Drains with accumulated pollutants may also overflow, leading to localised flooding and erosion, as well as risks to human safety and constructed assets. Open drains and basins can provide habitat for aquatic fauna and birds. Maintenance of these areas may need to include protecting their environmental values and minimising disturbance to vegetation. This guideline will focus on the maintenance of those elements of the stormwater drainage system that are not specifically designed to trap pollutants (e.g. pits, soak wells, pipes, open channels and detention basins). For structural best management practices that are designed to trap pollutants, each device should have a detailed and site-specific maintenance plan (see Chapter 9).

### 2.2.3 Manual litter collections

The manual collection of gross pollutants (especially litter) in locations where it may be blown or washed into the stormwater drainage network or directly into water bodies is a common management practice, particularly in urban areas and along main roads. Collections are typically undertaken by staff from government agencies (e.g. in ‘hot spots’, such as along the road corridor in commercial areas), volunteers during ‘clean-up days’, the private sector in relation to their own premises (e.g. around commercial and industrial sites) and sectors of the community that sponsor an area. This management practice is often implemented for aesthetic reasons. However, there is evidence that a regular manual litter collection program can significantly reduce the loads of pollutants entering water bodies via the stormwater drainage network. The practice can, in some circumstances, be used to provide an opportunity to raise the public's awareness of stormwater pollution.

### 2.2.4 Litter bin design, positioning and cleaning

The design, location and maintenance regimes surrounding public litter bins (and accompanying recycling facilities) can facilitate litter control, particularly in public spaces in urban areas and potential litter ‘hot spots’ in non-urban locations (e.g. roadside rest areas). In remote locations however, public litter bins may attract illegal dumping of large volumes of waste (e.g. places where people camp). Caution is needed, as this management practice should not be considered in isolation from the local context in which it will be

applied or from supporting measures (e.g. signage, public participation and enforcement). Strategies that are considered to be effective in reducing local littering in public places include placing bins in locations that are convenient to the public, designing bins to catch the attention of the public, keeping observable litter to a minimum (e.g. through frequent collections), providing signage, designing public open space to minimise areas that are hidden from public view and involving the community in litter management initiatives.

### 2.2.5 Road / pavement repairs / resurfacing and road runoff

Activities to repair potholes and degraded footpaths and resurface roads have the potential to contaminate stormwater. Substantial amounts of pollutants are generated during daily roadway use, which can threaten the health of local water bodies by contributing heavy metals, hydrocarbons, sediment, gross pollutants and nutrients. The risks to stormwater quality include discharges of hydrocarbons during road resurfacing work (e.g. from a spill), discharge of sediments, heavy metals and hydrocarbons from road surfaces, bitumen overspray during road resurfacing activities, alkaline slurry from concrete cutting activities and wastewater from the washing of machinery and tools. Specific management practices need to be applied to minimise these risks, such as planning maintenance activities, modifying road resurfacing and footpath maintenance practices, managing spills and sweeping. Strategic planning and employing good road and bridge maintenance practices are efficient and low-cost means of minimising contamination of stormwater runoff and reducing the risk of environmental harm to the receiving environment.

### 2.2.6 Maintenance of premises typically operated by local government

This guideline briefly outlines key stormwater management practices that are often required on premises that may be operated by local government. These premises include parks, cemeteries, sports fields, nurseries, depots, buildings and road reserves. Note that BMP 2.2.7 specifically addresses stormwater management on parks, gardens and sports fields. Local governments may operate a wide range of facilities that have the potential to contaminate stormwater and/or generate large volumes of stormwater due to a high percentage of impervious surfaces. To thoroughly identify, assess, manage, monitor and continually improve the management of stormwater-related risks from these premises, it is recommended that operators implement an environmental management system (EMS) (explained more fully in BMP 2.5.1). A risk assessment that identifies and evaluates the potential stormwater-related risks is strongly recommended prior to the application of new management practices. This guideline provides a basis for undertaking this assessment and developing a tailored, site-specific stormwater management plan/procedure.

### 2.2.7 Maintenance of gardens and reserves

The maintenance practices applied to grassed areas and gardens can have a significant potential impact on stormwater and groundwater quality. Potential pollutants include nutrients, sediment, pesticides, wastewater from washing machinery (e.g. mowers), and organic matter (e.g. grass clippings). Possible impacts include eutrophication and elevated levels of turbidity in receiving waters, leading to a variety of adverse impacts on aquatic flora and fauna. This guideline focuses on best management practices related to plant selection and landscaping design, nutrient and irrigation management, lawn mowing, top dressing and pruning, and pest management. The objectives are to minimise pollutants leaving the site via stormwater or shallow groundwater, minimise adverse impacts on the site's hydrology, minimise the use of fertilisers and irrigation water, maximise water and nutrient recycling and, where possible, save time and money on maintenance practices.

### 2.2.8 Maintenance of vehicles, plant and equipment (including washing)

The storage and maintenance of vehicles, plant and equipment can contaminate stormwater with pollutants such as petrol, diesel, kerosene, coolants, solvents, brake fluid, motor oils, lubricating grease, sediment and heavy metals. The washing of vehicles, plant and equipment can also produce highly contaminated wastewater. This best management practice outlines recommended guidelines for vehicle storage and equipment storage areas, cleaning plant and equipment, refuelling areas and vehicle maintenance. These management practices are applicable to maintenance activities undertaken by government agencies, construction and maintenance companies, operators of automotive maintenance premises and residents that maintain their own vehicles. Pollution prevention and good ‘housekeeping’ practices for the maintenance of vehicles, plant and equipment as addressed in this guideline can help reduce the influence of automotive maintenance practices on stormwater runoff and local water supplies. These practices include storing and maintaining vehicles, plant and equipment in covered areas, using drip pans and washing vehicles in wash bays.

### 2.2.9 Building maintenance

Building maintenance practices such as washing of buildings and paved surfaces, sandblasting, painting, rendering and graffiti removal generate contaminated wastewater that is a potential threat to the stormwater system and can be acutely toxic to aquatic biota in the receiving water body. Once construction is completed, pollutants in runoff from roofed areas and paved surfaces may continue to enter stormwater after every rainfall event. These pollutants include flaking paint containing heavy metals, nitrogen from atmospheric deposition, litter from the building’s footpaths, hydrocarbons and heavy metals from the building’s roadways and nutrients from fertilised lawns and garden beds. Management practices can be applied during building maintenance and post-construction stages to minimise the risk of stormwater and groundwater pollution and, to a lesser extent, minimise the volume of stormwater discharge. These guidelines include procedures for the proper storage, use and disposal of hazardous and non-hazardous wastes, techniques to prevent wastewater from entering the stormwater system and recommendations for inspection and maintenance of stormwater-related structures.

### 2.2.10 Stormwater management on industrial and commercial sites

Industrial and commercial premises have significant potential to pollute stormwater, for example, through poor control of industrial processes or inadequate facilities for waste disposal. The transport, handling and storage of goods and wastes can also result in the contamination of stormwater. Small to medium-sized industrial premises have been identified as representing a significant cumulative risk to the health of water resources in the Perth metropolitan area. Improving practices that potentially impact on stormwater and groundwater at these premises is a priority for water resource protection. Recommended pollution prevention practices include identifying and assessing stormwater-related risks on the site, developing management plans or procedures to manage the identified risks and training all staff to undertake their roles in relation to these management plans/procedures. This BMP guideline outlines good ‘housekeeping practices’ to keep the workplace clean and management practices to minimise the risk of accidental spills. Cleaner production techniques are also outlined, such as waste minimisation, stormwater/ roof water recycling and using alternative materials during production processes to prevent the generation of hazardous wastes. These techniques minimise the risk of stormwater contamination and reduce the export of stormwater and stormwater pollutants from the site.

## 2.3. Educational and participatory practices

### 2.3.1 Capacity building programs for local governments and stormwater management industry professionals

Capacity building is a holistic approach to knowledge building and transfer, which fosters professional skill development, competency, innovation and confidence. Capacity building is also a means to facilitate network building, linkages and training for continuous improvement. Providing people with the information and skills they need to make better decisions is an essential part of promoting best practice stormwater management. This guideline outlines the steps to developing a stormwater-related capacity building program. These programs can be run at a variety of scales, from a program that covers a small local government area to one that covers an entire State. Capacity building programs may include a suite of tailored training and education packages to promote best practice in stormwater management to local government and stormwater industry professionals. Other components of the program may include accreditation systems, demonstration sites and promotional activities (e.g. competitions and annual awards). Projects may include training events, information registers, websites, newsletters, travelling ‘road shows’ and manuals or guidelines.

### 2.3.2 Intensive training of landowners on aspects of stormwater management

This best management practice typically involves intensive training for volunteer residents to provide information on alternative lawn and garden care practices. These programs may focus on source controls, with the aim of minimising stormwater pollution, particularly with respect to nutrients. Programs may address water conservation, plant selection (e.g. growing local native plants or plants that require less water and fertiliser), fertiliser use, weed and pest management, irrigation practices, stormwater and shallow groundwater reuse, composting and soil amendment. These programs are applicable to all areas, particularly areas with sandy soils that have low nutrient and moisture retention capabilities; areas draining to sensitive water bodies or water bodies that are under stress from nutrient inputs; drinking water catchments; areas with large gardens and lawns; and areas subject to erosion (e.g. due to steep slopes).

### 2.3.3 Encouraging participation by the community in stormwater management

Stormwater-related community participation programs seek to engage the community so that they understand the nature of the problem and can participate in the development and implementation of solutions. Community members, given support and time, can quickly build knowledge and positively contribute to the formulation of new and sustainable approaches to stormwater management. This best management practice fosters ownership of stormwater-related problems by the local community. A *participatory* approach can be applied to common stormwater-related activities, such as the development of a stormwater management plan or program to protect the health of a local waterway. Encouraging public participation in decision-making is a ‘bottom-up’ approach that has been shown to more effectively change people’s behaviour than traditional ‘top-down’ education methods. The technique can be applied to common stormwater-related activities such as the development of management plans; education/participation programs (e.g. programs within a catchment to protect the health of a local waterway or wetland and anti-litter campaigns within a commercial district); and specific activities such as stormwater drain stencilling and clean-up activities.

### 2.3.4 Education and participation campaigns for commercial and industrial premises

This best management practice includes industry-specific training and environmental accreditation programs to increase the uptake of environmental management and cleaner production techniques. Many industrial and commercial premises have a significant risk of contaminating stormwater and shallow groundwater due to the type of activities they undertake (e.g. fuel and chemical storage associated with automotive repair industries). For education campaigns involving commercial or industrial premises, care must be taken to specifically tailor messages to a particular target audience. While the approach needs to be tailored, the recommended procedure of firstly surveying the target audience, designing the campaign (involving the target audience where possible), delivering the campaign and finally evaluating the campaign is generic. To maximise the effect of the campaign, the complementary use of site assessments, incentives (e.g. positive recognition, assistance) and disincentives (e.g. penalties) should also be considered.

### 2.3.5 Focused stormwater education involving new estates

The employment of a developer-funded Stormwater Management / Environmental Officer for a large residential estate/ land development has great potential and should be considered as part of the development's overall stormwater management plan. The officer would play a role during the construction stage to ensure that best practice stormwater management techniques are implemented. This could include educating builders and sub-contractors while they are on-site and helping to maintain the integrity of structural controls, such as infiltration systems, during construction. The officer could also monitor construction practices and erosion and sediment controls. The role could be valuable in educating residents on water sensitive management practices at the building stage, when there is the greatest potential to adopt measures such as waterwise and fertilise wise gardening (e.g. through plant selection) and the reuse of shallow groundwater or roof water. The Stormwater Management Officer would also have a role during post-construction in educating new landowners about sustainable practices for washing cars, car maintenance (e.g. changing oil), composting, disposing of animal wastes, disposal of swimming pool discharges, bin washing and how to keep materials, such as lawn clippings and sediment, out of the stormwater management system. The officer could help establish an ongoing environmental group for the catchment area and run community education and participation events. The role could be broadened to include education on all aspects of sustainable living, for example energy efficiency, waste minimisation and litter management.

## 2.4 Funding, policy, regulatory and enforcement practices

### 2.4.1 Funding programs for stormwater management

Effective stormwater management requires substantial resources. Resources are typically obtained from short-term grants, consolidated revenue or general rates, environmental levies and/or stormwater-related fees. Establishing a dedicated, stable source of funding is one of the key foundations for a successful stormwater management program and is required to ensure long-term viability of the program and public support. Short-term funding programs have sometimes led to poor outcomes, for example, gross pollutant traps that were hastily built with grant funds, but never maintained due to a lack of ongoing funding. Local government authorities are increasingly establishing their own dedicated funding mechanisms, usually in the form of an environmental levy or a property-based stormwater fee. Funding mechanisms can be structured to provide economic incentives for implementation of stormwater management controls and can be based on 'polluter pays' and 'user pays' principles. This BMP outlines the steps for creating a stormwater funding utility. Stormwater utilities are a dependable and equitable approach available to local government or stormwater management authorities to finance stormwater management. Resistance to

property-based stormwater fees is often minimal where the need for stormwater funding is clearly communicated to the local community and the community is involved in the design of the funding mechanism.

#### 2.4.2 Point source regulation of stormwater discharges and enforcement activities

Regulation of specific commercial and industrial premises (e.g. automotive industries, nurseries, landfills, waste recycling facilities, etc.) is a widely used and potentially highly effective technique to minimise stormwater and groundwater pollution. Such premises are typically licensed by a government agency, with their activities controlled through legally enforceable licence conditions that are regularly checked by enforcement officers who audit the premises. Control of point sources of stormwater pollution is generally considered to be easier than controlling diffuse sources (e.g. runoff from roads and rural land uses), and more rewarding on a cost-benefit basis. As such, a well-managed point source regulation program should be a priority of agencies that are responsible for managing stormwater and groundwater quality. Enforcement of regulations is usually considered an option of last resort, although experience around the world has demonstrated that it is often needed and is highly effective at managing behaviour that has the potential to pollute stormwater or groundwater. Common examples of laws to prevent or minimise specific forms of stormwater pollution include those that discourage illegal dumping of wastes, control discharges to stormwater and/or groundwater from commercial and industrial premises, discourage littering and encourage best practice stormwater management on building sites.

#### 2.4.3 Illicit discharge elimination programs

Illicit connections are defined as illegal and/or improper connections to stormwater drainage systems and receiving waters. Illicit discharge elimination programs seek to identify and remove illegal or inappropriate waste streams entering the stormwater network. The most obvious of these waste streams include trade wastes from commercial and industrial premises and wastewater from domestic premises. Illicit connections to stormwater can be surprisingly common and represent a major source of pollution. This BMP outlines the principal components of illicit discharge elimination programs and techniques to identify these discharges. To be effective, these programs need to be supported by targeted education campaigns and regulatory mechanisms that enable action to be taken to eliminate the discharge and prosecute offenders. Case studies indicate that very large volumes of liquid wastes can be prevented from entering stormwater. Identifying and eliminating illicit connections and discharges is a simple and cost-effective way to eliminate some of the worst pollution from stormwater and improve the health of receiving water bodies.

### 2.5 Catchment planning practices

#### 2.5.1 Risk assessments and environmental management systems

Managing stormwater at the catchment or citywide scale is a challenging task, as there are typically many sources of pollution and limited resources to manage them. Each of these sources poses a different level of risk to the health of receiving waters. One way of identifying stormwater management risks, assessing them, prioritising them, and allocating resources to manage them is to use 'risk assessments' and associated 'environmental management systems'. Risk assessment is defined as the process of risk analysis and risk evaluation. Environmental management systems provide the framework within which an organisation can systematically develop its environmental policy, identify and assess its risks, develop measures to manage these risks, monitor the success of these measures, report on its environmental performance, and revise its environmental programs where necessary. The use of these tools for managing stormwater is highly applicable to local government authorities, government departments, industry and

business, for example, when stormwater management plans are developed or when operations are reviewed to ensure all practicable steps are being taken to prevent or minimise stormwater pollution. The process of undertaking risk assessment may also identify serious breaches of environmental legislation and help educate staff about best practice stormwater management.

### 2.5.2 Managing the total water cycle

Increasingly, agencies responsible for stormwater management are realising that the issue cannot be managed in isolation from other elements of the water cycle. The new approach to managing water resources in an integrated fashion is known as ‘total water cycle management’, or ‘integrated water resource management’, or ‘water sensitive urban design’. Stormwater, water supply and wastewater/effluent are all considered during the design process. The new, integrated approach to water management has significant benefits compared to the traditional approach of managing these streams in isolation, including the potential to reduce development costs, reduce water pollution, reduce the consumption of scheme water, and reduce water balance problems by minimising changes to pre-development hydrological regimes. Water efficiency, reuse and recycling are integral components of total water cycle management.

## 2.1 Construction practices

### 2.1.1 Land development and construction sites

#### Description

These guidelines provide information on management practices that may be applied at construction sites to improve stormwater management and environmental performance. These guidelines may also be applicable to land developments and government agencies that are responsible for land development, such as LandCorp.

Land development and construction sites may be a major source of stormwater pollution. For example, some activities that may allow pollutants to be transported via stormwater management systems to receiving water bodies (e.g. waterways, wetlands, groundwater and marine environments) include:

- Litter and waste storage (e.g. litter collection areas that allow litter to be blown by wind or washed away by rainfall).
- Washing-down practices (e.g. washing-down concrete mixers and painting tools).
- Vehicle tracking of soil from the building site onto roads.
- Placement and storage of delivery products, particularly sand and soil stockpiles (e.g. if sand is stored where it may be tracked by vehicles onto roads, or blown or washed into roads, and then into stormwater management systems).
- Dewatering (e.g. in areas with acid sulfate soils, dewatering activities may cause sulfide minerals in the soil to oxidise and leach acidity, heavy metals and aluminium into groundwater). Contaminated groundwater may then adversely impact on receiving water bodies.

The Western Australian Clean Site – Building a Better Environment Program can provide additional information and support (refer to the Additional Information section).

Appendix 1 – Building Activities, Waste Materials and Relevant Best Management Practices outlines the waste materials and relevant best management practices for different trades in the building industry.

#### Reasons for management of litter, waste and washing-down practices

Contaminants, such as sediment, solvents, paints, adhesives, cement, cement mixer wash-water, lime and litter (e.g. packaging including polystyrene, cardboard and plastic), may be transported via stormwater management systems to receiving water bodies. Where building sites are adjacent to receiving water bodies, contaminants may enter directly from the building site.

These contaminants may harm aquatic ecosystems and cause adverse aesthetic impacts on neighbouring land and receiving water bodies. For example:

- Lime and cement, including cement mixer wash-water, may cause changes in pH in receiving waterways and wetlands. This may harm aquatic flora and fauna.
- Litter (particularly polystyrene, cardboard and plastic) may cause adverse aesthetic impacts, as it may be blown or washed into neighbouring land, stormwater management systems and receiving water bodies. Litter may also harm aquatic fauna, for example plastic may entangle aquatic fauna.
- Contaminants such as paints and solvents (e.g. turpentine) contain toxic compounds that may harm aquatic flora and fauna. For example, oil-based paints form a thin layer over the surface of the water. This may harm aquatic flora and fauna by preventing sufficient oxygen from entering the water body.

- Litter and cement may block stormwater management systems, increasing maintenance costs and the risk of localised flooding.

## Reasons for erosion and sediment control

Erosion and sediment control is used to prevent or minimise:

- Sedimentation of receiving water bodies. For example, sediment may smother aquatic plants and filter feeders, encourage weed species and harm aquatic habitats, such as deep pools in waterways.
- Sedimentation of stormwater management structures and drains. This may increase maintenance costs and the risk of localised flooding. For example, sediment may compromise the capacity of vegetated swales to adequately manage stormwater flows.
- Increased turbidity in receiving water bodies, which may irritate the gills of fish and reduce photosynthesis in aquatic flora. Reduced photosynthesis may result in deoxygenation of the water and adverse impacts on aquatic flora and fauna, such as fish kills.
- Environmental harm from pollutants that attach to soil particles (e.g. heavy metals, nutrients and pesticides).
- Increased safety risks due to sediment on roads or footpaths.
- Decreased value of properties due to the loss of topsoil and visual impacts.
- Increased costs associated with street sweeping and ‘downtime’ on building sites due to waterlogged conditions or time spent repairing the damage of erosion.

## Applicability

The following management practices are applicable to land developments and construction sites in all areas, particularly in catchments or sites with:

- ‘traditional’ (piped) stormwater management systems;
- sensitive receiving water bodies;
- steep slopes; or
- a high proportion of directly connected impervious surfaces (e.g. the roof water from buildings drains directly to the street’s drainage system).

These guidelines may be relevant to local governments and State government agencies that co-ordinate, manage or regulate land development and construction sites, such as:

- land developers (e.g. LandCorp);
- managers of major land development and construction projects (e.g. roads, bridges, drainage works and buildings);
- those who may enforce controls on private sector developments.

The following recommended practices are applicable for all sites:

- litter and waste management (non-hazardous material);
- litter and waste management (hazardous material);

- washing-down practices; and
- water conservation practices.

Erosion and sediment controls should be based on site conditions. The 'Erosion and sediment control practices (relatively flat sites)' section is applicable for non-constrained sites where there is a low risk of off-site migration of sediment. The 'Erosion and sediment control practices (constrained sites)' section is applicable for sites where there is a high risk of off-site migration of sediment, or where there is a sensitive receiving environment.

## Recommended Practices

Refer to the Additional Information section for information sheets on the following recommended practices.

### Litter and waste management (non-hazardous material)

The following procedures are recommended for the proper storage and disposal of *non-hazardous wastes* (e.g. wood, tiles, bricks, metal, soil, dried cement and packaging wastes such as polystyrene, cardboard and plastic) on *all construction sites*.

- ✓ Designate a waste collection area on-site that does not receive runoff from upland areas and does not drain directly to a water body or the road. The waste collection area should be placed as far away as practicable from roads and stormwater management systems, water bodies (if applicable) and the lowest point on the site.
- ✓ Ensure that waste containers have lids so they can be covered before periods of rain, or keep containers in a covered area whenever possible.
- ✓ Ensure waste containers do not release light-weight material, such as polystyrene, cardboard and paper, during strong winds.
- ✓ Where bins are emptied on-site by a waste contractor, inspect the area immediately afterwards and undertake 'dry' clean-up methods where necessary (e.g. sweeping up spilled litter and debris).
- ✓ Schedule collection events to prevent waste containers from overfilling.
- ✓ Clean up spills immediately.
- ✓ During demolition activities, provide extra containers for waste materials and schedule more frequent collections.
- ✓ Ensure all wastes are recycled or taken to authorised disposal sites that are appropriate for the types of waste generated from the site. For information about waste acceptance criteria and determination of the appropriate type of landfill for disposal of the collected material, refer to the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002), available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300. Further information about recycling is available from Waste Wise WA via <[www.wastewise.wa.gov.au](http://www.wastewise.wa.gov.au)> or by telephoning (08) 9278 0300. The website includes a list of contractors that will recycle building wastes (from the home page, select 'Recycling', then 'Recycle it!').
- ✓ For large building sites, or building businesses that manage many sites, develop a Waste Management Plan to ensure that solid and liquid wastes are minimised and stored correctly to reduce the risk of stormwater contamination. This plan may explore opportunities for waste

minimisation (e.g. ensuring the correct amounts of raw materials are purchased to decrease the amount of excess materials that are discarded) and reuse and recycling of wastes and unused materials. Support is available from Waste Wise WA. Further advice is available in the *Wastewise Construction Handbook* (DEH, 1998), available by telephoning the Department of Environment and Heritage (Australia) on (02) 6274 1111 or via <[www.deh.gov.au/industry/construction/wastewise/handbook/index.html](http://www.deh.gov.au/industry/construction/wastewise/handbook/index.html)>.



*Figure 1. Inadequate waste containment and spillage of waste onto the road. (Photograph: Clean Site, Keep Australia Beautiful Council WA.)*



*Figure 2. Site fencing for litter containment and security. (Photograph: Clean Site, Keep Australia Beautiful Council WA.)*

To minimise wastes, the following waste management hierarchy is recommended:

1. **Reduce:** Reduce wastes using improved estimation methods and reuseable products.
2. **Reuse:** Modify procedures so that materials may be reused, for example wood, tiles, formwork, bricks.
3. **Recycle:** Builders may work with waste contractors to recycle wood, metals, cardboard, soils, bricks, clay tiles, concrete, mortar, screed, plasterboard and plaster.

### Litter and waste management (hazardous materials)

The following steps should be undertaken to ensure appropriate disposal of *hazardous* wastes (e.g. paints, adhesives, solvents, contaminated soils, asbestos and Schedule 1 substances) on *all construction sites*:

- ✓ Store materials and equipment that could contaminate stormwater (e.g. fuel, paint, solvents and cement) under covered areas wherever possible and as far away as practicable from roads and stormwater management systems, water bodies (if applicable) and the lowest point on the site. Guidelines for fuel and chemical storage, including Department of Industry and Resources guidelines and Department of Environment Water Quality Protection Notes, are listed in Section 2.0 Fuel and Chemical Storage Guidelines in the *Environmental Management and Cleaner Production Directory* (DoE and SRT, 2004). Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>, <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning (08) 9278 0300.
- ✓ The original product label should never be removed from hazardous wastes in containers (e.g. solvents), as the labels contain important safety information.

- ✓ Design a contingency plan for accidental chemical spills, and clean up spills immediately. Follow clean-up instructions on the package. Use an absorbent material such as sawdust or kitty litter to contain the spill where it is safe to do so. Refer to the Water Quality Protection Note: *Chemical Spills – Emergency Response Planning* (WRC, 2002a) for further advice. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300. Or contact the Department of Environment’s Emergency Pollution Response Unit on (08) 9222 7123 (after hours 1800 018 800). Further information about emergency response is available via <<http://emergency.environment.wa.gov.au>>.
- ✓ Hazardous wastes should never be mixed during disposal unless specifically recommended by the manufacturer.
- ✓ Local waste management authorities should be consulted about the requirements for disposing of hazardous materials (e.g. contaminated soils, asbestos). Further information and support is available from Waste Wise WA via <[www.wastewise.wa.gov.au](http://www.wastewise.wa.gov.au)> or by telephoning (08) 9278 0300.
- ✓ If producing controlled wastes (i.e. wastes that may cause environmental or health risks, such as any wastes that cannot be disposed at a Class I, II or III landfill site), the producer must use a controlled waste carrier to remove that waste (DoE, 2004b). The Department of Environment regulates the transportation of these waste through the application of the Environmental Protection (Controlled Waste) Regulations 2004 (available via <[www.slp.wa.gov.au/statutes/av.nsf/doi](http://www.slp.wa.gov.au/statutes/av.nsf/doi)>). *Attachment 1 for Application Forms (Controlled Waste Categories and Descriptions)* (DoE, 2004c) contains a list of controlled wastes, available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> (refer to ‘Land’ / ‘Controlled Wastes’ / ‘Forms’) or by telephoning (08) 9278 0300.
- ✓ Staff should be aware of the Environmental Protection (Unauthorised Discharge) Regulations 2004. The regulations include an on-the-spot infringement notice system for *minor* pollution offences. These powers can be delegated to local government officers. On-the-spot fines carry a penalty of \$250 to \$500, which increases to \$5,000 if the matter proceeds to court. The fines apply to land development and construction premises and cover the discharge of Schedule 1 substances to stormwater or groundwater. These substances include acid with a pH less than 4, alkali with a pH more than 10, hydrocarbons, solvents, degreasers, detergents, dust, engine coolant, pesticides, paint, dyes, sediment and substances containing heavy metals (Raine, 2004). The regulations are available via the State Law Publisher’s website, <[www.slp.wa.gov.au/statutes/av.nsf/doi](http://www.slp.wa.gov.au/statutes/av.nsf/doi)>, <[www.slp.wa.gov.au](http://www.slp.wa.gov.au)> or telephone (08) 9321 7688.

### Washing-down practices

- ✓ Designate a wash-down area for the site. This area should be located as far away as practicable from roads, stormwater management systems and water bodies (if applicable).
- ✓ Contain wash-water using temporary bunds (e.g. constructed from soil or sand bags), where appropriate, particularly if the wash-down area must be located near roads, stormwater management systems and water bodies.
- ✓ If the bricklayer’s concrete mixers are located near stormwater management systems, water bodies or the lowest point of the site, collect wash-water from the mixer in a wheel barrow and allow the wash-water to soak into the ground in the designated wash-down area (if practicable).



Figure 3. Cement mixer wash-water runoff and sand on the road. (Photograph: Clean Site, Keep Australia Beautiful Council WA.)



Figure 4. Contained wash area to collect runoff. (Photograph: Clean Site, Keep Australia Beautiful Council WA.)

- ✓ Clean equipment before washing (e.g. wipe excess paint from brushes and rollers to remove paint before washing, or brush sand and mud from equipment).
- ✓ For paint equipment wash-water: Water-based paint wash-water should be diverted into a contained area on-site that is lined with newspaper. When it is dry, place the newspaper containing the paint residue in a solid waste bin. Solvents used for clean-up of oil-based paints should be filtered for reuse or taken to a waste depot that is licensed to accept these wastes. The paint residue left after filtering should be placed in a solid waste bin. Where possible, rather than washing brushes and rollers, seal in an airtight bag for reuse. Unused paint should be kept in the tin or other sealed container and disposed at a waste depot licensed to receive this waste.
- ✓ Ensure that wastewater is allowed to infiltrate into the soil (for small quantities of non-hazardous wastewater), discharged to sewer (an Industrial Waste Permit is required), or contained and disposed of off-site at an appropriate licensed treatment/disposal facility (for hazardous waste, such as solvents). See 'Litter and waste management (hazardous materials)' section for information on hazardous waste disposal. Further information about connection and discharge of wastewater to sewer is available from the Water Corporation via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)> or by telephoning the Customer Service Centre on 13 13 95.

## Water conservation

Conserve water by turning off taps after use, ensuring water drums are not leaking and minimising the volume of water used during washing-down practices.

## Erosion and sediment control practices (relatively flat sites)

The following practices are recommended for land development and construction sites with a low slope and low risk of off-site migration of sediment. Simple Site Management Plans are required for these sites to prevent or minimise sand tracking from vehicles onto footpaths and roads, and to prevent positioning of stockpiles (particularly sand) near roads, where sediment may easily enter stormwater management systems and receiving water bodies.

The Site Management Plan should address the following:

- ✓ Site planning. For example, use a simple map to identify the lowest point on the site, the appropriate location of stockpiles such as sand (e.g. keep sand stockpiles as far from the road and the lowest point of the site as practicable), where to place sediment fences (e.g. on lowest side of the site), and which trees and vegetation will be retained).
- ✓ Minimising the area of disturbance.
- ✓ Dust control and wind erosion.
- ✓ Barriers to trap wind-blown sediment, sand and litter.
- ✓ Stabilised entry and exit points (i.e. to prevent soil being tracked onto footpaths and roads).
- ✓ Housekeeping practices (e.g. sweeping up and removing any sand tracked by vehicles onto roads, and appropriate disposal of wash-waters to prevent water erosion).
- ✓ Positioning of stockpiles such as sand.



Figure 5. Sand stockpile erosion onto a road. (Photograph: Clean Site, Keep Australia Beautiful Council WA.)



Figure 6. Soil stockpile contained by a sediment fence. (Photograph: Clean Site, Keep Australia Beautiful Council WA.)

- ✓ In Perth and the South West region, the plan should be guided by the *Erosion and Sediment Control Guidelines for the Swan Coastal Plain* in Section 5.1.2 of the *Local Government Natural Resource Management Policy Manual* (EMRC, 2002) or the *Erosion and Sediment Control Manual for the Darling Range* (Upper Canning/Southern Wungong Catchment Team, 2001). Refer to the Additional Information section for more details.
- ✓ For large-scale developments, ensure all on-site staff are trained to understand their responsibilities with respect to stormwater management (including management of litter, liquid wastes, maintenance of erosion and sediment control structures, dust control, subcontractors, etc.). At small-scale (i.e. residential) construction sites, building companies should ensure compliance by providing simple guidelines to sub-contractors.

## Erosion and sediment control practices (constrained sites)

Erosion and sediment control practices should be a high priority on sites where:

- There is a significant erosion risk (e.g. land development or construction activities on the Darling Scarp in Perth/the South-West in winter); or
- There is significant potential for soil to enter stormwater management systems, receiving water bodies, or areas of native vegetation; or
- Receiving water bodies are known to be sensitive to changes in turbidity, sediment loads, litter and/or pollutants; or
- Public safety and/or assets could be at risk due to off-site migration of sediment (e.g. sediment on roads, blocking of drains causing localised flooding).

In addition to the practices recommended for erosion and sediment control for relatively flat sites (i.e. sites with low slopes), the following steps should be undertaken when developing an Erosion and Sediment Control Plan for constrained sites:

- ✓ Undertake an evaluation of the site's erosion risk. A simple methodology is provided in EMRC (2002).
- ✓ Prepare a detailed map of the site that includes information such as property boundaries, contours, area of disturbance, access points, location of all permanent and temporary erosion and sediment control measures (e.g. sediment fences, diversion drains), location of existing vegetation to be retained or removed, location of water bodies and drainage structures, etc. (see EMRC, 2002 for more details).
- ✓ Provide supporting information, such as a description of the existing site conditions and maintenance strategies (including roles and responsibilities), drawings of erosion and sediment control structures, and design criteria and calculations.

It is essential to plan an approach to managing erosion and sediment control before the site has been disturbed. The Erosion and Sediment Control Plan is the primary tool for undertaking and documenting this planning process. The plan should aim to:

- ✓ Minimise the area disturbed by the development.
- ✓ Minimise the time disturbed areas are exposed without stabilisation.
- ✓ Conserve and safely stockpile topsoil for later distribution.
- ✓ Divert up-slope runoff around the disturbed area and safely dispose of this water to a stabilised area.
- ✓ Progressively rehabilitate disturbed areas.
- ✓ Institute a comprehensive maintenance program for all erosion and sediment control measures.



*Figure 7. Silt fence for controlling sediment during land development. (Photograph: André Taylor, Ecological Engineering Pty Ltd.)*

- ✓ In Perth and the South West region, these plans should be consistent with the *Erosion and Sediment Control Guidelines for the Swan Coastal Plain* in Section 5.1.2 of the *Local Government Natural Resource Management Policy Manual* (EMRC, 2002) and the *Erosion and Sediment Control Manual for the Darling Range* (Upper Canning/Southern Wungong Catchment Team, 2001). Refer to the Additional Information section for more details.

## Dewatering and acid-sulfate soils

Dewatering activities must be approved by the Department of Environment or the Swan River Trust. The following conditions apply:

- ✓ Dewatering operations should be consistent with the *Dewatering of Soil Water Quality Protection Note* (WRC, 2003).
- ✓ Disposal of water to stormwater drains that discharge to waterways or wetlands should not be considered, unless other options are not available.
- ✓ Consult the Department of Environment and/or the local government authority to determine suitable water quality criteria for the water being discharged from the site.
- ✓ A contingency plan is required to manage discharged water (e.g. if the water quality deteriorates during pumping).
- ✓ Consider the presence of acid sulfate soils. The Department of Environment's *Acid Sulfate Soils Guideline Series: Guidance for Groundwater Management in Urban Areas on Acid Sulfate Soils* (2004a) and the Western Australian Planning Commission's *Planning Bulletin No. 64: Acid Sulfate Soils* (2003) provide additional guidance.

## Contaminated sites

Extreme care is needed where soils are disturbed or exposed on potential or confirmed 'contaminated sites'. Consult with the Department of Environment and the local government authority to determine a suitable stormwater management strategy.

Further information is available via <<http://contaminatedsites.environment.wa.gov.au>> or by telephoning the Department of Environment on (08) 9278 0300.

## Management systems for government agencies and large-scale operations

The following management arrangements are recommended for State or local government agencies to plan for, and deliver, excellent standards in stormwater management during land development and construction projects. Businesses that regularly undertake large-scale land development or construction activities are also encouraged to adopt these practices.

- ✓ All operational staff, contractors or sub-contractors should be trained to use appropriate site and waste management procedures and Site Management Plans/Erosion and Sediment Control Plans.
- ✓ Regularly audit compliance with relevant plans, guidelines or procedures for stormwater management on construction sites.

- ✓ Government agencies and businesses that regularly undertake land development and construction activities are encouraged to develop an EMS. Refer to Section 2.5.1 for further information.
- ✓ Where contractors undertake construction projects, any contract management arrangements should include provisions for ensuring sound stormwater management. For example:
  - Clearly specifying stormwater management requirements in the contract. Contract specifications may ensure compliance, with penalties for non-compliance.
  - Ensure that the tender selection process considers the likely performance of the contractor in managing stormwater during construction.
  - If the Site Management Plan/Erosion and Sediment Control Plan is prepared by a contractor, allow time and financial resources for evaluation of the plan.
  - Allocate a budget for designing and implementing stormwater management practices. The budget should be based on the cost of fully implementing an approved Site Management Plan/Erosion and Sediment Control Plan, with a contingency allowance.
  - Ensure the Site Management Plan/Erosion and Sediment Control Plan is fully implemented and significant consequences to the contractor result from a failure to comply (e.g. financial penalties).

## Benefits and Effectiveness

These management practices can be expected to:

- Reduce loads of pollutants entering stormwater and shallow groundwater (particularly sediment, heavy metals, litter, hydrocarbons, organic matter, paint and solvents), thereby minimising the risk to the health of receiving water bodies.
- Reduce risk of an isolated discharge from a building site causing an environmental incident (e.g. wastewater from a cement mixer causing a fish kill in a local waterway) or aesthetic impacts (e.g. polystyrene waste being blown by wind into a local wetland).
- Reduce risk to public safety and assets.
- Reduce risk of nuisance to nearby residents.
- Retention of valuable topsoil and building/landscaping materials that may be washed off-site.
- Reduce risk of localised flooding that is caused by litter/waste or sediment blocking local drains.
- Improve marketability of the development (particularly for subdivisions where lots are sold prior to construction of buildings).
- Have broad educational benefits (e.g. providing examples of best practice stormwater management on construction sites).
- Reduce risk of breaching environmental legislation and being subject to prosecution.
- Reduce risk of public complaints.
- Reduce costs associated with removing litter and sediment from drainage channels or detention basins downstream of the site; removing litter and sediment from roads and footpaths; collecting windblown

litter from around the site; replacing eroded topsoil; re-contouring eroded areas; and ‘down time’ due to water-logged conditions on the site impeding workers.

Appropriately designed, implemented and maintained *erosion controls* on land development and construction sites can be highly efficient and may reduce loads of Total Suspended Solids (TSS) by up to 85 - 90% (Taylor and Wong, 2002c; Schueler and Holland, 2000; Lehner *et al.*, 1999). Total phosphorus (TP) loads may be reduced by up to 80% (Taylor and Wong, 2002c; Lehner *et al.*, 1999).

Well-designed, implemented and maintained *sediment controls* usually deliver up to 60 - 70% removal of TSS (US EPA, 1997 and 2001; Schueler and Holland, 2000).

A typical best practice construction site, with a combination of *erosion and sediment controls* may have a TSS removal efficiency of approximately 60% (i.e. sediment and erosion control measures can trap approximately 60% of the load of suspended sediment in stormwater).

Taylor and Wong (2002c) provide estimates of pollutant removal efficiencies for common erosion control measures (e.g. turfing, seeding, mulching) and sediment control measures (e.g. sediment basins, sediment fences, straw bales).

## Challenges

The following challenges may need to be addressed to improve implementation:

- Site and equipment considerations, such as space on the site and time needed to perform some maintenance practices (e.g. space for an extra bin for recycling of building materials that would normally be discarded as solid waste).
- Procedures and training materials must be regularly updated.
- In some areas, local service providers may not be available for hazardous waste and recyclable material removal and processing.
- Site supervisors need to implement training to address resistance to changes in work practices.
- There are safety and localised flooding risks associated with placing geofabric filters over stormwater drain inlets when rainfall is imminent.
- It may take time for construction businesses (and associated regulatory personnel), to develop skills and expertise in planning, implementing and maintaining cost-effective Waste Management Plans and Site Management Plans/Erosion and Sediment Control Plans. Technical skills are needed within Government agencies, for example those officers assessing a proposed Site Management Plan/Erosion and Sediment Control Plan before development.
- Erosion and sediment control measures may require ongoing maintenance.
- A sustained enforcement program is essential for widespread cultural change (Lehner *et al.*, 1999).

## Cost

Generally, the costs associated with these stormwater management practices are minimal, except where large volumes of wastewater need to be treated as ‘hazardous waste’.

Erosion and sediment control costs may vary greatly, depending on the characteristics of the site, climate, and type of development. However, cost estimates for some erosion and sediment control measures are provided in the Table 1 below. Product suppliers and construction contractors are a good source of accurate estimates.

**Table 1. Cost estimates for individual erosion and sediment control measures**

Erosion and sediment control measure	Approximate unit cost (2004 dollars)
Weed free hay (straw) bales	\$4 to \$7/metre (m)
Sediment fence	\$1.30/m, plus the cost of backfilling or digging a shallow (100 to 150 millimetre) trench
Level bank (sediment trap-level)	\$5 to \$11/m
Mulching (with seed)	\$0.20 to \$0.3/square metre (m <sup>2</sup> )
Geomat® type products	\$3 to \$6/m <sup>2</sup> (excluding site earthworks, e.g. \$3/m <sup>2</sup> for the product, 6/m <sup>2</sup> total for installation)
Geocell® type products*	From \$11/m <sup>2</sup> (excluding site earthworks)
Riprap type drain lining 300 mm thick (permanent)*	\$33/m <sup>2</sup> (excluding site earthworks)
Reno mattresses 300 mm thick (permanent)*	\$49/m <sup>2</sup> (excluding site earthworks)
Revetment mattresses 80 mm thick (permanent)*	\$35 to \$42/m <sup>2</sup> (excluding site earthworks)
Rock gabions (permanent)*	\$164/m <sup>2</sup> (excluding site earthworks)

Source: based on EMRC (2002) quoting UCSWCT (2001) (updated to 2004 prices by applying an inflation rate of 3%/annum). Those sediment and erosion control measures indicated with a \* are usually used when managing constrained sites, e.g. sites with steep slopes or high risk of water erosion. Refer to 'erosion control and soil stabilisation', 'geosynthetic products' 'landscape supplies' and 'landscape contractors and designers' in the *Yellow Pages* ([www.yellowpages.com.au](http://www.yellowpages.com.au)).

Taylor and Wong (2002c) provide cost estimates for some temporary erosion control measures (e.g. turfing, seeding, mulching) and sediment control measures (e.g. sediment basins, sediment fences, straw bales). However, this information is based on overseas studies.

Costs may be incurred preparing, implementing and auditing a Site Management Plan/Erosion and Sediment Control Plan. These costs may vary depending on the type of project and the site conditions.

## Additional Information

This guideline provides a brief outline of the topic. For detailed technical guidance, refer to the recommended resources below.

Clean Site - Building a Better Environment is a new education and training program being run by Keep Australia Beautiful WA and the Department of Environment. Clean Site aims to instruct the building industry in litter and waste management, resource recovery and recycling, and erosion and sediment control. The program works with local councils, industry associations, developers, builders, trades and suppliers to promote behavioural changes and achieve positive environmental outcomes.

Clean Site aims to achieve positive gains for the building industry such as:

- Improved cost savings
- Better resource utilisation
- Improved occupational health and safety on site
- Better community relationships

The program and associated materials were developed by Keep Australia Beautiful National. Information sheets include *Excavating Your Site*, *Contained Wash Areas*, *Sand and Soil Stockpiles*, *Concrete Works*, *Brick Works*, *Builders and Supervisors*, *Painting*, *Plastering*, *Soil On Site Checklist*, *Delivering to a Building Site*, *Litter and Building Waste*, *Stabilised Entry and Exit Points*, *Sediment Fencing*, *Diversion of Up-Slope Water*, *Using Less Building Materials* and *What Building Materials Can Be Recycled?* (KABC, 2005a to KABC, 2005p) For more information telephone the Clean Site Coordinator on 9278 0300.

Other recommended Australian resources include:

- The Western Australian *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). The Directory includes fuel and chemical storage guidelines in Section 2.0 and lists Western Australian, national and international environmental guidelines for construction operations in Section 3.11. The Directory is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.
- Western Australian Water Quality Protection Notes, including *Chemical Spills – Emergency Response Planning* (WRC, 2002), *Industrial Sites Near Sensitive Water Resources* (WRC, 1999), *Washdown of Mechanical Equipment* (WRC, 1998) and *Stormwater Management at Industrial Sites* (WRC, 2002). Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.
- *Keeping Our Stormwater Clean – A guide for building sites* (EPA Victoria and Melbourne Water, undated). Available via <[www.clearwater.asn.au/CDs/Builders\\_Guide/HTML](http://www.clearwater.asn.au/CDs/Builders_Guide/HTML)>.
- The Clearwater Information Exchange (Victoria) website (MAV and SIAV, undated). Available via <[www.clearwater.asn.au/infoexchange.cfm](http://www.clearwater.asn.au/infoexchange.cfm)>. Refer to the ‘Building and Construction’ topic.
- *Stormwater Pollution at Building Sites* and *Small Business Solutions to Pollution* for builders (NSW EPA, undated). Available via <[www.epa.nsw.gov.au/envirom/stormwater.htm](http://www.epa.nsw.gov.au/envirom/stormwater.htm)> and <[www.epa.nsw.gov.au/small\\_business/builders.htm](http://www.epa.nsw.gov.au/small_business/builders.htm)>.
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- *Stormwater Management Kit – Building Sites* (MAV, SIAV and VLAA, 2003) CD-ROM. Available via <[www.litter.vic.gov.au](http://www.litter.vic.gov.au)>.
- *Waste Wise Construction Handbook* (DEH, 1998). Available via <[www.deh.gov.au/industry/construction/wastewise/handbook/index.html](http://www.deh.gov.au/industry/construction/wastewise/handbook/index.html)>, <[www.deh.gov.au](http://www.deh.gov.au)> or by telephoning the Department of Environment and Heritage (Australia) on (02) 6274 1111.

The following Western Australian guidelines outline erosion and sediment control best management practices to manage drainage, erosion, sediment loss and dust, and improve housekeeping practices. They include advice about how to prepare an Erosion and Sediment Control Plan, erosion control measures (e.g. diversion drains, drop structures, level spreaders, vegetation stabilisers) and sediment control measures (e.g. stabilised and limited points for site access, sediment traps, straw bales, sediment fences, stormwater inlet filters and vegetated buffers):

- Eastern Metropolitan Regional Council (2002). *Erosion and Sediment Control Guidelines for the Swan Coastal Plain: Local Government Natural Resource Management Policy Manual*, EMRC, Western Australia. Available by telephoning (08) 9424 2222 or via <[www.emrc.org.au](http://www.emrc.org.au)> (select ‘Services’ / ‘Environmental Services’).

- Upper Canning/Southern Wungong Catchment Team (2001). *Erosion and Sediment Control Manual for the Darling Range, Perth, Western Australia*. Edited by B. Lloyd and R. Van Delf, Miscellaneous Publication 17/2001. Agriculture Western Australia, Perth, Western Australia.

The United States Environmental Protection Agency's on-line *National Menu of Best Management Practices for Storm Water Phase II* has fact sheets on the following practices (via <[www.epa.gov/npdes/menuofbmps/menu.htm](http://www.epa.gov/npdes/menuofbmps/menu.htm)>):

- Good housekeeping measures for waste management (e.g. general construction site waste management, such as spill prevention and control plans, vehicle maintenance and washing areas; and education and awareness practices such as contractor certification and inspector training, construction reviewers, best management practice inspection and maintenance, and model ordinances or design criteria).
- Runoff control measures (e.g. minimising clearing by using land grading, permanent diversions, preserving native vegetation and designing construction entrances; and stabilising drainage ways using check dams, filter berms, grassed lined channels and riprap).
- Erosion control measures (e.g. stabilise exposed soils by using chemical stabilisation, mulching, permanent seeding, sodding or turfing and soil roughening; and protecting steep slopes using geotextiles, gradient terraces; soil retention; temporary slope drain; protecting water bodies using temporary stream crossings, vegetated buffers; and phased construction, construction sequencing and dust control).
- Sediment control measures (e.g. install perimeter controls using temporary diversion dykes, wind and sand fences, brush barrier, silt/sediment fence; install sediment trapping devices using sediment basins and rock dams, filters, chambers and traps; inlet protection using stormwater management system inlet protection).
- Additional fact sheets on turf reinforcement mats, vegetative covers and dust control.

For information on the placement and maintenance of the building's external litter and recycling bins, see the guidelines provided in Section 2.2.4.

For information on developing and maintaining an environmental management system for a large construction site (or construction company), see the guidelines provided in Section 2.5.1.

## Examples / Case Studies

Australian case studies are available from:

- Curtin University's Centre of Excellence in Cleaner Production (Western Australia). The Centre has a case study on cleaner production and waste management by a home building company, and links to other Australian and international case studies available via <<http://cleanerproduction.curtin.edu.au/casestudies.htm>>.
- Clearwater's website information exchange (Municipal Association of Victoria and Stormwater Industry Association of Victoria), available via <[www.clearwater.asn.au/infoexchange.cfm](http://www.clearwater.asn.au/infoexchange.cfm)>.
- The Department of Environment and Heritage (Australia). The Department has a Waste Wise Construction Program, with case studies available via <[www.deh.gov.au/industry/construction/wastewise/index.html](http://www.deh.gov.au/industry/construction/wastewise/index.html)>.
- The Housing Industry of Australia's Greensmart® Program website has a list of participating businesses, available via <[www.greensmart.com.au](http://www.greensmart.com.au)>).

- Lehner *et al.* (1999) has some good case studies about how United States regulatory agencies have implemented regional or citywide erosion and sediment control programs. Available via <[www.nrdc.org/water/pollution/storm/stoinx.asp](http://www.nrdc.org/water/pollution/storm/stoinx.asp)>.

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## Appendix 1. Building Activities, Waste Materials and Relevant Best Management Practices

\*The relevant best management practices column briefly outlines reasons for some of the best management practices. For further details, please refer to the ‘Reasons for management of litter, waste and washing-down practices’ and ‘Reasons for erosion and sediment control’ in the Description part of this Section. Refer to the Recommended Practices section for detailed guidance on relevant best management practices.

Waste Wise WA can provide guidance on resource recovery, recycling and appropriate waste disposal practices. Further information is available via <[www.wastewise.wa.gov.au](http://www.wastewise.wa.gov.au)> or by telephoning (08) 9278 0300.

Trade/activity	Materials and wastes	Relevant best management practices*
Bricklayers.	Bricks, mortar (sand, cement, water, lime, plasticiser, dampcourse additive), wood pallets, chipboard, window and door frames, dampcourse, plastic packaging and strapping, cement bags.	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. Management of sand stockpiles and preventing/minimising sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly unused lime and cement and cement mixer wash-water disposal (as the pH may harm aquatic flora and fauna) and preventing wind-blown litter (to minimise adverse aesthetic impacts).</li> <li>3. Resource recovery. Bricks, sand and wood may be recycled.</li> <li>4. Minimise water use by turning off taps and ensuring water drums are not leaking.</li> </ol>
Building supervisors.	All materials and wastes. Sediment, food and drink wastes (e.g. paper and plastic), packaging wastes (including polystyrene, cardboard and plastic), paints, lime, cement and cement mixer wash-water, neighbourhood wastes dumped on site, adhesives, and solvents such as turpentine.	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. placement of sand stockpiles and preventing/minimising sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Ensure compliance with recommended practices and relevant legislation. Refer to ‘Litter and waste management (non-hazardous and hazardous wastes)’ in Recommended Practices. For example, unused cement and lime (the pH may harm aquatic flora and fauna) and unused hazardous (Schedule 1) substances such as paint and solvents (these may be toxic to aquatic flora and fauna). Other activities may include preventing wind-blown litter such as polystyrene, cardboard and plastic (to minimise adverse aesthetic impacts).</li> <li>3. Washing-down practices. E.g. the pH of cement mix wash-water may harm aquatic flora and fauna. Wash-waters containing paint and solvents from painting tools may be toxic to aquatic flora and fauna.</li> <li>4. Resource recovery, many building wastes may be recycled.</li> </ol>

Trade/activity	Materials and wastes	Relevant best management practices*
<p>Carpenters (interior and roof) and cabinet-makers and fitters.</p> <p>See also 'Roofs and gutters', if applicable.</p>	<p>Wood, packaging (e.g. plastic and cardboard), Laminex, chipboard, adhesives, paints, solvents, sandpaper.</p>	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly disposal of unused paints and solvents (may be toxic to aquatic flora and fauna) and preventing wind-blown litter (to minimise adverse aesthetic impacts).</li> <li>3. Washing-down practices. E.g. disposal of wash-waters containing paint and solvents from paintbrushes, rollers and trays.</li> <li>4. Resource recovery. Wood and cardboard may be recycled.</li> </ol>
<p>Ceiling fitters and flushers.</p>	<p>Plasterboard, plaster cornices, ceiling plaster, adhesives, fillers and sealers, setcoat, putty, cements, sandpaper, packaging (paper and plastic) and corner reinforcing mesh.</p>	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads).</li> <li>2. Litter and waste management. Particularly preventing wind-blown litter and disposal of unused adhesives and cement, as these materials may harm aquatic flora and fauna.</li> <li>3. Washing-down practices. E.g. the pH of cement mixer wash-water may harm aquatic flora and fauna.</li> <li>4. Resource recovery. Plaster products, i.e. plasterboard, plaster products may be recycled.</li> </ol>
<p>Concreters (e.g. pouring concrete building slab).</p>	<p>Concrete, cardboard, wood, polystyrene, black plastic membrane (high-density polyethylene (HDPE)), metal pins/stakes, steel reinforcing mesh.</p>	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly preventing wind-blown litter (e.g. polystyrene), management of cement mixer wash-water and concrete disposal practices (as dried cement may block stormwater management systems).</li> <li>3. Washing-down practices. E.g. the pH of cement mix wash-water may harm aquatic flora and fauna.</li> <li>4. Resource recovery. Metal, concrete and wood waste may be recycled. Recycled aggregate may be used in concrete to reduce consumption of this resource.</li> <li>5. Minimise water use.</li> </ol>
<p>Deliverers (particularly sand).</p>	<p>Sand, soil, bricks, tiles, timber, waste bins and other relevant products.</p>	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. placement of stockpiles, and preventing sand tracking from vehicles onto roads.</li> </ol>
<p>Electricians.</p>	<p>Packaging (cardboard and plastic), electrical cables, wooden and plastic electrical cable reels.</p>	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly preventing wind-blown litter and not burying waste in trenches).</li> <li>3. Resource recovery. Cardboard wastes may be recycled and electrical cable reels may be returned to distributors / manufacturers for reuse.</li> </ol>

Trade/activity	Materials and wastes	Relevant best management practices*
Painters (painting and cleaning).	Oil-based paint, water-based paint, solvents (e.g. turpentine), paint tins, sandpaper, polyfiller, masking tape, brushes, rollers, mixers, cardboard, plastic sheets.	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly preventing wind-blown litter and disposal of unused paints and solvents (may be toxic to aquatic flora and fauna).</li> <li>3. Washing-down practices. E.g. disposal of wash-waters containing paint and solvents from paintbrushes, rollers and trays.</li> <li>4. Minimise water use by ensuring taps are turned off after use.</li> </ol>
Plasterers and renderers.	Plaster, sand, screed (render scrapings), cement, water, lime, non-lime plasticiser.	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads).</li> <li>2. Litter and waste management. Particularly appropriate disposal of unused cement and lime, as the pH may harm aquatic flora and fauna.</li> <li>3. Washing-down practices. E.g. disposal of wash-waters containing plaster, cement and lime.</li> <li>4. Resource recovery. Sand, render and plaster may be recycled.</li> <li>5. Minimise water use by ensuring taps are turned off after use.</li> </ol>
Plumbers and drainers (underground and household).	Polyvinyl chloride (PVC) pipe and fittings, polystyrene, dampcourse, high-density polyethylene (HDPE) plastic, adhesives and solvents (e.g. solvent cement glue), packaging (cardboard and plastic).	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly appropriate disposal of unused solvents and adhesives (as these materials may be toxic to aquatic flora and fauna), not burying wastes in trenches and preventing wind-blown litter, such as polystyrene.</li> </ol>
Roofs and gutters (roof carpenters, fitters, tilers, trimmers, roof insulation technicians).  See also 'Carpenters', if applicable.	Wood, laminated veneer lumber (LVL), steel and plastic strapping, metal (e.g. downpipe and gutter off-cuts and zinc/aluminium coated steel sheets), clay or cement tiles, sealers (contain solvents), tile grout, packaging (plastic, metal, wood), roof insulation.	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly appropriate disposal of sealers (solvents may be toxic to aquatic flora and fauna) and grout (may block stormwater management systems and the pH may harm aquatic flora and fauna) and preventing wind-blown litter.</li> <li>3. Resource recovery. Clay tiles, metal, cardboard and wood may be recycled. Note: Copper Chromium Arsenate (CCA) treated timber can not be recycled.</li> </ol>

Trade/activity	Materials and wastes	Relevant best management practices*
Site works (earthworks operators, excavators, soakwell/sewer installers, electrician, gas technician, telecommunications technician, Water Corporation technician, retaining wall installers and fence removers/installers).	Green waste, rubble/excess soil, sand, PVC and HDPE plastic off-cuts, plastic cable reels, cement, fencing sheets, metal, wood, cardboard.	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. Appropriate placement of stockpiles, particularly sand, and preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly preventing wind-blown litter and not burying wastes in trenches.</li> <li>3. Resource Recovery. Sand, cardboard and sand/soil may be recycled.</li> </ol>
Tilers (interior).	Tiles, adhesive, mortar, grout, silicon, packaging (e.g. metal, cardboard and plastic), dampcourse products (contain solvents).	<ol style="list-style-type: none"> <li>1. Erosion and sediment control. E.g. preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management. Particularly appropriate disposal of adhesives (may be toxic to aquatic flora and fauna) and grout (the pH may harm aquatic flora and fauna) and preventing wind-blown litter.</li> <li>3. Washing-down practices. E.g. disposal of wash-waters that contain grout.</li> <li>4. Resource recovery. Metal and cardboard may be recycled.</li> </ol>
Pest controller (e.g. termite control).	Pesticides.	<ol style="list-style-type: none"> <li>1. Pesticide use consistent with Department of Health requirements and industry best management practices (not addressed here).</li> </ol>
Waste contractors (e.g. hazardous waste collection).	All relevant wastes.  Common hazardous wastes include paints (including lead paint, used extensively until 1970), asbestos and solvents).	<ol style="list-style-type: none"> <li>1. Sediment and erosion control. E.g. preventing sand tracking from vehicles onto roads.</li> <li>2. Litter and waste management and resource recovery. Ensure all wastes are recycled or taken to authorised disposal sites that are appropriate for the types of wastes generated from the site. Refer to the <i>Guidelines for Acceptance of Solid Waste to Landfill</i> (DoE, 2002). For hazardous wastes (Schedule 1), use best management practices consistent with the Department of Environment's requirements, including the Environmental Protection (Controlled Waste) Regulations, 2004. For further information, refer to the Litter and waste management (hazardous waste) sub-section in the Recommended Practices section.</li> </ol>

## 2.1 Construction practices

### 2.1.2 Soil amendment for urban gardens and lawns

#### Description

Many areas in Western Australia have sandy soils with low ability to retain moisture, nutrients and trace elements. Urban development may also diminish the capacity of soil to support plant growth, through processes such as the removal of topsoil and soil compaction.

Soil amendment is a technique used to create fertile topsoil by increasing the soil's ability to retain moisture and nutrients, and filter some contaminants, such as heavy metals, before they infiltrate into groundwater.

Soil amendment involves adding an agent to the soil to improve its structure, porosity, water holding capacity and nutrient recycling capacity. Potential amendment agents in an urban environment include compost, organic-rich soils, loam soils, natural clay, crushed limestone and gypsum.

'Soil amendment agents' are generally distinguished from 'fertilisers' by having a lower nutrient content, and a greater ability to retain and recycle both moisture and nutrients.

Soil amendment in urban areas is still an experimental technique in Western Australia. Some industrial by-products are not approved for use in urban areas. Refer to Recommended Practices for further information.

#### Applicability

The technique has potential applicability in urban areas where fertilisers are likely to be added (e.g. traditional residential gardens, lawns and parks). However, prior to applying the technique, consideration should be given to potential impact on groundwater dependent ecosystems (e.g. wetlands). For example, *widespread* use of soil amendment on sandy soils in Perth may decrease groundwater recharge, reducing the flow of groundwater to ecosystems down-gradient from the site. However, widespread use of soil amendment material may also reduce groundwater abstraction requirements for irrigation due to an increase in the soil's ability to retain water. This may potentially reduce the stress to groundwater dependent ecosystems caused by lowering of the groundwater table due to water abstraction. Such impacts should be assessed on a site-by-site basis by suitably qualified professionals.

Where soils have the potential to be compacted during development (e.g. Guildford Clays), soil amendment with an organic compost or loam could produce many of the hydrologic and pollutant reduction benefits demonstrated by overseas studies (see below).

In areas with sandy soils, soil amendment has potential as a way of retaining and recycling nutrients and water in the top 30 cm of soil beneath lawns and gardens.

#### Recommended Practices

The soil amendment process during urban development typically involves the following steps:

- Initial soil disturbance.
- Breaking up of the subsoil.
- Rock removal (where relevant).
- Distribution of imported soil amendment agent.

- Application of lime and fertiliser (if required after soil analyses have been undertaken and expert advice has been received).
- Soil integration (e.g. tilling 10 cm of compost placed on the surface of the soil, to a total depth of 30 cm).
- Grading and rolling the site prior to lawn or garden establishment.

Loams with a high organic content and composted green waste are recommended for use as urban soil amendment agents on the Swan Coastal Plain.

Where large-scale application of soil amendment agents is proposed, approval may be required under the *Environmental Protection Act 1986*. Contact the Department of Environment or the Environmental Protection Authority (EPA) for more information.

### Industrial by-products as soil amendments

Any soil amendment using industrial by-products should be consistent with the Department of Environment's Water Quality Protection Note - *Soil Amendment to Improve Land Fertility Using Industrial By-Products* (DoE, 2004).

Widespread application of industrial by-products (e.g. gypsum-neutralised red mud or red sand (RMG/RSG), fly ash and synthetic rutile production (SRP) wastes, also known as Titanium Dioxide residues) is not currently allowed in urban areas. Special restrictions may also apply in sensitive environments, such as Public Drinking Water Source Areas (i.e. drinking water catchments) and near conservation value wetlands, waterways and native vegetation. Refer to the Water Quality Protection Note for the latest recommendations.

Further information about research trials is available in the Research Trials on Industrial By-Products section.

## Benefits and Effectiveness

Enhancement of soils with *inorganic* soil amendment agents (e.g. natural clays) has great potential to increase the amended soil's Phosphorus Retention Index (PRI) and reduce the export of phosphorus (P) to stormwater and/or groundwater. For example, the PRI for Bassendean Sands is 0 – 0.5, while natural clays or loam soils have a PRI of 30 - 1,000 (WRC, 1998). However, more local research is needed in an urban context, to demonstrate and quantify the effectiveness of soil amendment using a range of amendment agents.

Enhancement of soils with *organic* soil amendment agents (e.g. compost) will increase the soil's water holding capacity, but does not always reduce nutrient export (see below). The following benefits of composted amended soils have been reported from overseas studies, where surface water flow dominates the post-development hydrologic regime.

Water quality management benefits include:

- Slow passage of potential pollutants so that soil microbes can decompose them.
- Reduced need for fertilisers and irrigation, as the compost supplies more nutrients, which are slowly released to plants.
- Increased soil stability, leading to reduced erosion potential.
- Added protection to groundwater resources, especially from heavy metal contamination.

- Reduced thermal pollution by detaining surface runoff (LID Centre, 2003).

Water quantity management benefits include:

- More rainwater being held on-site, this attenuates peak flows and decreases runoff.
- Base flows to local water bodies are maintained (important during dry periods).
- Increased groundwater recharge (compared to compacted clays) through better infiltration and by detaining the water on-site longer (LID Centre, 2003).
- Increased soil moisture.

Refer to the Examples / Case Studies section, below for further information.

When applied to sandy soils, such as those on the Swan Coastal Plain, compost amendment is not likely to produce all the benefits listed above, as the soils already have a very high infiltration capacity. However, when compared to the scenario of highly fertilised non-amended soils (i.e. in European-style residential gardens and lawns), the technique does have the potential to significantly reduce the export of nutrients (particularly phosphorus) to groundwater and reduce the need for irrigation.

## Challenges

The following challenges may need to be addressed to improve implementation, where approved soil amendment application is appropriate:

- In urban areas and sensitive environments, such as Public Drinking Water Source Areas, and adjacent to conservation value wetlands, waterways and native vegetation, there may be constraints placed on the *widespread* use of soil amendment agents.
- Determine the phosphorus retention capacity of the amendment agents, as these can vary considerably.
- Amended soils may re-release bound phosphorus if conditions become anaerobic. This limits the use of soil amendment to levels above the groundwater saturation zone.
- There is potential for re-release of phosphorus from amended soils if the pH of the stormwater becomes too acidic (e.g. pH < 5).
- Some areas may be unsuitable for the application of soil amendment agents, such as areas with acidic or alkaline parent soils that may mobilise heavy metals in some amendment agents (DoE, 2004).
- Amendment may reduce the permeability of some soils (e.g. sandy soils), and reduce groundwater recharge. Reduced groundwater recharge could adversely affect the health of groundwater dependent ecosystems that exist nearby. A buffer zone around such ecosystems may be required.
- Amended soils have a finite effective lifespan, if nutrients are not recycled by plants and microorganisms.
- Care is needed to prevent the introduction of contaminants in the amendment agents (e.g. heavy metals, poly aromatic hydrocarbons, radio-active materials, pathogens), that may be hazardous to human health, particularly in the context of residential premises where children or animals may ingest soil and vegetables may be grown. Care is required in what material is used and where.

## Industrial by-products

There are concerns about the suitability of some industrial by-products (e.g. RMG/RSG, fly ash and SRP wastes) for widespread soil amendment in urban areas, for example, the potential for leachate from RMG/RSG, fly ash and SRP wastes to cause heavy metal contamination.

Refer to the Department of Environment's *Soil Amendment to Improve Land Fertility Using Industrial By-products* Water Quality Protection Note for up-to-date guidance (DoE, 2004). This note currently recommends that industrial by-product soil amendment agents should not be used in urban areas and, as a general guide, should not be placed within 1.5 metres of the maximum seasonal water table. This criterion is based on an appropriate buffer distance to maintain the aerobic zone for plant roots and to stabilise any potential contaminants. It also allows for any groundwater mounding which may result from irrigated systems associated with intensive land use.

## Cost

The technique is relatively inexpensive, with costs including purchase, transportation and application of the amending agents, monitoring the effectiveness of pollutant removal, and replacement of amended soil if its pollutant removal capacity diminishes over time.

Taylor and Wong (2002c), citing Brosnan (2002), estimated the potential cost of soil with a high phosphorus retention capacity in Perth (delivered to sites within the metropolitan region) as approximately \$25 - \$30 per m<sup>3</sup>.

North American studies of compost amended soils below lawns have concluded that:

- Irrigation needs (and therefore costs) may be reduced by up to 60%.
- Fertilisation requirements and costs also decrease.
- Mowing and aeration requirements and costs remain the same.
- Weed control requires monitoring, as composts can contain weed seeds. The spread of weeds may be of significant concern if the development is adjacent to sensitive bushland or wetlands.
- Routine lawn maintenance and costs are reduced.
- Overall, the benefits offered by the technique outweigh the installation cost.
- For a case study in Seattle, the total estimated amended soil cost was approximately US\$11 - US\$33 per m<sup>2</sup> (in 1996 dollars), and the payback period was five to six years when compared to traditional topsoil and seeding, and within the first year when compared to traditional topsoil and turfing.

## Additional Information

### Potential soil amendment agents for the management of phosphorus

Possible amendments to retain phosphorus are crushed limestone (applicable to loam soils but may not be necessary on alkaline coastal sands), natural clay, loam soils. Optimum soil to amendment ratios have been determined from previous studies for some of the industrial by-products (see McAuliffe & Evangelisti, 1991). For other materials, the optimum ratios should be determined by phosphorus retention and permeability tests.

The following industrial by-products are not approved for use in urban areas. However, field trials have shown they retain phosphorus when used as soil amendments: RMG/RSG, SRP wastes, and alkaline industrial by-products such as fly ash and lime kiln dust.

### Relative permeability and PRI of various substrates

The Phosphorus Retention Index (PRI) ranges given in the table below are intended for comparative purposes only. The PRI test was developed to compare the P retention capacities of virgin Western Australian soils, particularly those on the Swan Coastal Plain. When making an assessment of the P

retention capacity of industrial by-products, more exhaustive procedures and expert advice must be adopted, as chemical properties such as high pH may affect PRI results (see DoE, 2004 for details). The PRI test gives no indication of either the long-term cumulative capacity of amendments, the mechanisms controlling P retention, or the effect of solution P concentration on P retention. After these have been assessed from laboratory or field studies, the PRI test may be useful as part of a monitoring or quality control program for the industrial by-product. For natural soils, a reasonable estimate of P retention capacity from PRI is possible. Table 1 displays the relative permeability and PRI for various substrates.

**Table 1. Relative permeability and Phosphorus Retention Index (PRI) for various substrates**

Substrate	Permeability (m/day)	PRI
Bassendean Sands	30+	0 - 0.5
Karrakatta Sands	10+	2 - 4
Cottesloe Sands	10 +	5 - 12
Crushed limestone or lime sands	2 - 5	5 - 20
Natural clay or loam soils	<0.4	30 - 1,000+
Leached RMG*	May depend on local soil type and blend.	170 - 600
Leached RSG*	May depend on local soil type and blend.	13 - 54
SRP Wastes*	May depend on local soil type and blend.	90 - 1,000++

\* = Not currently allowed as a soil amendment agent in urban areas. Primary sources: WRC (1998) and Davidson (1995).

### Crushed limestone and lime sands

The adsorptive potential of calcium carbonate from crushed limestone or lime sands has been found to vary considerably between samples from different locations (Ho and Monk, 1988). A potential advantage of using limestone as a substrate amendment is that phosphorus is not released in response to failing redox potentials caused by oxygen stress (McAuliffe and Evangelisti, 1991). Due to inconsistency and uniformity between limestone samples, thorough testing is required to determine the most suitable mix and site from which to obtain limestone.

### Natural clay or loam soils

Natural clay or loam soils (e.g. Gingin loam and Marybrook loam) have been used as amendments to increase the phosphorus retention capacity of sands under agricultural production, and for sewage effluent disposal.

## Research Trials on Industrial By-Products

Industrial by-products (e.g. RMG/RSG, fly ash, SRP wastes and lime kiln dust) are not currently approved for widespread soil amendment in urban areas. However, this information may help to build a knowledge platform for future trials.

There is a national initiative to develop environmental guidelines for the application of industrial by-products as soil amendments. A draft discussion paper *Development of a National Framework for the Reuse and Recycling of Industrial Residues to Land Management Applications* has been prepared by the Environment Protection and Heritage Council.

Refer to the Recommended Practices section for further information.

## RMG and RSG

Gypsum neutralised bauxite residues have nutrient stripping potential. There are two by-products, red mud and red sand, which have different particle size distributions. When mixed with gypsum to produce RMG and RSG, the alkalinity of the residues is reduced, with the pH buffered at around 8.3 by calcium carbonate (Summers *et al.*, 1988). The high phosphorus retention capacity of RMG is attributed to adsorption of P by high concentrations of iron and aluminium oxides, adsorption and precipitation by calcium carbonate (CaCO<sub>3</sub>), and precipitation of P by soluble calcium (Ca) from gypsum. Leached RSG has a much smaller concentration of iron and aluminium oxides, and consequently its P retention capacity is only about one-fifth of leached RMG. There is also an approximate two-fold range in the P retention capacities of RMG and RSG from different alumina refineries.

Phosphorus adsorption to iron III (ferric) Fe<sup>3+</sup> in oxidising conditions is a reversible process, so P has the potential to be re-released in anaerobic conditions. It is unclear whether this applies to RMG/RSG because a significant proportion of the P is precipitated with calcium. As the sorption characteristics of RMG are determined by the alkaline pH, nutrients bound to amended soil may be re-released if the calcium carbonate in the amended soil is neutralised by percolating acidic water (McAuliffe & Evangelisti, 1991).

Studies undertaken by Ho *et al.* (1989) found that the major salts in the leachate of RMG amended sands were by-products of the alkalinity neutralisation process. Salt concentrations in groundwater immediately below soils amended with RMG are expected to rise, but with negligible long-term effects. Background concentrations are expected to return after 1 to 2 years.

Alcoa and the Department of Agriculture have trialled the use of RMG/RSG in the Peel-Harvey catchment.

## SRP wastes

There are two by-products of synthetic rutile production from mineral sands, both of which contain high concentrations of iron oxides. One is acidic and the other is alkaline (due to the presence of calcium carbonate). The latter product also contains gypsum and therefore resembles RMG in chemical composition. These by-products have a high capacity to retain P. The permeability of soil mixes is similar to soil mixes with RMG.

## Fly ash and lime kiln dust

Fly ash and cement or lime kiln dust (CKD or LKD) have some potential for use as soil amendments. These materials are alkaline due to the presence of very finely divided calcium carbonate or calcium hydroxide and have a similar mode of action in the long term to very fine limestone.

Fly ash trials have been conducted in WA. For example, in-field trials by the University of WA Turf Research Program, fly ash applied at 150 tonnes per hectare in the top 15 centimetres (cm) of soil significantly increased the amount of water retained (Sports Turf Technology, 2004). Other research is being conducted by Boral Material Technology and Fly Ash Australia.

These industrial by-products require further testing to determine their capacity for pollutant removal and effect on permeability.

## Examples / Case Studies

Refer to <[www.lid-stormwater.net](http://www.lid-stormwater.net)> for an overview of North American approaches to using soil amendments to reduce the rate of stormwater runoff, and reduce the overall nutrient export load.

## Compost amended soil

Compost amended soils usually reduce the net export of nutrients compared to non-amended soils. For example, Harrison *et al.* (1997) reported a relative reduction of:

- 70% of total P load;
- 58% of soluble-reactive P load; and
- 7% of nitrate load.

These load reductions may be associated with a substantial reduction in water flux rates rather than improvements in water quality (i.e. less water may leave the amended soils via stormwater or groundwater). For example, concentrations of nitrate in water draining from the compost amended soils can be higher compared to non-amended soils.

The study by Harrison *et al.* (1997) found that when compost amended soils were used for lawns, they produced a grass that was uniformly aesthetic, and required little or no fertilisation over the three month trial period. Harrison *et al.* (1997) concluded that the reduced need for lawn fertilisation may be the biggest environmental benefit of compost amendment. This benefit has been demonstrated in several studies conducted over three to six month trial periods.

The US EPA (1999) evaluated the benefits of compost amended soils for impoverished soils where surface water runoff dominates the hydrologic regime. For example, composted amended soil was found to increase water infiltration (and reduce surface runoff), increase fertility, and significantly enhance the aesthetics of the turf. The need for continuous fertilisation to establish and maintain the turf was reduced or eliminated. The compost also increased the concentrations of many nutrients in the runoff, particularly when the site was newly developed. However, due to increased infiltration, the nutrient mass runoff should be significantly reduced.

Taylor and Wong (2002c) estimated the potential reduction in total phosphorus loads that may be obtained from amendment of sandy soils in the Perth region from the work of Kelsey (2001). In a pollutant export modelling exercise for a proposed development near Perth, Kelsey used the following total phosphorus export rates based upon the best available information:

Residential land use:

- Lateritic soils TP = 0.15 kilograms/hectare/year (kg/ha/yr)
- Sandy soils TP = 1.2 kg/ha/yr

Rural land use:

- Lateritic soils TP = 0.11 kg/ha/yr
- Sandy soils TP = 1 kg/ha/yr

From these rates, Taylor and Wong (2002c) concluded that the use of lateritic top soils to amend sandy soils could have pollutant removal efficiencies of *up to* 87.5% and 89% for stormwater from residential and rural land use, respectively. Actual efficiencies are likely to be lower than these percentages due to the blending process that occurs during soil amendment.

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## 2.2 Maintenance practices

### 2.2.1 Street sweeping/cleansing

#### Description

Street sweeping is widely used in urban areas to reduce the accumulation of litter, leaves and coarse sediment from roads, carparks and footpaths. It is undertaken to improve aesthetics, public safety and stormwater quality. It is also the most studied non-structural best management practice for the improvement of urban stormwater quality.

Street sweeping as a stormwater quality BMP is an attractive option for many local authorities, as it is already in use (albeit primarily for aesthetic reasons), and roads, carparks and footpaths account for approximately 70% of impervious urban areas (VSC, 1999).

This guideline will focus on street *sweeping* rather than flushing, as the flushing of pollutants through the stormwater system is not recommended. There are many types of sweeping equipment (see NVPDC, 1996), with new technologies recently emerging that have the potential to collect a high proportion of fine sediments (with absorbed nutrients and heavy metals), unlike their predecessors.

Improvements in stormwater quality using street sweeping is best achieved by focusing on pollution ‘hot spots’ rather than routinely sweeping all streets (VSC, 1999). In addition, it is recommended that street sweeping be coordinated with other maintenance activities and events. For example, targeted street sweeping may be undertaken after:

- resurfacing works on a roadway;
- unloading of materials in an industrial or commercial area; or
- a public rally or major sporting event.

#### Applicability

Street sweeping may be undertaken by owners of commercial and industrial premises, developers during construction activity, the local government authority as part of a well-planned sweeping schedule, or by State government authorities after construction activities.

Although Taylor and Wong (2002c) concluded that while street sweeping appears to have limited benefits as a stormwater quality BMP when applied on a citywide scale using traditional equipment, it has significant benefits when applied in high risk areas and in specific circumstances. For example:

- Street sweeping is applicable for large industrial or commercial sites or residential construction sites, where access to pollutants on impervious surfaces can be easily controlled and resources are available for more frequent sweeping and sweeping at particular times.
- Street sweeping in areas with deciduous trees during autumn. Large volumes of leaf litter can be collected, which would minimise the loading of organic matter on sensitive water bodies.
- To collect large volumes of gross pollutants deposited as a result of a specific event in a clearly defined and easily accessible area (e.g. after a ticker tape parade or major sporting event).
- Programs that sweep streets, carparks and pavement before ‘first-flush’ runoff events, to collect accumulated sediment.
- To target high pollutant generator areas (e.g. commercial precincts, shopping centre precincts).

- The collection of absorbent material commonly used by incident response crews to contain liquids after traffic accidents.

Street sweeping in Perth has several advantages compared to many other parts of Australia. Firstly, there is evidence to suggest that the particle size distribution of sediment in Perth's urban areas generally has a higher percentage of coarser particles, making it more likely to be collected by street sweepers. Secondly, the city's long dry periods over summer provide a good opportunity for material that has accumulated on impervious surfaces (e.g. wind-blown litter and sediment) to be collected before it is washed into receiving waters. Areas like the lower Canning River catchment upstream of the Kent Street Weir occasionally experience harmful blue green algal blooms shortly after late summer/early autumn rainfall events. These blooms often occur after long, dry periods. Targeted street sweeping in such catchments is beneficial (i.e. targeting areas where nutrients may be associated with sediment and/or organic material that can be collected by a sweeper).

## Recommended Practices

Recommended practices for street sweeping are summarised below from VSC (1999) and NVPDC (1996):

### Planning and monitoring

- ✓ Ensure that street sweeping resources enable targeting of 'hot spots' to occur.
- ✓ Identify priority pollutants that could be collected by street sweeping (e.g. leaves from deciduous trees upstream of a lake) and priority locations where these pollutants may accumulate.
- ✓ Identify the best timing for street sweeping, to maximise capture efficiency while reducing costs.
  - Street sweeping should be strongly considered after a long dry period (e.g. mid summer), when large loads of material have accumulated on impervious surfaces and there is the potential for this material to be flushed into water bodies following the next major storm event (e.g. those in late summer/early autumn). Such storm events can be associated with harmful algal blooms in receiving water bodies.
  - Areas with a high percentage of deciduous trees should be swept during/after the autumn leaf fall.
  - Sweeping frequency should be increased during the wet season, as rainfall is a significant pollutant vector.
- ✓ Ensure street sweeping occurs at a time when vehicles do not block access to the kerb because significantly more particulates accumulate along the gutter line/kerb.
- ✓ Inspect the swept area before sweeping to determine the need and likely effectiveness, and after sweeping to *broadly* determine its value.
- ✓ Ensure that records are kept of the quantity and composition of collected material, as well as the cost, so that the cost-effectiveness of the sweeping program can be improved over time.
- ✓ Keep up to date with new street sweeping technology and ensure new equipment maximises the capture efficiency for pollutants of concern (e.g. phosphorus adsorbed to fine particles of sediment). Local research to understand the pollutants on impervious surfaces is highly recommended (e.g. understanding the typical particle size distribution of sediments and the association of nutrients and toxicants with sediment particles of varying size).

### Coordination with other activities

- ✓ Undertake a risk assessment to identify those activities whose impacts on stormwater quality could be minimised through street sweeping. For example, street sweeping would be beneficial prior to the scouring of new water mains or at the end of the day around a construction site where sediment has tracked on to the road.
- ✓ Ensure routine maintenance programs that have a need for street sweeping (such as road repair works) include street sweeping as part of their procedures.
- ✓ Identify infrequent activities that may require street sweeping after the event (e.g. a street market or ticker tape parade).

### Community coordination

- ✓ Advise the community of street sweeping schedules and encourage people to remove vehicles from the street so that the sweeper can access the kerb.
- ✓ Install temporary parking restrictions to gain access to the kerb in areas that are heavily trafficked.

### Operational restrictions

- ✓ Ensure street sweepers do not discharge any solid or liquid waste to the drainage system. Such wastes should be assessed to determine the correct form of disposal in consultation with operators of liquid and soil waste disposal facilities. For information about waste acceptance criteria and determination of the appropriate type of landfill for disposal of the collected material, refer to the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002).
- ✓ Discourage the washing of footpaths and flushing of kerbs unless necessary for safety reasons. Where flushing is necessary, investigate opportunities to trap the stormwater for subsequent disposal (e.g. to a grassed area) or filter it prior to discharge to stormwater.
- ✓ Where mechanical sweeping equipment has limited access to an area, hand sweeping is recommended.

## Benefits and Effectiveness

Street sweeping has significant benefits when applied in high risk areas and in specific circumstances, particularly when new technology sweepers are used.

In 1999, Walker and Wong reviewed the street sweeping literature and data from Australian field studies (including Western Australian studies) to evaluate the effectiveness of this BMP for stormwater quality improvement. However, new street sweeping technologies have emerged in recent years, making much of the research that was undertaken in the 1980s and 1990s obsolete. Therefore, the following conclusions should not be applied to new street sweeping technology. Taylor and Wong (2002c) summarised their principal findings and conclusions as:

- Literature from overseas studies indicates traditional street sweeping is relatively ineffective in reducing the load of particles smaller than 125  $\mu\text{m}$  (in diameter) on the street surface.

- The typical range of suspended solid particle size in Australian urban stormwater is 1 - 400  $\mu\text{m}$  (in diameter), with approximately 70% of the particles being smaller than 125  $\mu\text{m}$  (in diameter). As mentioned in the Applicability section, however, areas like Perth may not be ‘typical’ with respect to particle size distribution, due to the higher proportion of coarser particles.
- For typical Australian conditions, street sweeping as it was practised in the late 1990s was unlikely to effectively reduce pollutants of concern (i.e. fine suspended particles <125  $\mu\text{m}$  with adsorbed heavy metals and nutrients).
- Australian field studies found significant loads of gross pollutants in stormwater draining from urban areas that had been subject to a daily street sweeping regime. Drawing on the findings of studies on the generation of gross pollutants in Melbourne, Walker and Wong (1999) suggest that loads of gross pollutants in stormwater draining from urban areas depend more on the type of rainfall (i.e. the available *energy* to mobilise and transport gross pollutants) than reductions to the load of gross pollutants on the street surface (i.e. through street sweeping).
- While newer street sweeping technology<sup>8</sup> more effectively removes the finer fraction of suspended particles under experimental conditions (see Sutherland and Jelen, 1996), ‘the effectiveness of street sweeping programs depends more on factors such as land-use activities, the inter-event dry period, street sweeping frequency and timing, access to source areas and sweep operation than the actual street sweeping mechanism’ (Walker and Wong, 1999, p. 4).

While street sweeping frequency is a variable that can influence pollutant removal efficiency, Taylor and Wong (2002c) caution that slightly increasing the frequency will not *necessarily* increase the efficiency of the BMP, due to other factors such as the type of rainfall (e.g. its timing). For example, the influence of sweeping frequency on the load of litter entering stormwater from Californian highways was investigated in a US\$2.8M Litter Management Pilot Study (Caltrans, 2000). The study found that increasing the frequency of mechanical sweeping from monthly to weekly did not statistically reduce ( $\alpha = 0.05$ ) the count or weight of litter in stormwater (as measured at stormwater drain outlets) or the total load of litter in the stormwater system (Caltrans, 2000). In addition, statistical analysis between treatment and control areas failed to show a reduced concentration of chemical constituents in stormwater that could be attributed to the increased sweeping frequency.

As discussed in the Recommended Practices section, planning the sweeping program will significantly increase its effectiveness.

Highman (2004) found that the vacuum mounted rotary brush street sweeper was relatively ineffective at collecting smaller particles (i.e. <150  $\mu\text{m}$ ), but it was effective at removing >150  $\mu\text{m}$  particles. Highman (2004) concluded that without street sweeping, more pollutants would have reached downstream stormwater treatment systems (e.g. inlet pits) or receiving water bodies. The material collected by street sweepers can also block some stormwater treatment systems, resulting in stormwater bypassing the treatment systems.

For *quantitative* information on ‘sweeper removal efficiencies’ and ‘reductions in the surface contaminant load’ that have been associated with various street sweeping studies, see Taylor and Wong (2002c) and/or Walker and Wong (1999).

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<sup>8</sup> For example the ‘small-micron surface sweeper technology’ can reportedly remove particles as small as 4  $\mu\text{m}$  (in diameter), and produce a total removal efficiency of approximately 70% for particles smaller than 63  $\mu\text{m}$  (Sutherland and Jelen, 1997). Another technology is the ‘regenerative air sweeper’ that can reportedly produce a removal efficiency of approximately 32% for particles smaller than 63  $\mu\text{m}$  (Sutherland and Jelen, 1997). For more details, see Taylor and Wong (2002c).

## Challenges

The following challenges may need to be addressed to improve implementation, as reported by Schueler (2000), US EPA (2001) and Taylor and Wong (2002c):

- Determining the optimal sweeping frequency, which is region specific, and needs to draw upon local research (this is the primary limitation). Such frequencies have not yet been determined for Western Australia.
- Determining reliable pollutant removal efficiencies for modern ('high efficiency') street sweepers in a local context (again, additional local research is required in this area).
- Overcoming operational problems that diminish street sweeping performance such as speed, parked cars, and the ability to get access to the kerb<sup>9</sup>.
- Budgeting for the cost of new technology sweepers.
- Budgeting for the cost of appropriately disposing of highly contaminated waste that may be classed as hazardous and require special disposal arrangements.
- The capability of street sweepers (i.e. their ability to capture a high percentage of fine sediments and associated pollutants), although this limitation is reducing with time.
- Training sweeper operators.
- The inability of sweepers to collect some forms of pollutants (e.g. oils and greases, as well as nutrients in a dissolved form).

## Cost

An approximate cost of monthly street sweeping in Western Australia is \$55 per kerb km in 1998 dollars (Davies and Pierce, 1998). Adjusted for inflation (at a rate of approximately 3% per annum) this rate is approximately \$66 per kerb km in 2004 dollars. However, this cost is at the high end of the scale because most streets do not require a monthly street sweeping program.

Indicative costs have been provided by the Town of Victoria Park, Perth (Dawson, 2004, pers. comm., 29 October). This Town is home to approximately 27,500 people and covers an area of approximately 17.6 km<sup>2</sup>. Current estimates are that it costs approximately \$130,000 using one street sweeper to collect approximately 720-1080 tonnes of waste in one year. The level of service is:

- Main roads: swept fortnightly.
- Albany Highway (a main arterial road that has a high concentration of commercial/shopping premises): swept three times a week.
- Residential streets: swept monthly, for 8 months in a year.
- Large carparks (managed by the Town): swept fortnightly.
- Shopping centre carparks (managed by the centre owners): swept daily.
- Industrial areas: swept fortnightly.

<sup>9</sup> US studies have demonstrated almost 90% of contaminants on streets typically accumulate within 30 cm of the kerb (VSWCB, 1979).

- Stormwater gullies are cleaned and educted once a year, before winter, but usually after the ‘first-flush’ rains. A few problem areas are educted more often, particularly in winter, and the stormwater drains with gross pollutant traps are educted every three weeks during winter.

## Additional Information

A wide range of guidelines and research reports are available on this subject (see references below). High quality performance data is also available on the US BMP Database (<[www.bmpdatabase.org](http://www.bmpdatabase.org)>). However, new street sweeping technologies have emerged in recent years, making much of the research that was undertaken in the 1980s and 1990s obsolete.

## Examples / Case Studies

### Calculation of optimal sweeping frequency - Northern Virginia, USA

As noted previously, determining the optimum sweeping frequency based on local research is important. In guidelines for local stormwater managers, the Northern Virginia Planning District Commission (NVPDC, 1996) undertook this work, and recommended street sweeping frequencies of at least one sweep per week for residential areas and one to three sweeps per week for commercial and industrial areas, to maximise its effectiveness.

These recommendations represent a significant change to *typical* street sweeping frequencies in the region, which were based primarily on meeting aesthetic and safety needs (i.e. one sweep every six months for residential areas and one sweep every three months for industrial areas).

### Control of parked cars to optimise sweeping effectiveness - Wisconsin, USA

Gaining access to the kerb is another limitation of street sweeping, particularly in areas where cars are parked during the day and overnight. Like most limitations to street sweeping, this constraint can be managed if resources are available. A successful example reported by Taylor and Wong (2002c) comes from the City of Madison, Wisconsin. The City of Madison undertook a pilot study that aimed to test whether the surface pollutant removal efficiency of street sweeping could be improved by applying parking restrictions to areas where gaining access to the kerb was often difficult.

The study included a public education, parking enforcement and a street sweeping component. As a result, the total quantity of pollutants collected by street sweeping increased in volume by 118% (from 5.25 to 11.46 cubic metres per kerb kilometre swept). In addition, a public survey found 97% of respondents were aware of the new parking restrictions and the revenue gained from parking enforcement activities enabled the education and enforcement aspects of the program to be self-funding in the long term (Lehner *et al.*, 1999). No data was gathered on the effect on stormwater quality.

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## 2.2 Maintenance practices

### 2.2.2 Maintenance of the stormwater network

#### Description

Maintenance of the stormwater drainage network includes inspection, cleaning and repair of open and piped drains, pits, treatment devices, detention basins and outfall structures (VSC, 1999). This network needs to be regularly cleaned to maintain its performance (US EPA, 2001).

Regular cleaning of the stormwater drainage network provides an opportunity to remove pollutant loads that would otherwise enter receiving water bodies after heavy rainfall. In addition to transporting pollutants, drains with accumulated pollutants may also overflow, leading to localised flooding and erosion, as well as risks to human safety and constructed assets.

This guideline will focus on the maintenance of those elements of the stormwater drainage system that are *not* specifically designed to trap pollutants (e.g. pits, soak wells, pipes, open channels and detention basins). For structural BMPs that are designed to trap pollutants (see Chapter 9), each device should have a detailed and site-specific maintenance plan. Such plans should be prepared when the BMPs are designed and provide guidance on a suitable inspection regime and maintenance practices (including guidelines on the equipment to be used, health and safety procedures, waste disposal arrangements, etc.). These plans should also be prepared in consultation with relevant maintenance personnel.<sup>10</sup>

Most stormwater drainage networks have some capacity to capture and temporarily store pollutants (e.g. coarse sediment and litter). Such pollutants may be temporarily stored in drop inlets, gully pits<sup>11</sup>, flat open drains or detention basins and ultimately removed by either large storm events or maintenance by the asset manager (Taylor and Wong, 2002c). This is particularly the case where the stormwater drainage network has infiltration pits/soak wells or detention basins along its length. These features can provide ‘hot spots’ for accumulation of gross pollutants and contaminated sediments. For example, in the Mills Street drainage catchment in Perth, sediments from open drains and detention basins have been found to contain high concentrations of heavy metals (copper, lead and zinc in particular), hydrocarbons and nutrients (SRT, 2003a).<sup>12</sup> The type of land use and industries upstream of the drainage system should be considered in predicting what types of pollutants are likely to be trapped in the device or sediments. Sediments in open drains and basins may also contain iron monosulphide black oozes (MBOs) (black, organic rich oozes on the bottom of drains and basins, usually occurring in drains with slow flowing summer water flows). Sediments that contain MBOs will require special removal techniques to prevent oxygenation and subsequent acid release and deoxygenation of the water body. Some sediments can accumulate pyrite between cleaning events that could result in a net release of acid on drying of sediments.

Curtin University of Technology WA monitored the distribution of pollutants in sediment in two stormwater detention basins in a residential area of the Town of Victoria Park (Oldmeadow and Watkins, 2004). The study found that the highest concentrations of metals resided in the uppermost organic-rich layers of the sediments and decreased in concentration with depth. Values of most contaminants at depth were very low, indicating that the stormwater detention basins were acting to prevent significant metal

<sup>10</sup> For an example of a newly developed manual that sets out maintenance requirements for a wide range of structural BMPs for stormwater quality improvement, see *Hastings Maintenance and Operational Procedures (MOP) Manual for Stormwater Quality Improvement Devices* (Ecological Engineering, 2003).

<sup>11</sup> ‘Drop inlets’, ‘gully pits’, and ‘catchbasins’ are all terms for structures in the stormwater drainage network that receive stormwater as it first enters the enclosed, public stormwater drainage system (e.g. from a road surface or commercial property). Designs vary depending upon the locality, but these structures often have the ability to trap small amounts of coarse sediment and gross pollutants (albeit temporarily).

<sup>12</sup> For example, half of the sediment samples analysed from this catchment exceeded 400 mg/kg for TN and 110 mg/kg for TP (SRT, 2003a).

pollution of the underlying aquifer, whilst still performing their designed function of groundwater recharge from stormwater runoff. The researchers also found that nutrient levels in the sediments were low and suggested that nutrient inputs to the system were minimal (Oldmeadow and Watkins, 2004). The potentially high levels of contaminants such as heavy metals must be considered during the removal and disposal of the top layer of sediments from open drains and basins.

## Applicability

This management practice is applicable to all areas with stormwater drainage systems, but is particularly relevant where the system has an increased risk of pollutant accumulation (e.g. due to flat grades or the existence of nodes in enclosed drainage systems where pollutants can accumulate). In general, drainage networks that have a high proportion of open drains and detention basins provide a greater opportunity for the capture of contaminants than equivalent enclosed systems.

‘Leaky’ drainage systems that are built on sandy soils will need a relatively intensive maintenance regime to inspect and, if necessary, clean out trapped stormwater pollutants at dedicated infiltration points (e.g. gross pollutants and contaminated sediments). However, a gross pollutant and sediment trap installed before the entry of the leaky pipe system can reduce the maintenance requirements to no greater than the requirements of a traditional enclosed drainage system.

These guidelines are primarily intended to assist local government authorities and drainage service providers (such as the Water Corporation). However, they are also relevant to managers of privately owned stormwater drainage assets (e.g. those responsible for stormwater drainage structures on commercial or industrial sites).

## Recommended Practices

In the Perth region, maintenance of open drains, detention basins and infiltration basins is a significant issue for some stakeholders, as it can affect the export of contaminants from some drainage catchments. For example, a range of maintenance-related recommendations have been made for the Mills Street catchment in Perth (see SRT, 2003b). Some recommended maintenance practices are provided below for these types of assets.

### Inspection and maintenance frequencies

- ✓ Identify pollutant ‘hot spots’, where relatively large quantities of pollutants of concern regularly accumulate in the drainage system.
- ✓ Focus on those parts of the stormwater drainage network with relatively flat grades or low flows, as pollutants tend to accumulate in these areas.
- ✓ Undertake regular inspections of ‘hot spots’ to assess whether pollutants are accumulating.
- ✓ Inspect all stormwater drains and detention basins at least once a year, preferably immediately prior to the wet season. Typical maintenance frequencies for assets in Perth are defined in the Water Corporation’s *Drainage Maintenance Standards* (2004).
- ✓ Adjust the maintenance frequency of the drainage network to suit pollutant accumulation rates and seasonal conditions (flexibility of the maintenance regime is required given the uncertainty with accumulation rates and rainfall patterns).
- ✓ Prepare an inspection program that assigns inspection tasks, frequencies and responsibilities.

## Desilting and pollutant removal operations

Management of desilting operations should aim to minimise movement of low dissolved oxygen and potentially heavy metal rich slugs of water downstream of cleaning operations. A major issue is that removed material may be too wet for landfill disposal, but contain too many solids for disposal to the wastewater system. Management of handling, drying and final disposal of the materials needs to be considered.

- ✓ Use suitable equipment to extract the waste from the drainage system (e.g. for enclosed drains and pits, machinery that operates via suction rather than flushing, where possible).
- ✓ Where flushing must be used, ensure that wastewater is collected and suitably disposed. This wastewater is usually prohibited from being discharged to sewer. Discharge is an offence unless approved by the Water Corporation, and approval is only given in some special circumstances. Further information is available from the Water Corporation via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)> or by telephoning the Customer Service Centre on 13 13 95.
- ✓ For major desilting works involving drainage assets that may be regarded as 'waterways' by members of the community (rather than 'drains'), consult with local residents and relevant community groups before undertaking work.
- ✓ Management precautions when planning cleaning of open drains and basins should include spot testing to determine whether there is a potential soil acidity issue or the presence of iron monosulphide black oozes (MBOs).
- ✓ For guidance on how to manage acid sulfate soils, see the Department of Environment's *Acid Sulfate Soils Guideline Series: Guidance for Groundwater Management in Urban Areas on Acid Sulfate Soils* (2004a) and the Western Australian Planning Commission's *Planning Bulletin 64: Acid Sulfate Soils* (2003).
- ✓ For guidance on how to manage MBOs, contact the Land and Water Quality Branch at the Department of Environment.
- ✓ Work in dry weather, when the drainage facility is dry or during low flow conditions. This will reduce the volume of material that will require disposal.
- ✓ Do not disturb the banks of the drain, unless they are eroded and need stabilisation.
- ✓ If banks need stabilisation, explore physical and vegetative options, rather than scraping contaminated sediment onto the banks where it will erode again. Examples of native plant species that could be used to stabilise the lower, middle and upper banks are suggested in the drainage improvement report for the Mill Street drain catchment (SRT, 2003b). Further information about determining local native plant species and sourcing and planting local native plants is provided in Section 2.2.7. Biodegradable erosion control matting (e.g. jute matting or equivalent) should also be considered for steep slopes that are at a higher risk of erosion until vegetation stabilises these areas. In extreme cases, structural measures may need to be explored (e.g. use of rock lining).
- ✓ Determine if there are any sensitive flora or fauna in the vicinity of the work site and establish precautions to protect these species when undertaking maintenance works. Records should be kept by maintenance staff of any area that requires special maintenance procedures (e.g. an area where maintenance activities need to be scheduled around months when birds nest in the area).

- ✓ Remove sediment, litter and weeds from the drainage asset without altering its design invert level. This is particularly important in areas where nutrient-rich base flow enters open drains in summer months and transports these nutrients to sensitive waterways and wetlands. In such locations, all effort should be made to minimise the deepening of open drains and detention basins.
- ✓ Analyse a representative sample of the sediment before it is removed. In most of the urbanised catchments in the Perth region, removed sediment will contain high levels of nutrients and will often contain high levels of heavy metals and hydrocarbons (SRT, 2003a; Oldmeadow and Watkins, 2004). Analysis will determine if the sediment is suitable for use as a soil amendment, if it can be disposed on-site, or if it is contaminated and requires disposal at a landfill.
- ✓ When maintaining detention basins, be aware that the highest levels of contaminants are usually found in sediments closest to the outlet (SRT, 2003a; Oldmeadow and Watkins, 2004).
- ✓ Sediment should not be left alongside the drain or basin where it can erode and re-enter the drainage system.



*Figure 1. Sediment excavated from the Harvey Main Drain and stockpiled on the banks. Sediment has buried fringing vegetation and may be washed into the waterway. (Photograph: Department of Environment.)*



*Figure 2. Sediment cleared from a stormwater compensation basin and spread on the banks. Mill Street Compensation Basin, Welshpool. (Photograph: Department of Environment.)*

- ✓ If the sediment requires disposal in a landfill, refer to the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002) to determine the appropriate landfill type and the waste acceptance criteria. The Department of Environment regulates the transportation of wastes that may cause environmental or health risks. It does this through the application of the Environmental Protection (Controlled Waste) Regulations 2004. Controlled waste is generally defined as all liquid waste, and any waste that does not meet the acceptance criteria for a Class I, II or III landfill site. The *Guideline for Controlled Waste Generators* (DoE, 2004b) specifies that a generator is a person whose activities produce, or apparatus result in the production of controlled waste. Generators are required to use a DoE controlled waste licensed carrier to transport the material off-site and be in possession of a controlled waste tracking form.
- ✓ Sediment might require dewatering before removal from the site. This can be done by temporarily stockpiling (in a location where leachate does not flow back into the drainage asset) to allow for evaporation. Leachate should be managed in accordance with the Environmental Protection (Unauthorised Discharge) Regulations 2004. Alternatively, the sediment can be removed as a sludge/slurry and disposed in accordance with the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002) and the Environmental Protection (Controlled Waste) Regulations 2004. All loads should be covered when being transported.

- ✓ Before leaving the site, ensure that collected vegetative matter and litter have been removed, sediment has not been 'tracked' onto sealed roads, and the site does not pose a significant erosion risk.
- ✓ Ensure that all staff or contractors are suitably trained to implement these procedures.
- ✓ Enhancement of the drainage asset's ability to trap pollutants should be attempted in accordance with a plan that has been developed by people with suitable expertise using best practice design manuals for structural best management practices (see Chapter 9). This includes the introduction of meanders and riffles to drains, the construction of features to stop short-circuiting in detention basins, enlargement of basins, altering the bathymetry of drainage assets, planting alongside the drainage asset to lower groundwater levels and reduce nutrient concentrations in shallow groundwater, and the planting of bands of native vegetation perpendicular to the flow direction. These works can also be designed to enhance the habitat value of the waterway or basin and create an aesthetic landscape feature. See Chapter 6 for further information about retrofitting existing infrastructure to achieve multiple benefits. For major works, an environmental management plan may also have to be prepared, which details how the construction process will minimise impacts on water quality.

### Mowing and other types of mechanical vegetation maintenance

- ✓ Ensure that the proposed work is really necessary. The vegetation may appear unsightly, but may be providing a soil stabilisation role, habitat to valuable fauna and shading of the water column.
- ✓ Under no circumstances should vegetative matter (e.g. grass clippings, removed weeds) enter the water in the drainage asset, or be placed in locations where they could be blown or washed into the drainage asset. It is best to remove vegetative matter and litter from the site. Such material can be taken to an approved disposal site/transfer station where it can be recycled or disposed.
- ✓ When maintaining recreational areas alongside open drainage channels or detention basins, try to maintain a buffer zone of at least 10 metres where no fertilisation of lawns and gardens occurs. This strip should consist of suitable native plant species. Where possible, bank-side vegetation regimes should be designed to shade water in the drainage asset.
- ✓ Where appropriate, maintain firebreaks along drainage easements in accordance with local government requirements. One of the primary reasons for verge maintenance in rural areas is the reduction of fire risks (Foley<sup>13</sup>, pers. comm., 2004).
- ✓ The existence of non-native annual grasses along the top of the banks is a matter of concern to some water quality managers (e.g. SRT, 2003b) because such vegetation provides little shading and a poor buffer, requires regular mowing, can block drainage inlets and can contaminate the waterway following maintenance (e.g. from cut material entering the water column). Where a grassed landscape is preferred (e.g. for aesthetic reasons), it is recommended that conventional grasses be replaced with native perennial grasses, where practicable. Possible species are recommended in SRT (2003b).
- ✓ Avoid using machinery that contributes to bank instability.

<sup>13</sup> Michael Foley, City of Swan.

- ✓ Avoid washing machinery on-site. Ideally, vehicles and machinery should be washed in a sewered wash bay. An Industrial Waste Permit is required to connect and discharge these wastes to sewer. Further information is available from the Water Corporation via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)> or by telephoning the Customer Service Centre on 13 13 95. See Section 2.2.8 for further information.
- ✓ When refuelling machinery, ensure that fuel is not spilt on soil, vegetation or water. Ideally, refuelling should occur well away from drains and waterways. See Section 2.2.8 for further information.
- ✓ Report all environmental incidents (e.g. fish kills, oil spills) and the presence of noxious weeds to responsible parties for action as soon as practicable after their identification.

### Use of herbicides for weed control

- ✓ Herbicides should only be used after an examination of alternatives (e.g. physical removal of weeds, biological control, planting of native species that can out-compete weeds species, or planting of species that will shade out weed species and help lower the water temperature in the drainage asset). Ideally, a rigorous and scientifically based decision-making process should be used to determine the best methodology (including the type of control agent, method of application and timing of application) for managing weeds on a site-specific basis. Water and Rivers Commission Water Note 22 *Herbicide Use in Wetlands* provides guidance on minimising the risk of herbicide use to aquatic ecosystems. Frogs in particular have been found to be sensitive to most herbicides, however some products have been developed that are far less toxic to frogs.
- ✓ A weed management plan should be prepared for significant hot spots and priority areas (see SRT, 2003b, for details). Further information about the types of weeds in wetlands and waterways is provided in Water and Rivers Commission Water Notes 1 and 15. Guidelines for planning and implementing revegetation programs are outlined in the Water and Rivers Commission River Restoration Manual Chapters RR 4, 5 and 8.
- ✓ All practical attempts should be made to avoid herbicides entering water in drainage assets (e.g. avoid spraying in windy conditions).
- ✓ Be careful that weed control activities do not generate an erosion problem (e.g. along the banks of open drains). To minimise this risk, consider planting native species two weeks after spraying the weeds (see Section 2.2.7 and SRT, 2003b, for more details, including possible species).
- ✓ The service provider undertaking spraying activities must have knowledge of the weed species and the best time to spray.
- ✓ Where large volumes of chemicals are present on-site, ensure that a spill clean-up kit is available and personnel are trained in its use.
- ✓ Avoid washing equipment on site.
- ✓ See Section 2.2.7 for more information on pesticide use.

## Benefits and Effectiveness

The US EPA (2001) reported that regular cleaning of the stormwater drainage network can increase dissolved oxygen levels in stormwater, reduce levels of bacteria, reduce the load of common stormwater

pollutants entering receiving waters (e.g. sediment, nutrients, litter, organic matter), minimise localised flooding and minimise erosion that is caused by localised flooding.

Pit (undated) and Lehner *et al.* (1999) reported that the annual maintenance of catch basins within the City of Bellevue's enclosed stormwater drainage system in Washington was likely to produce the following reductions in average annual stormwater runoff:

- 10% - 25% reduction in the loads of lead and total solids; and
- 5% - 10% reduction in the chemical oxygen demand and loads of total phosphorus, total kjeldahl nitrogen and zinc.

Quantitative information on pollutants removal efficiencies associated with the maintenance of open drainage channels and detention basins in WA is not available. In regions like Perth however, there is evidence to suggest that accumulated sediments in urban areas are enriched with nutrients, heavy metals and hydrocarbons (e.g. SRT, 2003a; Oldmeadow and Watkins, 2004). The flat grades, high infiltration rates, and relatively low rainfall intensity of the region would help sediments to be deposited in the drainage network rather than being flushed through it. Given these circumstances, it would seem likely that a high-quality drain inspection and maintenance program would be effective at removing considerable quantities of contaminants (including nutrients) from the system, thus preventing these contaminants from entering sensitive water bodies. Maintenance programs could target areas that are most likely to generate contaminated sediments and potentially discharge the sediments to sensitive receiving water bodies (e.g. conservation category wetlands).

## Challenges

The following challenges may need to be addressed to improve implementation:

- Determining an optimal maintenance regime (e.g. best locations, frequency and timing).
- Agreeing among stakeholders what the objectives of drain maintenance should be. For example, should a drainage authority be required to routinely remove non-noxious weeds from open drainage channels if they are not significantly affecting water quality or the drain's hydrology?
- Appropriate disposal or reuse of the liquid and/or solid waste, which can be highly contaminated and/or voluminous. For example, sediment removed from open drains and detention basins in Perth is voluminous, usually nutrient-enriched, and potentially contaminated with heavy metals and hydrocarbons (depending upon the location). See the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002).
- Ensuring maintenance teams do not inadvertently change the original bathymetry of open drains and detention basins.
- Designing an efficient maintenance regime that covers stormwater management systems of differing designs.
- Trapping wastewater that results from flushing enclosed stormwater management systems (i.e. pipes) before it enters receiving waters. The wastewater from flushing enclosed (i.e. piped) stormwater management systems is usually prohibited from being discharged to sewer. Discharge of this wastewater to sewer is an offence unless approved by the Water Corporation, and approval is only given in some special circumstances.
- Where flushing is used for enclosed (i.e. piped) stormwater management systems, a significant water source is often required. Note that the efficiency of stormwater flushing decreases when the length of the drain exceeds 210 metres.

## Cost

An approximate cost for maintenance involving the removal of pollutants from many small pits in an enclosed stormwater drainage network has been obtained from Brisbane City Council (Sivaanathan, 2002). In 2001-02, it cost approximately \$2.80 per inlet to remove pollutants from a stormwater gully trap pit full of sediment, litter and/or vegetative matter. This cost included pollutant removal, transport and authorised disposal of the waste (as non-hazardous solid waste).

Indicative costs have also been documented by MCC (1997) for Moreland City in Melbourne. This City is home to approximately 137,000 people and covers an area of approximately 51 km<sup>2</sup>. In 1997, it cost Council approximately \$147,000 to service 10,000 pits (cleaned twice a year), at a service level of 385 pits cleaned per week. This produced approximately 150 tonnes of collected waste.

Indicative cost information for the maintenance of open drains and detention basins using advanced environmental practices<sup>14</sup> was obtained from Brisbane City Council. The current unit rate is \$80 - \$100/m<sup>3</sup> if the material can be used as 'clean fill' and \$150 - \$180/m<sup>3</sup> if contaminant levels require disposal at an authorised landfill (Sivaanathan, 2004).

Disposal costs (2004) for the Red Hill Landfill Facility (Eastern Metropolitan Regional Council) are:

\$74/m<sup>3</sup> for inert (class I, II)

\$80/m<sup>3</sup> (class III)

\$88/m<sup>3</sup> (class IV)

Wastes must be classed as 'spadeable' according to the Department of Environment waste acceptance criteria (DEP, 2002).

Such costs will vary depending on the specific task, equipment, the location of the project, and the local waste disposal requirements. Current unit rates for routine cleaning activities should be available from local government authorities in the area and/or the Water Corporation (if they manage stormwater assets in the area).

## Additional Information

The Water Corporation (2004) has a document titled *Drainage Maintenance Standards*. These standards include brief comments about inspection frequencies and required tasks for the maintenance of all their drainage-related assets. In addition, the Swan River Trust (2003b) has made recommendations on the way current open drainage maintenance practices could be improved with a view to decreasing the export of contaminants from urban drainage systems in the Mills Street Main Drain. Most of the Trust's recommendations are also relevant to open drains in other areas of WA.

Before flushing is used as a cleaning technique for enclosed drainage, discussions should occur with environmental regulators (e.g. the Department of Environment) to determine waste disposal requirements for the resulting wastewater. Trials may be necessary to:

- determine the quality and quantity of wastewater (to enable decisions relating to disposal to be made);
- ensure maintenance equipment and practices effectively collect the wastewater; and/or
- test the practicality and effectiveness of on-site treatment options for the wastewater.

<sup>14</sup> In Brisbane, drain desilting activities at 'control points' that are undertaken by local government are licensed by the State government under the *Environmental Protection Act 1994*. Accordingly, licence conditions are applied which result in relatively strict requirements (e.g. mandatory water quality monitoring during works, performance reporting, etc.).

## Examples / Case Studies

Mineart and Singh (2000) reported a study in San Francisco, California, which investigated whether an increased cleaning frequency of stormwater drain inlets could result in increased removal of urban stormwater pollutants. They examined the mass of pollutants captured during monthly, quarterly, semi-annual and annual clean-outs of drop inlets. They concluded that monthly maintenance collected the greatest volume of pollutants in residential, commercial and industrial areas, with a reduction in annual copper loads entering the city's water bodies of at least 3% - 4%, and possibly higher (i.e. 11% - 12%), if the monthly maintenance also captured pollutants from illegal dumping activities.

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## 2.2 Maintenance practices

### 2.2.3 Manual litter collections

#### Description

The manual collection of gross pollutants (e.g. litter) in locations where it may be blown or washed into the stormwater drainage network or water bodies is a common management practice in urban areas and along main roads. Collections are typically undertaken by:

- staff from government agencies (e.g. in ‘hot spots’, such as along the road corridor in commercial areas);
- volunteers during ‘clean up days’;
- the private sector in relation to their own premises (e.g. around commercial and industrial sites); and
- sectors of the community that sponsor an area (e.g. a section of highway).

This management practice is often implemented for aesthetic reasons. However, there is evidence that a regular manual litter collection program can significantly reduce the loads of pollutants entering water bodies via the stormwater drainage network. The practice can, in some circumstances, be used to provide an opportunity to raise the public's awareness of stormwater pollution.

#### Applicability

This management practice is applicable where gross pollutants (particularly litter) are accumulating in locations that are easily accessed by maintenance teams or volunteers. It is particularly relevant where:

- these pollutants have a high risk of entering the stormwater drainage system or water bodies (e.g. litter in an urbanised catchment with a steep grade and a high percentage of directly connected impervious surfaces);
- the receiving water bodies host environmental values that would be threatened by the discharge of litter in stormwater (e.g. swimming beaches and urban wetlands with high aesthetic or conservation values); and/or
- ‘hot spots’ are easily identified (e.g. pockets where wind-blown litter accumulates).

#### Recommended Practices

The key steps to establishing a manual litter collection program include:

- ✓ Identify ‘hot spots’ where litter accumulates.
- ✓ Identify areas where there is a high risk of litter entering the stormwater management system or receiving water bodies.
- ✓ Determine a suitable maintenance regime (including collection frequency, collection methods, personnel, health and safety requirements, etc.).
- ✓ Develop a simple monitoring and evaluation plan to determine the effectiveness of the program (for guidance on this issue, see Taylor and Wong, 2002d).

- ✓ Explore opportunities to raise awareness of stormwater pollution and littering during the clean up activities. For example, signage can be used to explain the purpose of clean up activities, and large volumes of collected waste can be used as a graphic reminder of the quantities of litter that are generated in the region. When specific ‘clean up days’ are organised for volunteers, there are usually many media opportunities (e.g. involvement of high profile public figures, statistics on the tonnage of waste collected and details of unusual items that have been found).



*Figure 1. Manual litter collection on the Swan River foreshore.  
(Photograph: Clean Up Australia.)*

Other recommendations include the following:

- ✓ Place a strong emphasis on maintaining safety standards. For example, manual litter collectors may find hazardous substances (e.g. syringes) and volunteers may have limited training. Specialist ‘sharps containers’ and associated instructions/training should be provided.
- ✓ In areas where the collected litter includes a high percentage of potentially recyclable items (e.g. glass and plastic bottles), the collected waste should be sorted into recyclable and non-recyclable streams. Typically, roadside litter will contain a high proportion of recyclable material.

## Benefits and Effectiveness

The Californian Department of Transportation undertook the three-year, US\$2.8M Litter Management Pilot Study to assess the efficiency of various litter management practices on major highways (Caltrans, 2000).

The study found that increasing the frequency of manual litter collections along highways from monthly to weekly:

- decreased the litter quantity in stormwater at all stormwater outfalls (a statistically significant finding with  $\alpha = 0.05$ ); and
- decreased the average annual litter load in stormwater by 30% (by weight), 41% (by volume) and 33% (by count) compared to control sites (Berger, 2001; Caltrans, 2000).

Novotony (1984) reported litter control activities (e.g. bin placement and manual litter collections) can effectively control gross pollutants, especially in areas with a high proportion of directly connected impervious areas. Citing Syrek (1981), Novotony found that ‘litter control measures can reduce the amount of deposited litter by 50% – 70%’ (p. 1242).

## Challenges

The following challenges may need to be addressed to improve implementation:

- Cost, as it is labour intensive.
- Occupational health and safety procedures must be addressed, particularly when volunteers are involved.

- Consideration of how smaller items can be collected, as only medium to large items of litter are typically collected.
- Determining an optimum maintenance frequency for a given area.

## Cost

A typical roadside manual litter collection program may involve two maintenance staff, a vehicle, and basic health and safety equipment. Two maintenance personnel can cover approximately one kilometre of the road corridor in one hour. Local disposal costs for solid, non-hazardous waste should also be included.

The Californian Department of Transport estimated manual litter collections of medium to large items along highways (i.e. items greater in size than, but not including, cigarette butts) cost approximately US\$40 - US\$45 per kilometre (Berger, 2001).

## Additional Information

The following websites are recommended resources:

- Clean Up Australia, available via <[www.cleanup.com.au](http://www.cleanup.com.au)>;
- Victorian Litter Action Alliance, available via <[www.litter.vic.gov.au](http://www.litter.vic.gov.au)>. Select 'Resources and Links' for other relevant resources.

## Examples / Case Studies

Main Roads Western Australia operates a 'Mobile Work Camp Unit' that covers more than 4,000 kilometres of main roads each year and collects roadside litter (Clean Up Australia Day, 2003). In 1999, this group collected 950,000 glass bottles (29% of collected items), 869,160 aluminium cans (26%) and 814,230 plastic bottles (25%).

The 'Clean Up Australia' program is an example of a successful national program with activities in Western Australia. Relevant statistics include:

- Over 4 million people have participated in the program since its inception.
- Over the past eleven years, volunteers have collected approximately 150,000 tonnes of rubbish in Australia, which equates to approximately 4 million full 'wheelie bins'.
- In 1999, the program involved 8,700 clean up sites in Australia and collected 12,000 tonnes of litter (the majority of which was recyclable).
- Cigarette butts were the most littered item in the last 5 consecutive years to 2003.
- Beaches, waterways and parklands were the most littered and polluted sites in 1999.
- In 1993, the program was exported internationally to become 'Clean Up the World', which is now active in 105 countries and involves over 35 million people (Clean Up Australia Day, 2003).

A recent Australian manual litter collection program involved collecting gross pollutants from the Brisbane River and its banks in Queensland. The initiative was funded from stakeholder groups in the region and involved a litter collection boat to raise public awareness of the importance of healthy waterways. The program cost approximately \$130,000 in 2000-01, including litter handling, disposal and reporting. This level of funding enabled approximately 135,000 items of litter to be collected (Chandler, 2002).

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## 2.2 Maintenance practices

### 2.2.4 Litter bin design, positioning and cleaning

#### Description

The design, location and maintenance regimes of public litter bins (and accompanying recycling facilities) is an important source control for litter, particularly in urban areas.

#### Applicability

This management practice is suitable for public spaces in urban areas and potential litter ‘hot spots’ in non-urban locations (e.g. roadside rest areas). In remote locations however, the placement of public litter bins may attract illegal dumping of large volumes of waste (e.g. places where people camp).

This management practice is particularly relevant where:

- Litter has a high risk of entering the stormwater drainage system or water bodies (e.g. litter in an urbanised catchment with a steep grade and a high percentage of directly connected impervious surfaces);
- The receiving water bodies host environmental values that would be threatened by the discharge of litter in stormwater (e.g. swimming beaches and urban wetlands with high aesthetic or conservation values).

Caution is needed, as this management practice should not be considered in isolation from the local context in which it will be applied or from supporting measures (e.g. signage, public participation and enforcement). The Beverage Industry Environment Council (BIEC, 1999) emphasised this point in a report titled *What Works: New South Wales Littering Behaviour Interventions*. This report concluded that ‘waste reduction and litter prevention interventions in public places will be effective when strategies fit the characteristics and circumstances of the various public place activities...’ (p. 8).

#### Recommended Practices

The following practices for reducing littering in public places are recommended. [Source: Curnow *et al.* (2002); VSC (1999); Reeve *et al.* (2000) summarised reviews by Huffman *et al.* (1995) and BIEC (1997a).]

- ✓ Placing litter and recycling bins in locations that are convenient/accessible to the public (i.e. located close to the source of litter, such as fast food outlets, ATMs and exits from large public venues).
- ✓ Undertaking site assessments to identify those bins that are the most heavily used, particularly near stormwater management systems and water bodies. These bins should be subject to increased levels of inspection (and if necessary, maintenance).
- ✓ Designing bins that catch the attention of the public and are easily identifiable.
- ✓ Being consistent to avoid confusion (e.g. making the colours and shape of litter and recycling bins consistent).
- ✓ When designing bins, the bin opening should be small enough to discourage illegal dumping, yet acceptable for normal litter items.

- ✓ Decisions made regarding the size of bins should seek to minimise the required emptying frequency while discouraging illegal dumping.
- ✓ Assessing the need for specialist bins in specific locations (e.g. for cigarette butts, sharps, etc.).
- ✓ Placement of politely worded signage close to where littering occurs. Contact Keep Australia Beautiful Council for further advice (telephone (08) 9278 0300).



Figure 1. Waste and goods dumped outside charity bins in Perth. (Photograph: Dieter Solonec, Paraquod Association of WA.)



Figure 2. Example of charity bin sticker to discourage dumping. (Sticker source: Paraquod Association of WA.)

- ✓ Keeping observable litter to a minimum (e.g. through frequent collections) as littering rates are reduced in areas that are regularly cleaned – ‘clean equals clean’.
- ✓ Typically, bins should be emptied before they reach 75 - 80% full. The service provider that undertakes bin emptying should be responsible for clearing up unconfined litter within a specified radius of the bin (e.g. two metres). The frequency of bin emptying will vary depending on the location, however a general guide in urbanised areas is that:



Figure 3. Make sure bins are emptied regularly – rubbish attracts rubbish! (Photograph: Keep Australia Beautiful Council WA.)

- street litter bins will need emptying at least daily; and
- park litter bins will need emptying at least weekly (MCC, 1997).
- ✓ Involving the community in litter management initiatives (e.g. involve users of public areas in the design and placement of bin facilities).
- ✓ Acting on behaviour (e.g. with rewards and/or sanctions, as appropriate).
- ✓ Encouraging responsibility (e.g. behaviour change programs to encourage people to take responsibility).
- ✓ Designing public open space to minimise areas that are hidden from public view.
- ✓ Integrating programs (e.g. anti-litter educational strategies should be accompanied by the provision of litter bin and recycling infrastructure and sound maintenance regimes).

- ✓ Demonstrating commitment (e.g. agencies promoting anti-litter messages must lead by example).

In relation to *recycling bins*, Quinn (1999) suggested that the following key elements must exist for recycling to work in public places:

- ✓ The bins should be labelled using appropriate symbols and a recognisable and consistent system of colours.
- ✓ Bins should be grouped into stations with a litter bin at either end and recycling bins in the middle.
- ✓ Bins should only be provided for items which patrons easily identify with recycling.
- ✓ Recycling bins should have locked lids and holes in the lids the size and shape of the materials to be put in them.
- ✓ Litter bins should have the lids open.
- ✓ Bins should have overhead signs so that their location can be seen above a crowd.

## Benefits and Effectiveness

For litter bins to significantly reduce littering rates, they have to be part of an overall management strategy incorporating the Recommended Practices, outlined above. This view is supported by many local observational studies in Australia involving littering in public places.

## Challenges

The following challenges may need to be addressed to improve implementation:

- Complementary management measures are required (e.g. signage, enforcement activities, manual litter collections, street sweeping, involvement of the local community in bin design and placement and positive reinforcement of stakeholders that undertake desirable behaviour).
- Sound monitoring and evaluation is required as each local circumstance is different (for guidance on this matter, see Taylor and Wong, 2002d; BIEC, 2001).
- If the maintenance regime for clearing the litter and recycling bins is inadequate, the litter loads in stormwater may be worse than if no bins were provided. This is because littered areas promote littering behaviour.

## Cost

Indicative costs have been documented by MCC (1997) for Moreland City in Melbourne. This City is home to approximately 137,000 people and covers an area of approximately 51 km<sup>2</sup>. In 1997, it cost Council \$196,000 to service 1,022 bins, at a service level of 4,615 emptied bins/week. This produced approximately 615 tonnes of collected waste.

## Additional Information

The Beverage Industry Environment Council has sponsored a range of research projects and seminar series around Australia to assist stakeholders to design, implement and evaluate litter minimisation strategies. For more information on the Beverage Industry Environment Council's Litter Prevention Program, refer to <[www.biec.com.au/enviroresearch.html](http://www.biec.com.au/enviroresearch.html)> for further information.

Other recommended resources include:

- Clean Up Australia, available via <[www.cleanup.com.au](http://www.cleanup.com.au)>.
- Keep Australia Beautiful Council. Support is available by telephoning (08) 9278 0300. Useful references are available via <[www.kabq.org.au/nat](http://www.kabq.org.au/nat)>. Select 'Litter audit'.
- Victorian Litter Action Alliance, available via <[www.litter.vic.gov.au](http://www.litter.vic.gov.au)>.

## Examples / Case Studies

The City of Stonningham in Melbourne undertook a trial of 'cigarette butt bins' to reduce the littering of butts, which are typically the most littered item in urban areas. Prior to the installation of 15 'Smoke Zone Butt Bins', a series of surveys were undertaken to count the number of littered butts. This form of basic monitoring was repeated after the butt bins had been installed in a defined study area (KABV, 2003).

The evaluation concluded that the installation of the butt bins was associated with an overall reduction in the number of discarded butts along the survey site. The most pronounced reduction occurred where commuters were waiting to catch a tram into the central business district (KABV, 2003).

## References and Further Information

Beverage Industry Environment Council (BIEC) 1997a, *Understanding Littering Behaviour: A Review of the Literature*, Beverage Industry Environment Council, Sydney, New South Wales.

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- Taylor, A.C. and Wong, T.H.F. 2002c, *Non-Structural Stormwater Quality Best Management Practices - A Literature Review of Their Value and Life-cycle Costs*, Technical Report No. 02/13, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria. Available via <[www.catchment.crc.org.au](http://www.catchment.crc.org.au)> and <[www.clearwater.asn.au/infoexchange.cfm](http://www.clearwater.asn.au/infoexchange.cfm)>.
- Taylor, A.C. and Wong, T.H.F. 2002d, *Non-structural Stormwater Quality Best Management Practices - Guidelines for Monitoring and Evaluation*, Working Paper No. 02/6, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria. Available via <[www.catchment.crc.org.au](http://www.catchment.crc.org.au)>.
- Victorian Litter Action Alliance (undated). Retrieved: October 19, 2004, from <[www.litter.vic.gov.au](http://www.litter.vic.gov.au)>.
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## 2.2 Maintenance practices

### 2.2.5 Road/pavement repairs/resurfacing and road runoff

#### Description

Activities to repair potholes and degraded footpaths, as well as road and carpark resurfacing, have the potential to contaminate stormwater. Specific management practices need to be applied to minimise this risk, such as planning maintenance activities, modifying road resurfacing and footpath maintenance practices, managing spills and sweeping.

In addition, substantial amounts of pollutants are generated during daily roadway use, which can threaten the health of local water bodies by contributing heavy metals, hydrocarbons, sediments, gross pollutants and nutrients. Table 1 highlights typical highway runoff constituents and their primary sources.

**Table 1. Typical highway runoff constituents and their primary sources**

Constituent	Primary Sources
Particulates	Pavement wear, vehicles, atmospheric deposition
Nitrogen, Phosphorus	Atmospheric deposition, roadside fertiliser application
Lead	Tyre wear, vehicle exhaust
Zinc	Tyre wear, vehicle exhaust, grease
Iron	Vehicle rust, steel highway structures, moving engine parts
Copper	Metal plating, brake lining wear, moving engine parts, bearing and brushing wear, fungicides and insecticides
Cadmium	Tyre wear, insecticides
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and petrol, lubricating oil, brake lining wear, metal plating, asphalt paving
Manganese	Moving engine parts
Sulphate	Fuel
Petroleum/hydrocarbons	Spills, leaks of motor lubricants, hydraulic fluids, asphalt surface leachate

Source: US EPA (1997).

Potential risks to stormwater quality from roads, carparks and footpaths include:

- discharge of sediments, heavy metals and hydrocarbons from the wear and tear of the road surface, vehicle tyres and vehicle brake linings;
- discharge of hydrocarbons during road and carpark resurfacing work (e.g. during a spill or unexpected rainfall event);
- discharge of bitumen overspray during road and carpark resurfacing activities;
- discharge of alkaline slurry from concrete cutting activities; and
- discharge of wastewater from the washing of machinery and tools (e.g. cement mixers and pumps).

## Applicability

This management practice is applicable to all areas with roads, carparks and footpaths, and includes sealed and unsealed surfaces. It is particularly relevant in steeply sloping catchments with a high proportion of directly connected impervious surfaces and sensitive receiving waters.

Improving the quality of stormwater runoff from road surfaces is usually a priority in urban areas, given the significant load of stormwater pollutants that can be generated from road runoff, and the efficiency of traditional drainage systems in transporting this load to receiving waters. While the potential for environmental harm from road runoff is often significant, there is a high degree of variability in the quality of this runoff. For example, the US EPA (2001) noted that the level of pollutants found in road runoff is determined by many site-specific factors such as:

- traffic volume;
- traffic movement (e.g. areas where vehicle braking and acceleration is frequent);
- climate;
- maintenance regime, including incident response procedures (e.g. to manage vehicle accidents and spills);
- surrounding land use;
- design of the road and associated drainage network;
- presence of roadside vegetation (and the use of herbicides or insecticides on this vegetation); and
- frequency and type of accidents and spills that can discharge a variety of hazardous substances to stormwater.

## Recommended Practices

Management practices recommended by VSC (1999) and US EPA (2001) are summarised below. Ideally, these management practices would be part of an environmental management system (see Section 2.5.1) that includes regular training, auditing/risk assessments, performance reporting mechanisms, etc.

### Site preparation and planning

- ✓ Where there is the threat of material entering side entry pits during maintenance activities (e.g. road base, aggregate, or bitumen), install temporary inlet filters (e.g. using geofabric).
- ✓ Ensure material such as packing sand, cement, gravel, crushed rock and excavated material is stockpiled away from any drainage paths and covered to prevent erosion.
- ✓ Ensure that procedures and training exist so that resurfacing activities do not occur when rainfall is imminent or occurring. This guideline also applies to cement stabilisation activities.
- ✓ Pavement should be repaired in sections to reduce the spillage of paving materials during the repair of potholes and worn pavement.
- ✓ Ensure spill clean-up kits are available and site staff are trained in their use. These kits may be needed to trap hydrocarbons spills from machinery/plant or from runoff following an unexpected rainfall event during resurfacing.

### Bitumen/resurfacing work

- ✓ Do not carry out bitumen spraying in windy conditions.
- ✓ Place only the required amount of screenings on the bitumen.
- ✓ Ensure loose aggregate is swept up at the completion of works.
- ✓ Use pollution prevention techniques such as drip pans and absorbent materials for all paving machines to limit leaks and spills of paving materials.
- ✓ Consider the use of porous asphalt when replacing surfaces, to reduce the volume of stormwater runoff and associated pollutant loads.

### Concrete work

- ✓ Undertake concrete mixing and clean-up operations in a designated area that is capable of containing wastewater. Small amounts of wastewater can be allowed to evaporate or infiltrate into the soil.
- ✓ Ensure a contingency measure is in place to prevent any spilt material from entering the drainage network when using concrete pumps.
- ✓ Allow concrete waste and slurry to set before disposal off-site.
- ✓ Prevent wastewater from concrete cutting, brick cutting, or grinding activities from entering the stormwater system. Where it is not practical to trap this wastewater, or direct it to a permeable area for infiltration, the wastewater should at least be filtered through a geofabric material. However, filtering will not affect the pH of this wastewater, which can be very high for wastewaters involving concrete.
- ✓ Remove any cover material and formwork from the site once concrete has cured.

### 'Housekeeping' practices

- ✓ Remove all excess material from the work site before leaving, including all waste concrete, packing material and soil. Loose material should be swept from hard surfaces, not flushed.
- ✓ If equipment/plant needs to be washed on-site, ensure that it is undertaken in an area where stormwater will not be contaminated (e.g. on a well-grassed area). Ideally, equipment/plant should be washed in a seweried wash bay. An Industrial Waste Permit is required to connect and discharge these wastes to sewer. Further information is available from the Water Corporation via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)> or by telephoning the Customer Service Centre on 13 13 95. Section 2.2.8 provides further best practice guidelines for maintenance and washing of vehicles and equipment.

### Related maintenance practices

- ✓ Regularly sweep roads, carparks and paths that are identified as ‘hot spots’ for sediments and gross pollutants (see Section 2.2.1 for more details).
- ✓ Regularly remove accumulated pollutants (e.g. sediments and gross pollutants) from nodes in the stormwater network that may accumulate pollutants, such as pits and infiltration sumps (see Section 2.2.2 and Chapter 9 for more details).
- ✓ Where roadside vegetation exists (e.g. along highways), ensure that it operates as an effective filter strip to improve the quality of road runoff and to promote infiltration. In addition, restrict the use of herbicides and insecticides on roadside vegetation, and ensure maintenance staff use appropriate handling and application procedures for these materials. See Section 2.2.7 for more information on vegetation maintenance practices. See Chapter 9 for more information on swales and vegetated filter strips.
- ✓ Use indigenous vegetation along roadsides, paths and in swales, as recommended in Section 2.2.7 and Chapter 9.

### Benefits and Effectiveness

The US EPA (2001) reported that limited data is available on the effectiveness of road maintenance practices in removing pollutants from stormwater runoff (e.g. see the limited data in the table below). However, preventative maintenance and strategic planning are recognised as cost-effective methods to minimise contamination of stormwater runoff and reduce the risk of environmental harm to the receiving environment.

**Table 2. Road maintenance management practices: indicative effectiveness and cost**

Management Practice	Effectiveness (% removal*)	Indicative Cost (in 1993 US dollars)
Maintaining roadside vegetation (as a filter strip)	Sediment control: 90% average. Phosphorus and nitrogen: 40% average. Chemical oxygen demand (COD), lead and zinc: 50% average. Total suspended solids (TSS): 60% average.	Natural succession of vegetation allowed to occur: • average = US\$100/acre/year; and • range = US\$50 - \$200/acre/year.
Street sweeping (see Section 2.2.1 for more information)	Smooth street, frequent cleaning: • TSS = 20% • COD = 5% • Lead = 25% Smooth street, infrequent cleaning: • TSS = N/A • COD = N/A • Lead = 5%	Average = US\$20/kerb mile. Range = US\$10 - \$30/kerb/mile. (See Section 2.2.1 for Australian costing data)
Litter control	N/A	Accepted as economical practices to control or prevent stormwater impacts.
General maintenance	N/A	Accepted as economical practices to control or prevent stormwater impacts.

\* Assumed to be either the approximate per cent reduction in the stormwater’s average annual loads or event mean concentrations.

Source: US EPA (1997).

## Challenges

The following challenges may need to be addressed to improve implementation:

- Budgeting for the cost and effort associated with implementing new procedures, additional equipment and staff training.
- Budgeting for the cost associated with delaying maintenance work (e.g. waiting to undertake resurfacing activities until rainfall is unlikely to occur).
- Overcoming the difficulty in trapping and/or effectively treating wastewaters on hard surfaces (e.g. wastewater from concrete cutting equipment, where there is no opportunity to direct this wastewater to an infiltration area).
- It relies upon staff fully implementing procedures, as well as the continual improvement of procedures and practices. An environmental management system can provide the framework to minimise this risk (see Section 2.5.1 for more details).

## Cost

The primary costs associated with introducing improved stormwater management practices during road/pavement maintenance involve the purchase of new equipment, the time associated with implementing new procedures, the time associated with staff training and the cost of accessing specialist expertise. Some indicative cost information from the US is provided in Table 2. Employing good maintenance practices is an efficient and low-cost BMP to eliminate or reduce the impacts of pollutants associated with road systems.

## Additional Information

Further information about roadside swales and vegetated filter systems is provided in Chapter 9. For more information on planning, construction and maintenance of roads, see the Department of Environment's *Roads in Sensitive Environments* Water Quality Protection Note (DoE, 2004).

## Examples / Case Studies

None are currently documented, although improved road maintenance practices are being implemented throughout Australia, particularly where agencies are implementing environmental management systems. For example, Main Roads Western Australia are developing an 'Environmental Guideline: Water Protection', which addresses road / bridge construction and maintenance issues.

## References and Further Information

Department of Environment 2004, *Roads in Sensitive Environments*, Water Quality Protection Note, July 2004, Department of Environment, Perth, Western Australia.

United States Environmental Protection Agency (US EPA) 1997, *Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters*. United States Environmental Protection Agency on-line guideline. Cited at: <[www.epa.gov/owow/nps/MMGI/Chapter4/index.html](http://www.epa.gov/owow/nps/MMGI/Chapter4/index.html)> (first published as a guideline in 1993).

United States Environmental Protection Agency (US EPA) 2001, *National Menu of Best Management Practices for Storm Water Phase II*. United States Environmental Protection Agency on-line guideline: <[www.epa.gov/npdes/menuofbmps/menu.htm](http://www.epa.gov/npdes/menuofbmps/menu.htm)>.

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## 2.2 Maintenance practices

### 2.2.6 Maintenance of premises typically operated by local government

#### Description

This guideline will *briefly* address key stormwater management practices that are often required on premises that may be operated by local government. These premises include cemeteries, parks, sports fields, nurseries, depots, buildings and road reserves. These premises have the potential to contaminate stormwater and/or generate large volumes of stormwater due to a high percentage of impervious surfaces. Note that Section 2.2.7 specifically addresses stormwater management on gardens and reserves.

To identify, assess, manage, monitor and continually improve the management of stormwater-related risks from these premises, it is recommended that operators undertake a risk assessment and develop a plan to address those risks, or implement an environmental management system (EMS). As explained more fully in Section 2.5.1, an EMS provides a management framework, which is documented as an international standard, to help set objectives/policy, undertake site-specific risk assessments, develop specific management strategies (e.g. procedures), undertake regular audits to check performance, report on performance and continually improve performance. Typically, a specialist environmental manager will be engaged to establish and/or maintain an EMS. In some situations, the system will also be subject to periodic assessment and certification by an independent auditor. Alternatively, a stormwater management system could be developed. See the City of Greater Shepparton, Victoria example/case study in Section 2.5.1.

#### Applicability

These management practices are applicable to the types of premises typically operated by local government. However, this is a *generic* stormwater guideline that may need to be supplemented with site-specific practices. A risk assessment that identifies and evaluates the potential stormwater-related risks is strongly recommended prior to the application of new management practices. The guideline presented here provides a basis for undertaking the assessment and developing a tailored, site-specific stormwater management plan/procedure.

#### Recommended Practices

The following management practices are typically applicable to premises operated by local government.

##### Depots

- ✓ Identify sources of potential stormwater contamination and seek to remove the risk of stormwater contamination by covering storage areas, bunding storage areas, or removing unnecessary materials/equipment from the site (see Section 2.2.10).
- ✓ Keep stormwater that is likely to be relatively ‘clean’ separate from potentially contaminated stormwater.
- ✓ Seek to minimise the percentage of the site that has directly connected impervious surfaces. See Chapters 6 and 9 for the types of structural controls that can reduce the amount of directly connected impervious surfaces.

- ✓ Undertake washing of vehicles, equipment and plant in a sewerage wash bay (see Section 2.2.8). An Industrial Waste Permit is required to connect and discharge these wastes to sewer. Further information is available from the Water Corporation via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)> or by telephoning the Customer Service Centre on 13 13 95.
- ✓ Ensure materials that are potentially erodible are covered (preferred solution), stored out of the way of drainage paths, and/or subject to downstream sediment controls.
- ✓ Ensure spill clean up kits are available, where necessary, and staff are familiar with their use (see Section 2.2.10).
- ✓ Sweep up loose materials (e.g. sediment) as soon as possible after the material has accumulated on hard surfaces, rather than flushing it to stormwater (see Section 2.2.10).
- ✓ Ensure staff using the depot are familiar with the site's stormwater-related risks, requirements (e.g. procedures), and consequences for failing to comply with these requirements.
- ✓ Seek expert advice on the installation of structural stormwater management devices (e.g. oil-water separators, devices that trap sediment and hydrocarbons), and install these devices where necessary. The installation of structural stormwater management devices should be an option of last resort. Where devices are installed, a sound maintenance regime will need to be developed and implemented (see Chapter 9).
- ✓ Stabilise any exposed soil on the site through erosion control methods (see Section 2.1.1), particularly where there is a risk that the soils may be contaminated due to historic site activities.
- ✓ Investigate opportunities to reuse stormwater and/or shallow groundwater on the site (e.g. for vehicle washing or toilet flushing).

## Buildings

- ✓ Investigate opportunities to reuse stormwater (roof water) and/or shallow groundwater in the building (e.g. for toilet flushing) or on the surrounding garden (e.g. for irrigation). Reuse should occur via water efficient devices both within the building and around the garden.
- ✓ During construction activities, ensure that sound erosion and sediment control practices are undertaken, as well as best practice housekeeping practices for construction activities (see Section 2.1.1).
- ✓ Minimise the percentage of the site's area that contains directly connected impervious surfaces (e.g. promote opportunities for filtration and infiltration of stormwater). See Chapter 9 for further information.
- ✓ Install structural stormwater management devices (e.g. rain gardens, bioretention systems), where necessary (see Chapter 9). Where devices are installed, a sound maintenance regime will need to be developed and implemented.
- ✓ Where stormwater is allowed to infiltrate into the groundwater, assess the risk of groundwater contamination and, where necessary, undertake pre-treatment of stormwater and/or recycling of shallow groundwater.

- ✓ Ensure the building's maintenance practices include regular sweeping of loose litter, sediment or leaves from hard surfaces, the provision of appropriate litter and recycling bins (with signage), and the emptying of these bins before they are 75% full (see Sections 2.2.3 and 2.2.4).
- ✓ Ensure that flaking paint on roofs does not contaminate stormwater.
- ✓ If a building is washed, contaminated wastewater should be prevented from entering stormwater (e.g. by directing wastewater to an infiltration area, or through the use of absorbent material). For more information on building maintenance practices, see Section 2.2.9.

### Planning and coordination of activities in parks, gardens and sports fields (from VSC, 1999)

- ✓ Monitor key pollution indicators for each park and garden (e.g. the number of people using the area, types of pollutants, proximity to water bodies, etc.).
- ✓ Determine appropriate work practices to minimise pollution risks, based on park activities. Determine where specialist maintenance methods and equipment may be required and, where necessary, implement structural controls to trap stormwater pollutants.
- ✓ For more information on designing and maintaining gardens and reserves, see Section 2.2.7.

### Nurseries

- ✓ Most of the management practices recommended for depots also apply to nurseries. However, there is a focus on minimising the discharge of stormwater from nurseries as there is a high risk that this stormwater could be contaminated by nutrients and pesticides.
- ✓ Seek to minimise the export of stormwater from the site by capturing stormwater for reuse as irrigation water, and capturing and reusing shallow groundwater that may be contaminated from on-site activities.
- ✓ Use slow-release fertilisers, where possible.
- ✓ Manage the nursery's watering regime to minimise runoff.
- ✓ Consider the use of soil amendment for sites with sandy soils that are not paved, to minimise the potential for contaminants to easily enter shallow groundwater (see Section 2.1.2).
- ✓ Minimise the use of insecticides through 'integrated pest management' practices.
- ✓ See Section 2.2.7 for more information on maintenance of plants/gardens.
- ✓ Refer to the *Nurseries and Garden Centres Water Quality Protection Note* (WRC, 2002) for further guidance on managing stormwater on nursery premises.
- ✓ The Nursery and Garden Industry Association, Department of Environment and other contributors are developing environmental best management practice fact sheets for nurseries. These guidelines will replace the existing guideline - *Environmental Management Best Practice Guidelines for the Nursery Industry* (Department of Agriculture, 2002).

## Highly maintained open space and sports fields (including golf courses)

- ✓ See Section 2.2.7.

## Road reserves

- ✓ Undertake erosion and sediment control on road reserves to minimise the export of sediment to stormwater (see Section 2.1.1). This is particularly important during maintenance activities involving re-grading the road shoulder and associated table drains.
- ✓ Undertake manual litter collections (see Section 2.2.3.).
- ✓ Maintain a healthy grass/vegetation cover to help filter and infiltrate stormwater.
- ✓ Minimise the use of herbicides and pesticides during the maintenance of road reserves (see Section 2.2.7).
- ✓ Further information about roadside swales and vegetated filter systems is provided in Chapter 9.

## Cemeteries

- ✓ Most of the management practices recommended for general park maintenance (see Section 2.2.7) and depots also apply to cemeteries.
- ✓ Seek to adopt the principles of water sensitive urban design along interior roadways (see Wong *et al.*, 2000, for guidance on this issue).
- ✓ Seek to minimise the export of stormwater from the site by capturing stormwater for reuse as irrigation water and/or capturing and reusing shallow groundwater that may be contaminated from on-site activities.
- ✓ Use slow-release fertilisers and integrated pest management practices where possible (see Section 2.2.7).
- ✓ Undertake basic erosion and sediment control measures on areas with disturbed soils (see Section 2.1.1).
- ✓ Where soils are poor at retaining moisture and nutrients, consider the use of soil amendment to minimise the potential for contaminants (e.g. nutrients from gardens) to easily enter shallow groundwater or stormwater (see Section 2.1.2.). Soil amendment in this circumstance will also reduce the need for fertilisation and watering of lawns.
- ✓ Implement a water efficient irrigation scheme to minimise runoff during watering periods (e.g. an automated system that uses sensors to detect soil moisture).

## Benefits and Effectiveness

The benefits and effectiveness of the practices outlined in this guideline are only discussed in general terms.

Sound stormwater management on the types of premises covered by this guideline should result in:

- Reduced loads of pollutants entering stormwater and/or shallow groundwater, thereby minimising the risk to the health of receiving waters.
- Reduced potential for organisations managing these premises to be subject to complaints from stakeholders or enforcement by environmental regulators.
- Reduced need for scheme/mains water because of stormwater and/or groundwater reuse.
- Reduced need for downstream, end-of-pipe, stormwater treatment devices (as the practices in this guideline are all *source* controls).
- Reduced need for the application of fertilisers, herbicides and/or pesticides.
- In some cases, reduced volumes of stormwater discharge (e.g. because of stormwater reuse and/or infiltration).

## Challenges

The main challenge for implementing these management practices is the cost and effort required to undertake a risk assessment at the premises, develop site-specific management practices (using this guideline), implement these practices (including training staff) and monitor their implementation. However, it is suggested that this barrier should be overcome, particularly if the organisation is a government agency that should lead by example.

## Cost

Meaningful cost information cannot be provided due to the generic content in this guideline.

## Additional Information

Section 3.20 of the Department of Environment and Swan River Trust (2004) *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* contains resources for local government operations.

## Examples / Case Studies

Examples of cleaner site management practices are provided in Section 2.2.10 and of parks and gardens maintenance are provided in 2.2.7.

## References and Further Information

Lehner, P.H., Aponte Clarke, G.P., Cameron, D.M. and Frank, A.G. 1999, *Stormwater Strategies: Community Responses to Run-off Pollution*, Natural Resources Defence Council, New York, New York. Cited at <[www.nrdc.org/water/pollution/storm/stoinx.asp](http://www.nrdc.org/water/pollution/storm/stoinx.asp)>.

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Wong, T.H.F, Breen, P.F. and Lloyd, S.D. 2000, *Water Sensitive Road Design - Design Options for Improving Stormwater Quality of Road Runoff*, Cooperative Research Centre for Catchment Hydrology Technical Report No. 00/1, Cooperative Research Centre for Catchment Hydrology, Victoria, Melbourne.

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Water and Rivers Commission 2001, *Herbicide Use in Wetlands*, Water Notes, No. 22, Water and Rivers Commission, Perth, Western Australia.

Water and Rivers Commission 2002, *Nurseries and Garden Centres*, Water Quality Protection Note, March 2002, Water and Rivers Commission, Perth, Western Australia.

Water and Rivers Commission 2002, *Stormwater Management at Industrial Sites*, Water Quality Protection Note, November 2002, Water and Rivers Commission, Perth, Western Australia.

## 2.2 Maintenance practices

### 2.2.7 Maintenance of gardens and reserves

#### Description

This guideline focuses on the following management practices that can be applied at parks, gardens, road/drainage reserves and turfied sports fields/venues:

- Plant selection and landscaping design
- Nutrient management
- Irrigation management
- Pest management
- Lawn mowing, top dressing and pruning

The maintenance practices applied to grassed areas and gardens can have a significant potential impact on stormwater and groundwater quality. Potential pollutants include nutrients, sediment, pesticides, wastewater from washing machinery (e.g. mowers), and organic matter (e.g. grass clippings). Possible impacts include eutrophication and elevated levels of turbidity in receiving waters, leading to a variety of adverse impacts on aquatic flora and fauna.

As detailed guidelines are currently available for these practices, including several comprehensive Western Australian guidelines (see Additional Information), this section will:

- reference these guidelines; and
- briefly summarise key aspects that relate to stormwater management.

Note: Xeriscaping and zeroscaping are terms used in various places in the world. Xeriscaping is derived from the Greek word ‘xeros’, which means ‘dry’. Thus, xeriscaping can be simply translated as meaning ‘dry landscaping’. The primary goal of xeriscaping is to create a visually attractive landscape that uses plants selected for their water efficiency (City of Albuquerque, 2003). The Western Australian Waterwise program is based on the same principles. Zero-scaping is sometimes used in relation to landscaping with a focus on water conservation but is not equivalent to xeriscaping. Zero-scaping creates a harsher and less diverse landscape, primarily using rocks and drought-tolerant plants species such as cacti. In contrast, xeriscaping can produce a cool and lush landscape, using a wide variety of water efficient plants (City of Albuquerque, 2003).

#### Applicability

The following management practices are applicable to all areas where maintenance is undertaken on parks, gardens, road/drainage reserves and turfied sports fields/venues (e.g. ovals, golf courses and bowling greens). However, they are particularly relevant to areas of open space that:

- drain to sensitive receiving waters (e.g. conservation category wetlands, or the Swan-Canning estuary system that is under stress from nutrient inputs);
- are close to water bodies (e.g. river-side parks);
- have soils with poor moisture and nutrient retention capabilities (e.g. sandy soils on the Swan Coastal Plain);

- are subject to erosion (e.g. areas on steep slopes);
- are subject to intense rainfall events that may generate surface runoff; and
- are subject to intensive maintenance practices (e.g. highly maintained golf courses).

## Recommended Practices

### Plant selection and landscaping design

- ✓ Plant local native species. This will reduce the risks of grass cuttings, deciduous leaves, nutrients and pesticides entering water bodies. Local native plants require less irrigation and maintenance (e.g. little or no nutrient or pesticide application) than exotic species and provide habitat and food for native fauna.



*Figure 1. Domestic garden with native plants. Native plants require little or no watering, nutrient and pesticide application. (Photograph: Sally Cousans.)*



*Figure 2. Native vegetation street verge planting, Causeway exit, East Perth. (Photograph: Department of Environment.)*

- ✓ Where local native species are not planted:
  - Minimise the use of deciduous plants. Deciduous plants drop all of their leaves over a short period and decompose quickly, which results in an excessive release of nutrients into water bodies. The leaves also clog stormwater systems. Deciduous plants also change the local habitat values, such as altered shading levels over waterways and reduced micro-habitat zones on the plants. See Water Note 25: *The effects and management of deciduous trees on waterways* (Water and Rivers Commission, 2002) for more information.
  - Do not plant declared or noxious weeds. Many common plants, such as lantana, gazania and lavender (French and Italian), are weeds. To find out what plants are weeds in Western Australia, go to the Weed Species in WA section of the Department of Conservation and Land Management's Florabase website: <<http://florabase.calm.wa.gov.au/win>>. To determine which plants are weeds of national significance, go to the Weeds Australia website: <[www.weeds.org.au/natsig.htm](http://www.weeds.org.au/natsig.htm)>.



*Figure 3. Deciduous leaves can release a large amount of nutrients into receiving water bodies. (Photograph: Eastern Metropolitan Regional Council.)*

- Minimise the amount of grassed/lawn areas.
- Minimise the extent of water-consuming planting.
- Apply the basic principles of hydro-zoning (grouping plants on the basis of having similar water requirements) to planting design.
- Match the plants to the soil type.
- ✓ Maximise the use of water conserving elements and techniques, such as using mulches, ground covers and porous paving instead of lawn.

## Nutrient management

- ✓ For turf and grassed areas, use the guidelines provided by DEP & WRC (2001) to determine each area's fertilisation requirements. This process involves visual inspection of the turf; regular analysis of leaf tissue, soil and water; consideration of the grass species, turf and grass use, weather patterns, ground temperatures, air temperatures, water availability, sunlight intensity and soil conditions; the use of catalysts (where necessary) to convert soil nutrients to a form that can be utilised by plants; synchronising the application of fertiliser with the needs of the plant; and adopting the principle of frequently applying small amounts of fertiliser. DEP & WRC (2001) also provides guidance on calculating fertiliser application rates, and specific factors that should be considered when determining nitrogen and phosphorus application rates.
- ✓ When applying nitrogen to sandy soils on the Swan Coastal Plain, the quantity of nitrogen applied in any one application should not exceed 40 kg/ha (DEP & WRC, 2001).
- ✓ Where phosphorus is being applied, special consideration must be given to the level of available phosphorus in the soil; the Phosphorus Retention Index (PRI); and the results of leaf tissue analysis. See DEP & WRC (2001) for fertilisation recommendations for soils with various PRI ranges and see the Phosphorus Action Group's *Fertilise Wise Guides* (see the Additional Information section).
- ✓ When determining a suitable fertilisation regime, recognise that reducing the amount of water used on gardens and lawns will also reduce the need for fertilisation (WAWC, 2004).
- ✓ Where 'fertigation' is used to supply plants with soluble nutrients in irrigation water, care is needed to frequently apply very small amounts of nutrients to the plants at a rate at which the roots can take up most, if not all, of the nutrients. This is necessary to minimise the percentage of nutrients that move past the root zone and enter shallow groundwater, as well as the cost of fertilisation. DEP & WRC (2001) suggest that fertigation 'is ideally suited for the soils of the Swan Coastal Plain that have a poor capacity to retain nutrients. It has the advantage that the fertilisers are only applied when water is required (not in winter) but it has the disadvantage that it requires accurate irrigation systems to avoid areas of over and under application of nutrients' (p. 16).
- ✓ Use slow-release fertilisers where possible. Avoid using fertilisers in areas where runoff can result in the fertiliser entering the drainage system or water bodies.
- ✓ If fertiliser is required, apply in spring or early autumn (September, October, November, March and April). Apply the fertilisers often and in small amounts during the spring and early autumn period.

- ✓ Applying organic matter or soil amendment to the upper 15 cm of sandy soils can produce multiple benefits. These include the slow release of nutrients, and the retention and recycling of soil moisture and nutrients. For more information on soil amendment, see Section 2.1.2.
- ✓ While fertilisers are usually applied immediately before watering (WAWC, 2004), extreme care must be taken to ensure that this watering does not generate runoff or leachate to shallow groundwater.
- ✓ Where possible, establish a buffer zone at least 50 metres wide between fertilised areas and water bodies.
- ✓ Where drainage channels flow through fertilised areas (e.g. golf courses), apply the principles of water sensitive design to establish a ‘treatment train’ within the drainage corridor (e.g. by using controls such as unfertilised buffer zones, swales, wetlands, ponds, stormwater recycling, etc.).
- ✓ On intensive horticultural sites that are using high amounts of fertilisers and have sandy soils and shallow groundwater, construct leachate barriers that drain nutrient-rich groundwater to collection basins for reuse. Alternatively, establish shallow groundwater bores down-gradient from the fertilised area to recycle leached nutrients via irrigation systems.

## Irrigation management

Detailed guidance on water conserving irrigation practices is available in DEP & WRC (2001) and on the Water Corporation’s website (<[www.watercorporation.com.au/savingwater](http://www.watercorporation.com.au/savingwater)>). The following management practices are highlighted as being important with respect to stormwater:

- ✓ Ensure that the irrigation system is water efficient (e.g. drip or trickle systems, sprinklers that produce large droplets, sprinklers with matched precipitation rates<sup>15</sup>, high-quality controllers that have the ability to run separate watering programs for lawn and garden areas, and rain sensors that can be used to prevent irrigation after summer rain storms).
- ✓ Ensure the design, sensors and settings used for automated irrigation systems do not produce surface runoff from the area being watered or from adjacent impervious surfaces.
- ✓ The necessary amount of irrigation should be determined with due consideration of grass growth rate, soil type, daily evaporation rate, wind effects, soil temperature and available soil moisture (DEP & WRC, 2001). This can be achieved with modern soil moisture and air sensing devices such as tensiometers, soil moisture sensors, relative humidity measuring devices and wind velocity detectors. Alternatively, recommended irrigation frequencies for the application of 10 litres/m<sup>2</sup> of water for different types of ‘watering zones’ can be obtained from the Water Corporation’s website (<[www.watercorporation.com.au](http://www.watercorporation.com.au)>).
- ✓ Seek to recycle nutrient-rich shallow groundwater and/or stormwater from the site.
- ✓ Visually check irrigation systems every week to identify maintenance needs (e.g. the repair of leaks), or, for major irrigation systems, install an automated warning system to identify malfunctions.
- ✓ Apply mulch to garden beds to improve water retention, smother weeds and prevent erosion.

<sup>15</sup> A sprinkler array with ‘matched precipitation rates’ means the nozzles provide the necessary water to the plants without any plants being over-watered.

- ✓ Where required, apply soil wetting agents to overcome hydrophobic soil conditions and enhance infiltration of irrigation water. See DEP & WRC (2001) for details of recommended application rates for these agents.
- ✓ Use soil amendments to improve the water retention capacities of soils, where appropriate. For more information on soil amendment, see Section 2.1.2.
- ✓ Where nutrient-rich wastewater is used as a source of irrigation water, it is particularly important to control application rates so that surface runoff and shallow groundwater contamination does not occur. A comprehensive monitoring and evaluation program should be established to ensure that this objective is achieved.

## Pest Management

Integrated pest management (IPM) is a holistic approach to unwanted plant (weed) and insect control that examines the interrelationships between soil, water, air, nutrients, insects, diseases, landscape design, weeds, animals, weather and cultural practices to select an appropriate pest management plan (US EPA, 2001). The goal of an IPM program is to manage pests to an acceptable level while avoiding disruptions to the environment. It incorporates preventative practices in combination with chemical and non-chemical pest control methods to minimise the use of traditional pesticides (i.e. insecticides and herbicides) and promote natural control of pest species.

Three different non-chemical pest control practices are used to limit the need for chemical pesticides:

- Biological (e.g. predation of pest species by other organisms).
- Cultural (e.g. weeding, handpicking of pests, removal of plants with diseases).
- Mechanical (e.g. pruning, altering the mowing regime, slashing, covering weeds with black plastic or jute matting).

The most effective pest control methods are often a combination of non-chemical and chemical control methods (DEP & WRC, 2001). Where chemical pest control methods need to be used, less hazardous products (e.g. Roundup Biactive®) or target-specific chemicals should be used for control of nuisance/disease vector insects, rather than pesticides that are a greater threat to aquatic systems, such as diazinon and chlorpyrifos. The less hazardous chemical pesticides must still be used with the best practice precautions applied to other chemical pesticides.

Methods to reduce the risks from pesticides include:

- ✓ Apply according to the label's recommended rate.
- ✓ Do not apply pesticides when rain is occurring or imminent.
- ✓ Do not spray pesticides on windy days.
- ✓ Where possible, wipe or inject pesticides to avoid spray drift (Water and Rivers Commission, 2001).
- ✓ If possible, spray when surface water levels are low (Water and Rivers Commission, 2001).
- ✓ Do not apply pesticides when there is a high risk of impact to vulnerable stages of fauna development. For example, avoid the period from egg lay to dispersal of junior frogs into the surrounding area – this period varies, but is generally between late autumn and early spring (Water and Rivers Commission, 2001).

- ✓ Mix in a coloured dye so that you can see which areas have been sprayed.
- ✓ Avoid using surfactants in the pesticides, as frogs are particularly sensitive to surfactants (Water and Rivers Commission, 2001).
- ✓ Detailed guidance on pesticide selection and application, mixing and diluting pesticides, disposal of pesticide concentrates and containers, and pesticides storage can be obtained from the *Environmental Guidelines for the Establishment and Maintenance of Turf and Grassed Areas* (DEP & WRC, 2001).
- ✓ The *Code of Practice for the Use of Agricultural and Veterinary Chemicals in Western Australia* (Department of Agriculture, 2002) provides practical guidance for the safe, responsible and effective use of agricultural and veterinary chemicals. Issues covered include: duty of care, choice and purchase of chemicals, transport, storage, occupational safety and health, environmental protection, management and minimisation of spray drift, minimising residues in agricultural produce, record keeping and responsibilities for owners.
- ✓ Where pesticides are used in drinking water catchments in Western Australian, this use must be consistent with the State government policy *Pesticide Use in Public Drinking Water Source Areas* (WRC, 2000). In addition, pesticides must be stored in a covered, bunded and secured area. If disposal of unwanted pesticides and/or pesticide containers needs to be undertaken, consultation should occur with operators of local waste disposal/treatment facilities to identify options for reuse or disposal.

### Lawn mowing, top-dressing and pruning

- ✓ Remove litter and debris before mowing.
- ✓ Close cropping during mowing is not recommended, as it provides an opportunity for accelerated erosion and increases the area's irrigation requirements. As a general rule, no more than 33% of the grass leaf area should be removed during one mowing event (DEP & WRC, 2001).
- ✓ Where possible and where there is not a risk of cuttings entering adjacent water bodies, grass cuttings should be left on the lawn after mowing. Where grass cuttings are collected, they should be composted and reused as fertiliser. Compost should be stored in areas where stormwater and/or groundwater will not be contaminated.
- ✓ Grass cuttings should not be 'thrown' from the mower blades onto hard surfaces (e.g. roads) or into adjacent water bodies. If some cuttings are inadvertently deposited on roads or footpaths, they should be collected by 'dry' methods (e.g. sweeping) at the completion of mowing activities. Cuttings should not be blown or swept onto the road or into water bodies or the stormwater system.
- ✓ In areas adjacent to roads with a kerb and channel, coordinate activities such as mowing or pruning with street cleaning operations (VSC, 1999).



Figure 4. Remove grass cuttings from roads and paths to ensure they do not enter the stormwater system. (Photograph: South East Regional Centre for Urban Landcare.)

- ✓ Mowing equipment is commonly hosed down after use at a particular location to prevent the transfer of weeds between mowing sites. Where this is done, the rinse water can be infiltrated into the soil. Under no circumstances should this rinse water be directed to the stormwater system.
- ✓ Only use top-dressing to even out bumps and hollows in the lawn, and then only use special top-dressing mixes which contain organic matter (WAWC, 2004). A vegetated buffer should be maintained between the top-dressed area and stormwater drains or water bodies. In addition, top-dressing should not occur when intense and/or prolonged rainfall is likely.

## Benefits and Effectiveness

Collectively, these management practices seek to:

- reduce pollutant loads to stormwater and shallow groundwater (particularly nutrients, sediment, pesticides and organic matter);
- reduce the use of mains water for irrigation;
- reduce the volume of surface water runoff;
- where possible, save time and money on maintenance practices; and
- reduce health and safety risks associated with the use of chemical pesticides.

## Integrated pest management

IPM has been studied in Maryland, where it was used for managing street trees within a residential suburb (Taylor and Wong, 2002c). As a result, pesticide use was reduced by 79% - 87% due to spot application techniques and average annual costs were reduced by 22% (US EPA, 1997).

The US EPA (1997) also documented reports from a US lawn management company (the Natural Lawn Company) that it reduced its herbicide use by 85% - 90% by switching from blanket applications to spot application. Cost reductions of a similar magnitude were anticipated (Taylor and Wong, 2002c).

Taylor and Wong (2002c) reported that the cumulative performance of IPM and associated non-fertilised buffer strips at the Rosewood Lakes golf course in Reno, Nevada, was measured by long-term water quality monitoring in downstream wetlands. After eight years of water quality monitoring, pesticides were not detected in the wetlands and nutrient concentrations did not show seasonal fluctuations, despite seasonal applications of fertiliser on the course and the potential for surface run-off (Lehner *et al.*, 1999).

The US EPA (2001) highlighted the adverse impacts from water-soluble pesticides, such as diazinon, as a good example of why IPM practices are recommended. A study in the San Francisco Bay region found that diazinon contamination of urban streams resulted from application of this pesticide at a small number of sites in the catchment. Source controls are needed (i.e. the application of IPM practices by government authorities, businesses and homeowners) as structural controls can not significantly reduce pesticide levels once they have entered the stormwater management system.

## Challenges

The following challenges may need to be addressed to improve implementation:

- Resources (e.g. time, money and effort) should be invested for maintenance staff to learn and adopt new practices and management plans should be documented, regularly audited and updated.

- Reducing the popularity of green lawns, lush gardens and exotic plant species, as these are an impediment to the widespread adoption of waterwise and fertilise wise gardens and reserves, particularly the adoption of local native plants.
- For integrated pest management, the perception that there is no alternative to pesticide use is a significant barrier to overcome (US EPA, 2001).
- The cost of slow-release fertilisers, soil testing, installing water efficient irrigation systems, irrigation sensor systems and applying fertilisers frequently but sparingly are potential barriers to the adoption of these management practices. However, rebates are offered for many catchment friendly ('waterwise') gardening practices/systems.

## Cost

Costs are associated with the development of nutrient and irrigation management plans and the installation of water efficient irrigation or fertigation systems. These may involve significant up-front costs, however savings can be expected due to water conservation and reduced fertiliser use.

Studies have shown significant cost savings when integrated pest management is implemented, due to the significant reduction in applied pesticides (see Benefits and Effectiveness and Examples / Case Studies).

## Additional Information

Resources for catchment friendly gardening are available from:

- *Landscaping Training* - Everlasting Concepts: 4 Season Seminars – designed to assist landscape businesses and all levels of government to utilise WA plants on a large scale (including streetscapes, schools, golf courses, contemporary designs and public open spaces). Advice includes plant recommendations, mulching, soils, fertilising, irrigation, maintenance and environmental weeds. More information via <[www.everlastingconcepts.com.au](http://www.everlastingconcepts.com.au)> or by telephoning (08) 9275 3404.
- *Landscaping with Local Plants Policy and Guidelines for Local Government*, Section 2.3.2 in the *Local Government Natural Resource Management Policy Manual* (EMRC, 2004). For further information, contact the Eastern Metropolitan Regional Council on (08) 9424 2222. Available by telephoning (08) 9424 2222 or via <[www.emrc.org.au](http://www.emrc.org.au)> (select 'Services' / 'Environmental Services').
- *Environmental Guidelines for the Establishment and Maintenance of Turf and Grassed Areas* (DEP & WRC, 2001).
- *Sports Turf Technology (2004) Turf Sustain – A guide to turf management in Western Australia*. Available via <[www.sportsturf.net.au](http://www.sportsturf.net.au)>. Further information is available by telephoning the Swan River Trust on (08) 9278 0900.
- *Free Gardening Workshops* – Swan River Trust. These feature information and guidance on fertilise wise and sustainable gardening practices. Telephone (08) 9278 0900 for further information, or refer to <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)>.
- *Fertilise Wise Guides* - The Phosphorus Action Group's *Fertilise Wise Guides* advise gardeners on appropriate fertiliser types and application rates for soils in the Perth region. For further information and advice about the guides and other available resources, please telephone the Phosphorus Awareness Project Coordinator on (08) 9458 5564. You may also access Fertilise Wise information via the South East Regional Centre for Urban Landcare website <[www.sercul.org.au/pag.html](http://www.sercul.org.au/pag.html)>.
- *Local Plants Guides* – The North Metropolitan Catchment Group's (formerly the North East Catchment Committee, NECC) *Local Plants Community Education Strategy* provides strategies that local

government authorities can undertake to promote and encourage the use of local plants within their communities, as well as providing information and resources to the community to aid in its implementation. This includes a set of 'Grow Local Plants' brochures covering suitable species for five soil regions on the Swan Coastal Plain (matching the Fertilise Wise Guides brochures). It will also include comprehensive lists of plants that are suitable for street trees, hedging, etc. Local government authorities will be able to print the relevant brochures for their region, in conjunction with conducting one or more activities outlined in the strategy. For further information, telephone the Biodiversity Coordinator at the North Metropolitan Catchment Group (NMCG) on (08) 9271 7922.

- To select Perth plants suitable for your soil type, go to the APACE WA website <<http://web.argo.net.au/apace/soiltypes.htm>> or by telephoning APACE on (08) 9336 1262.
- *Purchasing Local Native Plants* – Go to the Everlasting Concepts website (<[www.everlastingconcepts.com.au](http://www.everlastingconcepts.com.au)>), which provides contact details for nurseries throughout WA that stock WA native plants. The website also provides information on how to grow native plants. In addition, the Friends of Kings Park hold several native plant sales throughout the year. Information about the Friends of Kings Park and plant sales is available via <[www.kpbg.wa.gov.au](http://www.kpbg.wa.gov.au)>. Select 'Growing Plants' / 'Community Involvement' / 'Friends of Kings Park' / 'Coming Events'.
- *Wildflower Society of Western Australia* – The Society provides a range of resources (e.g. books) and advice regarding planting local native plants. See their website <<http://members.ozemail.com.au/~wildflowers>>.
- *Growing Locals – Gardening with Local Plants in Perth* by Robert Powell and Jane Emberson (1996). This book can be purchased by telephoning the WA Naturalists Club on (08) 9228 2495 or via <[www.wanats.iinet.net.au](http://www.wanats.iinet.net.au)>.
- *Free Gardening Advisory Service* - Botanic Gardens and Parks Authority (08) 9480 3672 <[www.bgpa.wa.gov.au](http://www.bgpa.wa.gov.au)> (select 'Growing Plants' / 'Community Involvement' / 'Master Gardeners'). Volunteer Master Gardeners provide a free advisory service for home gardeners and non-commercial groups. For example, they can advise about propagation, potting, planting out, pests and pruning of native plants.
- *Designing and maintaining gardens* – Advice about how to grow local native plants, deal with pests and diseases effectively and responsibly, use less water and fertiliser, save time and money and attract Western Australian wildlife into your garden. Available via <[www.greatgardens.info](http://www.greatgardens.info)>.
- *Waterwise* - Waterwise gardening information on the following topics is provided on the Water Corporation website (<[www.watercorporation.com.au/savingwater](http://www.watercorporation.com.au/savingwater)>): common plants, catchcup instructions, irrigation, lawns, new gardens, new lawns, watering zones, waterwise garden centres, waterwise garden designs and waterwise garden irrigators.
- The *Sustainable Living in Western Australia* website, available via <[www.sustainableliving.wa.gov.au](http://www.sustainableliving.wa.gov.au)> (Government of Western Australia, 2004-2005), contains links to Western Australian resources for gardening and growing local native plants.
- Section 3.16 – Growing Local Plants to Protect Water Resources and Section 3.19 Landscaping, Gardens, Turf and Grassed Areas in the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300.

## Examples / Case Studies

### Turf/lawn management

*Turf Sustain* (Sports Turf Technology, 2004) has Western Australian case studies on the following topics:

- Nutrient monitoring – City of Canning (page 35);
- Turf establishment study – University of Western Australia (page 37);
- Improving turf conditions with nutrition – City of Cockburn (page 39);
- Nutrient monitoring and irrigation benchmarking – Sports Turf Technology and Department of Environment (page 41);
- Irrigation scheduling using soil moisture monitoring – City of Swan (page 49);
- Irrigation scheduling based on weather averages – City of Stirling (page 49);
- Using a weather station to schedule irrigation - Burswood Park Board (page 51);
- Using soil moisture sensors to control irrigation (page 53);
- Benefits of an irrigation audit (page 55);
- Modernising irrigation systems across council parks – City of Stirling (page 57);
- Rotary and reel mowing – City of Melville (page 67).

### Mowing

The Victorian Stormwater Committee (1999) documented a simple contract clause from the City of Manningham to reduce the effect of mowing activities on stormwater quality. This clause has two parts and is provided below:

‘Prior to grass cutting all loose litter, rubbish or debris is to be cleared from the mowing area.’  
(Performance criteria: absence of litter, rubbish or debris).

‘All grass clippings and other debris is to be swept or cleared from adjoining paths, gutters, paved surfaces and garden areas.’ (Performance criteria: no clippings or other debris after cutting operations).

### Integrated pest management

IPM was successfully applied at the 178 ha US National Arboretum in north-west Washington in the District of Columbia. As a result, pesticide use declined by 75%, resulting in an 80% reduction in costs (Lehner *et al.*, 1999). The program included:

- setting thresholds for pest-related plant damage (i.e. the arboretum had a higher tolerance for pest infection);
- catching pests early;
- using beneficial insects which are natural predators of the insects that harm the arboretum’s vegetation;
- handpicking insects off infected plants;
- reduced mowing of lawns;

- using biorational oils (i.e. natural soaps and oils); and
- using alternative growing methods.

## References and Further Information

- APACE WA (undated), *Major Soil Types Map and Full Catalogue List*. Retrieved 21 December 2004 from <<http://web.argo.net.au/apace/soiltypes.htm>>.
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## 2.2 Maintenance practices

### 2.2.8 Maintenance of vehicles, plant and equipment (including washing)

#### Description

The storage and maintenance of vehicles, plant and equipment can contaminate stormwater with pollutants such as petrol, diesel, kerosene, coolants, solvents, brake fluid, motor oils, lubricating grease, sediment and heavy metals. The washing of vehicles, plant and equipment can also produce highly contaminated wastewater that should not be directed to stormwater or groundwater.

#### Applicability

The following management practices are applicable to maintenance activities undertaken by government agencies, construction and maintenance companies, operators of automotive workshops and residents that maintain their own vehicles.

The US EPA (2001) highlighted the automotive repair industry as a significant generator of hazardous waste. Common activities at these premises include cleaning of engine parts, changing of vehicle fluids and replacement and repair of equipment.

These maintenance activities are undertaken in urban and regional areas; however, in high-density urban areas, the potential environmental impacts are more pronounced due to the greater concentration of vehicles and higher proportion of impervious surfaces (US EPA, 2001).

#### Recommended Practices

The Light Industry Project, the Motor Trade Association of Western Australia's Green Stamp Programs and the Centre of Excellence in Cleaner Production can provide training, support and further information. Refer to the Additional Information and Examples / Case Studies sections.

The following management practices are recommended by VSC (1999), US EPA (2001) and MTA of WA environmental guidelines (October 2004).

##### Storage

- ✓ Store vehicles, plant and equipment in secure, bunded and undercover areas where possible.
- ✓ Schedule and record the results of regular plant inspections.
- ✓ Designate parking areas for each vehicle to facilitate leak tracing.
- ✓ Develop procedures for identifying, reporting, repairing and cleaning up leakages.

##### Cleaning plant and equipment

- ✓ See the MTA WA's Environmental Guidelines *Cleaning Vehicles, Cleaning Up Spills, Degreasers and Detergents, Mobile Mechanical Repairers, Oil Separators, Parts Washers and Purchasing Spill Kits* for more information.
- ✓ Clean plant and equipment regularly and routinely.

- ✓ Install suitable signage, identifying the use of specific areas and prohibiting the disposal of liquid wastes to the stormwater system. Stencilling around all stormwater drains/inlets is also recommended (e.g. 'Rainwater only – flows to the river').
- ✓ Stormwater must be separated from wastewater. Ensure that all 'wash-down' activities are conducted in a dedicated wash bay. Wash bays should be covered and bunded where appropriate. Wash bays that are connected to sewer and have an area greater than 20 m<sup>2</sup> *must* be covered.



Figure 1. Green Stamp automotive premises, Balcatta. Under-cover, bunded wash-down area, with parts washer, wastewater treatment equipment and drums for recyclable materials. (Photograph: Department of Environment.)



Figure 2. Green Stamp automotive premises, Balcatta. Vehicle wash-down area, with collection drain for wastewater treatment. (Photograph: Department of Environment.)

- ✓ An Industrial Waste Permit is required to connect and discharge wastewater to sewer. Further information is available from the Water Corporation by telephoning the Customer Service Centre on 13 13 95 or via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)>.
- ✓ Wastewater from wash bays may require pre-treatment, such as silt traps and oil separation systems, prior to being discharged into wastewater systems (e.g. sewer or septics). For example, wastewater from degreasing operations must pass through an approved oil separation system before being discharged to sewer.
- ✓ Use grassed areas where infrequent on-site cleaning of mildly soiled vehicles is required and a wash bay is not easily accessible. No degreasing or parts cleaning should occur outside of designated cleaning areas. Mobile services should not degrease engines, unless the wastewater can either be captured for approved disposal by a licensed waste contractor or can be collected and pre-treated via an oil separation system before approved disposal to sewer (in accordance with an approved Industrial Waste Permit) or septic.
- ✓ The wash bay's water supply may be supplemented with stormwater (e.g. rain water from roofs).
- ✓ Design a contingency plan for accidental chemical spills, and clean up spills immediately. Refer to MTA WA's guideline, *Cleaning Up Spills*. For large spills, contact the Department of Environment's Emergency Pollution Response Unit on (08) 9222 7123 (after hours 1800 018 800). Further information is available via <<http://emergency.environment.wa.gov.au>>.

## Refuelling areas

- ✓ Use concrete paved areas because bitumen deteriorates as a result of fuel or oil spillage. The area's design should contain all spills and ensure spillages cannot enter the stormwater system. See the MTA WA's Environmental Guidelines *Bunds and Bunding, Cleaning Up Spills, Oil Separators, Preventing Oil Pollution* and *Purchasing Spill Kits* for more information.
- ✓ Design a contingency plan for chemical spills and train staff in the correct use of spill absorbents and clean up procedures. For large spills, contact the Department of Environment's Emergency Pollution Response Unit on (08) 9222 7123 (after hours 1800 018 800). Further information is available via <<http://emergency.environment.wa.gov.au>>.
- ✓ Clean up spills using 'dry' methods. Maintain kits containing dry clean up material (e.g. absorbents) and directions for its use adjacent to, or within, refuelling areas. Post signs to instruct operators not to 'top off' or overfill fuel tanks.
- ✓ Inspect fuel areas daily to identify any leakages.
- ✓ Ensure underground fuel tanks are subject to regular testing for leakages (e.g. pressure testing).
- ✓ Do not hose the refuelling area during cleaning activities, unless the resultant wastewater can be directed towards an oil separation system.

## Vehicle maintenance

- ✓ Where possible, perform vehicle maintenance indoors.
- ✓ If maintenance work is performed outdoors, designate a specific area, keep it clean at all times and use 'dry' clean up practices.
- ✓ Update the facility's schematics to accurately reflect all plumbing connections.
- ✓ Floor drains should be sealed off during maintenance activities.
- ✓ Keep drip trays or containers under the vehicles at all times during maintenance. The captured liquids should be disposed of through an approved system and / or recycled.
- ✓ Train staff in the correct use of spill absorbents and clean-up procedures. Spills should be cleaned up immediately. For large spills, contact the Department of Environment's Emergency Pollution Response Unit on (08) 9222 7123 (after hours 1800 018 800). Further information about emergency response is available via <<http://emergency.environment.wa.gov.au>>.
- ✓ Rags or absorbent cloths should be used to clean up small spills, dry absorbent material for larger spills, and a mop for general cleaning (i.e. not to clean up any spills). Mop water can be disposed of via the sink or toilet.
- ✓ Reinforce proper waste disposal practices by undertaking employee training. Ideally, training (as well as risk assessments, procedures, audits, reporting, etc.) would be undertaken as part of an environmental management system for the site (see Section 2.5.1).
- ✓ Promptly transfer used fluids to drums or hazardous waste containers for recycling or disposal by a licensed waste contractor.
- ✓ Do not pour liquid waste down the floor drains, sinks or outdoor stormwater drains / inlets.

- ✓ Drain all fluids from any end-of-life vehicles being kept on-site for scrap metal and / or parts.
- ✓ All cleaning activities should be conducted in a centralised area to facilitate the capture, treatment and/or disposal of wastewater and other hazardous liquids.
- ✓ Replace chlorinated organic solvents with non-chlorinated ones like kerosene or mineral spirits or water-based products.
- ✓ A licensed waste contractor should be used to remove used solvents from site either for recycling or approved disposal. Alternatively, solvent thinner recycling systems can be used on the premises, reducing purchase and disposal costs.
- ✓ Store all new and used batteries on sealed ground, in bunded undercover areas.
- ✓ When degreasing and cleaning parts, use water-based cleaning agents in preference to those that are solvent-based. Steam cleaning and pressure washing may also be used instead of cleaning agents.
- ✓ See the following MTA WA's Environmental Guidelines for more information: *Bunds and Bunding, Cleaning Up Spills, Coolant Management, Degreasers and Detergents, Managing Body Repairer Wastewater, Mobile Mechanical Repairers, Oil Separators, Parts Washers, Preventing Oil Pollution, Purchasing Spill Kits and Solvent Thinner Recycling Systems.*

## Benefits and Effectiveness

The US EPA (2001) noted in relation to vehicle maintenance that 'fluid spills and improper disposal of materials result in pollutants, heavy metals and toxic materials entering ground and surface water supplies, creating public health and environmental risks. Alteration of practices involving the clean up and storage of automotive fluids and cleaning of vehicles and vehicle parts can help reduce the influence of automotive maintenance practices on stormwater run-off and local water supplies' (p. 10).

Specifically, pollution prevention practices and good 'housekeeping' practices for the maintenance of vehicles, plant and equipment as addressed in this guideline should result in:

- Reduced loads of pollutants entering stormwater and shallow groundwater (particularly fuels, oils, solvents, sediment and heavy metals), thereby minimising the risk to the health of receiving waters.
- Reduced potential for organisations managing these premises to be subject to complaints from stakeholders or enforcement by environmental regulators.
- Reduced need for scheme/mains water because of stormwater reuse (e.g. at wash bays).
- Reduced need for downstream, end-of-pipe, stormwater treatment devices (as the practices in this guideline are all source controls).

## Challenges

The following challenges may need to be addressed to improve implementation:

- The facilities and time needed to perform maintenance work indoors may make this practice impractical or unappealing.
- It may be difficult to contain spills from vehicles that are brought on-site after working hours.
- Procedures and training materials for employees must be continually updated.

- Installation and maintenance of structural controls for pre-treatment of wastewater discharges and stormwater discharges can be expensive.
- There could be some reluctance to invest in fixed infrastructure (e.g. wash bays) when operating out of leased premises.
- Some facilities can be limited by the lack of local service providers with respect to hazardous waste removal, maintenance of wastewater treatment infrastructure, or provision of equipment to recycle hazardous substances.

## Cost

Given the numerous management practices covered by this guideline and the need to select and tailor these practices for each site, meaningful cost information cannot be provided.

## Additional Information

Refer to Section 2.2.10 for stormwater management on commercial and industrial premises. Refer to Section 2.3.4 for information about education and participation campaigns for commercial and industrial premises. For information on stormwater management at work depots, see Section 2.2.6.

The Examples / Case Studies part of Section 2.3.4 has information about the South East Regional Centre for Urban Landcare's Clean Drains - River Gains campaign to reduce nutrients and other contaminants in receiving water bodies. For further information, contact the South East Regional Centre for Urban Landcare (SERCUL), 69 Horley Road, Beckenham WA 6107, via <[www.sercul.org.au](http://www.sercul.org.au)> or by telephoning (08) 9458 5564.

The Motor Trade Association of Western Australia's Green Stamp program provides environmental assessments, training and support, including simple environmental management plans, case studies and environmental guidelines for automotive businesses and practices. Resources include the *Environmental Products and Services Directory* and guidelines such as *Asbestos Use and Disposal*, *Building New Premises*, *Bunds and Bunding*, *Cleaning up Spills*, *Cleaning Vehicles*, *Coolant Management*, *Degreasers and Detergents*, *Environmental Policy*, *Mobile Mechanics*, *New Environmental Laws*, *Oil Separators*, *Parts Washers*, *Preventing Oil Pollution*, *Purchasing Spill Kits*, *Solvent Thinner Recycling Systems*, *Wastewater Management for Body Repairers*, *Environmental Assessments for Body Repairers* and *Environmental Assessments for Mechanical Repairers*. Refer to the Examples/Case Studies section, below. Further information is available via <[www.greenstamp.com.au](http://www.greenstamp.com.au)> or by telephoning (08) 9345 3466.

The Light Industry Project is a network of industry, State and local government, community groups, education and training providers. The project aims to provide small to medium-sized businesses with on-ground support, positive incentives and resources. Different levels of training and support are available, depending on the needs of particular businesses and industry sectors. Further information is available by telephoning (08) 9374 3301 or via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.wastewise.wa.gov.au](http://www.wastewise.wa.gov.au)>. The Light Industry Project office is at the Swan Catchment Centre, 80 Great Northern Highway, Middle Swan WA 6056.

The Centre of Excellence in Cleaner Production, Curtin University of Technology, Western Australia, provides training, support and resources including checklists and environmental guidelines. Refer to <<http://cleanerproduction.curtin.edu.au>> or telephone (08) 9266 4520.

Refer to relevant Water Quality Protection Notes, available from the Department of Environment via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>, or by telephoning (08) 9278 0300. For example:

- *Mechanical Servicing and Workshops* (Water and Rivers Commission, 2002);
- *Mobile Mechanical and Cleaning Services* (Draft) (DoE, 2004);
- *Washdown of Mechanical Equipment* (WRC, 1998);
- *Industrial Sites Near Sensitive Water Bodies* (WRC, 1999);
- *Chemical Spills – Emergency Response Planning* (WRC, 2002);
- *Stormwater Management at Industrial Sites* (WRC, 2002);
- *Toxic and Hazardous Substances – Storage and Use* (WRC, 2002).

Refer to the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). Relevant Sections include Section 1.3 Training and Support, Section 2.0 Fuel and Chemical Storage, Section 3.2 Auto Dealerships (Car Yards), Section 3.3 Automotive and Mechanical Repair and Section 3.10 Industrial Cleaning. The Directory lists Western Australian, interstate and international environmental management and cleaner production resources. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.

## Examples / Case Studies

### Green Stamp Program - Motor Trade Association of WA

The Green Stamp Program was developed by the Motor Trade Association of Western Australia and the Western Australian Department of Environment, with funding assistance from the Waste Management and Recycling Fund. It originated in 1997 after the then Department of Environmental Protection released a set of Codes of Practice for three sectors of the automotive retail industry. The Department found that this approach had little or no impact on changing behaviour and believed that an industry-based approach may be more successful. The Motor Trade Association of Western Australia in conjunction with the Department developed a range of sector-specific environmental resources and initiatives. As the program developed, so too did the concept of developing an accreditation system for the industry to promote those businesses demonstrating industry best practice. The program currently consists of one full-time coordinator that manages the program's broad range of activities, including site assessments, environmental seminars, distribution of environmental guidance notes and directories, certification and promotion of Green Stamp Accredited businesses.

The program has identified and focused on several key areas considered essential to reducing the environmental impact of the automotive industry. These areas are:

- Storage practices associated with chemicals and other hazardous substances;
- Pre-treatment of wastewater from the workshop prior to approved disposal;
- Spill management to prevent pollution of ground and stormwater systems;
- Correct disposal of waste products (preferably to recycling or reuse);
- Air quality management;
- Energy and resource conservation; and
- The development and implementation of environmental management plans.

## Solvent recovery system, Western Australia

A Western Australian panel and paint repair workshop that repairs approximately 160 vehicles per month invested in a solvent recovery system in the mid-1980s. The system produces recycled solvent suitable for use in gunwash (for cleaning spray equipment), metal primers and polyester resins. The purchase of new solvents for gunwash has been reduced from approximately 200 L per month to approximately 20 L per month. This has resulted in reduced on-site pollution risk due to the storage of smaller volumes of solvents on the premises. The recycling system has also reduced the volume of waste solvent requiring disposal to zero. The savings from reduced new solvent purchases and zero waste disposal costs have resulted in an annual saving of \$3,792. More information can be obtained from the MTA of WA's Green Stamp website, under Eco-efficiency Case Studies: Solvent Recycling (<[www.greenstamp.com.au](http://www.greenstamp.com.au)>).

## Vehicle maintenance facilities in California

The Clean Bay Business Program in Palo Alto, California, regulated vehicle service facilities via licensing, education, inspections and the provision of incentives for good performance (Lehner *et al.*, 1999). When premises were first inspected under the program in 1992, only 4% of 318 facilities complied with regulations relating to discharges to stormwater and sewer. By the end of 1992, this percentage had risen to 41% and by 1998 it had risen to 94%. In addition, violations of regulations that specifically protect *stormwater* drains fell by 90% between 1992 and 1995. The program also found and eliminated 78 direct discharges to stormwater (e.g. washwater discharges).

The initial per-facility cost of running the Clean Bay Business Program was approximately US\$300, with a cost of US\$150 per annum for each subsequent year. The cost of improving stormwater management that was incurred by the *businesses* is unknown.

## Other case studies

Australian and international case studies are also available from:

- The Centre of Excellence in Cleaner Production, Curtin University of Technology, Western Australia. Refer to <<http://cleanerproduction.curtin.edu.au>> or telephone (08) 9266 4520.
- Section 1.6 - Case Studies in the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.

## References and Further Information

Department of Environment and Swan River Trust 2004, *Environmental Management and Cleaner Production Directory for Small and Medium Businesses*, DoE and SRT, Perth, Western Australia. Relevant sections include Section 2.0 Fuel and Chemical Storage, Section 3.2 Auto Dealerships (Car Yards), Section 3.3 Automotive and Mechanical Repair (including washdown) and Section 3.10 Industrial Cleaning. The Directory is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.

Green Stamp Program / Motor Trade Association of Western Australia, which includes Environmental Guidelines for a range of activities undertaken by automotive businesses. Cited October 2004 <[www.greenstamp.com.au](http://www.greenstamp.com.au)>.

Lehner, P.H., Aponte Clarke, G.P., Cameron, D.M. and Frank, A.G. 1999, *Stormwater Strategies: Community Responses to Run-off Pollution*, Natural Resources Defence Council, New York, New York. Cited at <[www.nrdc.org/water/pollution/storm/stoinx.asp](http://www.nrdc.org/water/pollution/storm/stoinx.asp)>.

United States Environmental Protection Agency (US EPA) 2001, *National Menu of Best Management Practices for Storm Water Phase II*. United States Environmental Protection Agency on-line guideline. Cited at: <[www.epa.gov/npdes/menuofbmps/menu.htm](http://www.epa.gov/npdes/menuofbmps/menu.htm)>.

Victorian Stormwater Committee (VSC) 1999, *Urban Stormwater - Best Practice Environmental Management Guidelines*, CSIRO Publishing, Melbourne, Victoria.

Water and Rivers Commission 1998, *Washdown of Mechanical Equipment*, Water Quality Protection Note, August 1998, Water and Rivers Commission, Perth, Western Australia.

Water and Rivers Commission 2002, *Chemical Spills – Emergency Response Planning*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 1999, *Industrial Sites Near Sensitive Water Bodies*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Mechanical Servicing and Workshops*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Radiator Repairers and Reconditioners*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Stormwater Management at Industrial Sites*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission (2002), *Toxic and Hazardous Substances – Storage and Use*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

## 2.2 Maintenance practices

### 2.2.9 Building maintenance

#### Description

Buildings and their immediate surroundings can be the source of stormwater pollution during:

- building maintenance practices (e.g. removal of graffiti, washing of buildings and paved surfaces, sandblasting, painting, rendering, etc.); and
- the post-construction phase (e.g. contaminated runoff from roofed areas and paved surfaces may enter stormwater after every rainfall event).

Building maintenance practices can produce contaminated wastewater, which can:

- be acutely toxic to aquatic biota in the immediate vicinity (e.g. solvents or chlorinated wastewater from these maintenance activities may drain to receiving waters via the stormwater drainage system);
- lead to long-term chronic impacts on the health of aquatic biota (e.g. lead-based paint flakes from these maintenance activities may be washed into receiving waters via the stormwater drainage system); and
- cause aesthetic impacts (e.g. paint flakes from these maintenance activities may be washed into receiving waters via the stormwater drainage system).

Pollutants may enter stormwater from a building's roof (e.g. from flaking paint containing heavy metals, or atmospheric deposition of nitrogen), paved surfaces (e.g. litter from the building's footpaths, or hydrocarbons and heavy metals from the building's roadways and carparks), and during intense rainfall, from pervious areas (e.g. runoff from fertilised lawns and garden beds).

Management practices can be applied during building maintenance and post-construction stages to minimise the risk of stormwater and groundwater pollution and, to a lesser extent, minimise the volume of stormwater discharge.

#### Applicability

These management practices are applicable to building maintenance in all areas, particularly in catchments with:

- a high proportion of directly connected impervious surfaces (e.g. carparks draining directly to the street's drainage system);
- steep slopes;
- 'traditional' (piped or constructed channel) stormwater management systems; or
- sensitive receiving water bodies.

## Recommended Practices

### Building maintenance activities (e.g. painting, sandblasting and graffiti removal)

- ✓ A ‘waste management hierarchy’ should be adopted when undertaking building maintenance activities. For example, first explore options that do not generate wastewater (e.g. painting over graffiti rather than removing it); then ‘dry’ methods (e.g. paint scraping with debris being swept up); then methods that involve little risk of stormwater discharge (e.g. spot application of solvents to remove graffiti using an absorbent ground sheet); then options that generate large amounts of relatively innocuous wastewater (e.g. high-pressure hoses that wash a building but do not remove paints). Options that generate large amounts of relatively hazardous wastewater (e.g. chlorinated washwaters from washing buildings with moulds) should be used only when other options are not available.
- ✓ These types of maintenance activities should not be used in wet weather or when rainfall is imminent.
- ✓ Used solvents and excess paint should be managed as ‘hazardous waste’. Accordingly, liaise with local waste management firms and the operators of local waste management disposal/treatment facilities to identify opportunities for recycling and appropriate disposal options. For information about waste acceptance criteria and determination of the appropriate type of landfill for disposal of waste material, refer to the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002).
- ✓ Where washing is necessary and wastewater contains only non-hazardous contaminants in particulate form, direct wastewater to an infiltration area. Where infiltration of wastewater is not possible, remove the suspended material by allowing sedimentation (e.g. building ‘check dams’ along the roadside channel using sandbags) and/or filtration (e.g. using filters made of geofabric on drainage inlets). Another filtration option is to build several ‘socks’ approximately 50 centimetres long, which are made of geofabric filled with crushed aggregate. These can be placed on hard surfaces between the source of the wastewater and the drainage inlet.
- ✓ Ensure spill clean-up kits are available and used for spills of solvents or paint. Site personnel should also be trained in their use.

The following maintenance practices are recommended for *painting activities*:

- ✓ Store materials undercover or in contained areas.
- ✓ Clean the work site daily. Use ‘dry’ methods for clean-up, where possible.
- ✓ Ensure paint or solvent leakages cannot enter the stormwater system. Treat a paint spill in the same manner as a ‘chemical spill’.
- ✓ Use a ground cloth/sheet to collect dust and paint residue during scraping, sanding and painting activities.
- ✓ Clean water-based paint equipment where residue cannot enter the stormwater system.
- ✓ Clean oil-based paint equipment where the liquid waste material can be collected and disposed of as hazardous waste.
- ✓ Avoid spray painting outdoors on windy days.

*Sandblasting* is sometimes undertaken to remove paint and dirt. A waste is produced from this process that consists of the blasting sand, paint and dirt. In some cases, these wastes can be hazardous, due to the presence of heavy metals from older types of paints. Such wastes should be contained, and it is recommended that a licensed waste management firm be engaged to test, transport and dispose of the material.

The following basic maintenance practices are recommended for *graffiti removal*:

- ✓ Ensure wastewater does not enter the stormwater system.
- ✓ Fit temporary geofabric filters on stormwater inlets, where required, to prevent pollutant entry.
- ✓ Sweep up the site immediately after works and dispose of waste materials appropriately.
- ✓ Use temporary bunding to contain potential pollutants.
- ✓ Undertake sound waste handling and disposal practices.
- ✓ For graffiti removal using wet sand blasting methods and where lead-based paint is not likely to be present in the wastewater, minimise the amount of water used. Then direct wastewater to landscaped areas where possible. If this is not possible, filter the wastewater to remove coarse sediment particles prior to its discharge to stormwater.
- ✓ For graffiti removal using high pressure washing and cleaning compounds, direct wastewater to landscaped areas where possible<sup>16</sup>, or pump the wastewater to sewer, (in accordance with an approved Industrial Waste Permit). Note that pre-treatment of wastewater may be necessary prior to its disposal to sewer if some types of cleaners have been used.

Guidelines for *surface cleaning activities* include:

- ✓ If wastewater should be connected and discharged to sewer, an Industrial Waste Permit is required. Further information is available from the Water Corporation via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)> or by telephoning the Customer Service Centre on 13 13 95.
- ✓ Where painted buildings are being washed and there is the likelihood of lead or mercury additives in the paint, wastewater should be directed to sewer (in accordance with an approved Industrial Waste Permit) or taken to a hazardous waste treatment facility by a licensed contractor.
- ✓ Where an acid wash is being used to remove mineral deposits on masonry, rinse the treated area with an alkaline soap to neutralise the acid residue. Direct rinse water to a landscaped area. Collect the acidic wastewater, neutralise the pH to between 6 and 11, and pump the wastewater to sewer (in accordance with an approved Industrial Waste Permit).
- ✓ Where washing building walls with soap, either discharge wastewater to a landscaped area, to sewer (in accordance with an approved Industrial Waste Permit), or to a waste treatment facility via a licensed waste transport contractor.
- ✓ Where washing building walls without soap and where lead-based paint is not likely to be present in the wastewater, direct wastewater to landscaped areas where possible, or if this is not possible, filter the wastewater to remove coarse sediment particles prior to its discharge to stormwater. Dispose of collected solids as non-hazardous solid waste.

<sup>16</sup> This guideline is not recommended in areas where cleaning compounds are used and groundwater contamination is likely (e.g. sandy soils on the Swan Coastal Plain).

## Maintenance of gardens, carpark and paving

- ✓ Regularly sweep up contaminants from paved/carpark surfaces.
- ✓ Identify ‘hot spots’ where contaminants such as litter, leaves and sediment regularly accumulate. Program regular inspections and removal of these materials using ‘dry’ clean-up methods to minimise the potential for stormwater pollution.
- ✓ Provide suitable litter and recycling bins around the building, and ensure that an adequate inspection and maintenance program is in place for these bins, where appropriate. For more details on this practice, refer to Section 2.2.4.
- ✓ Ensure vehicles that are parked on-site do not leak fluids (e.g. oils). Undertake regular inspections, provide drip pans where necessary, and immediately clean up any identified leaks/spills.
- ✓ Seek to reduce the amount of impervious surfaces directly connected to the stormwater system by promoting infiltration and filtration, where site conditions are suitable.
- ✓ Implement opportunities to reuse roof water and other forms of stormwater from the site (e.g. for toilet flushing and garden irrigation).
- ✓ Implement water conservation and integrated pest management practices and reduce fertiliser use on lawn and garden areas. Refer to Section 2.2.7 for further information.
- ✓ Minimise the use of inorganic fertilisers on lawn and garden areas (e.g. via soil amendment practices and use of organic fertilisers). Refer to Section 2.2.7 for further information.
- ✓ Seek to ensure permeable areas (e.g. lawns and gardens) have features that promote infiltration of stormwater (e.g. uncompacted soils, contouring that causes temporary ponding during heavy rain and use of mulch on garden beds).
- ✓ Seek to implement permeable paving as an alternative to traditional paving, where practical and where site conditions are suitable (e.g. areas with permeable soils and where groundwater tables are not high). Refer to Chapter 9 for more information on permeable paving.

## Maintenance of the building’s stormwater-related structures

- ✓ Regularly inspect and maintain all structural stormwater treatment, retention or infiltration devices. A maintenance and repair plan should be developed that clearly outlines inspection and maintenance frequencies, procedures for the disposal of wastes, equipment requirements, health and safety requirements. See Chapter 9 for more information.
- ✓ Inspect and, where necessary, maintain the site’s in-ground stormwater network (at least annually).
- ✓ Inspect and, where necessary, maintain the building’s drain inlets, spouting and downpipes (at least twice per year).

## Benefits and Effectiveness

These measures are generally simple, low-cost pollution prevention and minimisation practices with a low risk of failure. They can be applied at the source of pollution, and are likely to be more cost-effective than trying to achieve the same stormwater management benefits at a point downstream, using alternative methods (e.g. regional stormwater treatment devices).

These management practices may:

- Minimise risks to the health of receiving water bodies by reducing loads of pollutants entering stormwater and shallow groundwater (particularly sediment, heavy metals, litter, hydrocarbons, organic matter, paint and solvents).
- Reduce aesthetic impacts (e.g. coloured paint flakes being washed from a building's roof under high pressure into the stormwater system and into a local wetland).
- Reduce the pressure on downstream, end-of-pipe, stormwater treatment devices.

## Challenges

The following challenges may need to be addressed to improve implementation:

- Procedures and training materials must be regularly updated.
- Maintenance of a building's structural stormwater management devices may be limited by the absence of suitable maintenance plans that should have been developed when the devices were designed and installed.
- In some areas, local service providers may not be available for hazardous waste and recyclable material removal and processing.
- Implement training to address resistance to changes in work practices.
- Safety and localised flooding risks associated with placing geofabric filters over stormwater drain inlets when rainfall is imminent.

## Cost

Generally the costs associated with management practices outlined in these guidelines are minimal, except where large volumes of wastewater need to be treated as 'hazardous waste'.

## Additional Information

For information on maintenance of the site's drainage system, refer to the guidelines provided in Section 2.2.2.

For information on the placement and maintenance of the building's external litter and recycling bins, refer to the guidelines provided in Section 2.2.4.

This guideline has been developed assuming that maintenance is required. Taking a 'pollution prevention' approach, the need for maintenance may be reduced or eliminated through measures such as:

- incorporating maintenance considerations into the *design* of buildings; and
- multi-dimensional programs to minimise the occurrence of graffiti (e.g. ensuring quick removal of graffiti, installing sensor lighting in high risk areas, avoiding the creation of large surfaces that create a 'canvas' for graffiti attacks, creating partnerships with the community, providing areas where 'street art' is encouraged, using landscaping to make sites less accessible, etc).

## Examples / Case Studies

No documented case studies were identified.

## References and Further Information

- Department of Environmental Protection 2002, *Guidelines for Acceptance of Solid Waste to Landfill*, Department of Environmental Protection, Perth, Western Australia.
- Ecological Engineering Pty Ltd 2003, *Maintenance and Operations Procedures (MOP) Manual*, Manual prepared for the Hastings City Council, Ecological Engineering Pty Ltd, Port Macquarie, New South Wales.
- Housing Industry of Australia 2002-04, HIA Greensmart® Program (see <[www.greensmart.com.au](http://www.greensmart.com.au)>) and the guideline titled: *Stormwater Management Guide for Residential Buildings*, Housing Industry of Australia (PATHE Program), Canberra, Australian Capital Territory.
- New South Wales Environmental Protection Authority (NSW EPA) 1998, *Managing Urban Stormwater - Source Controls*, Draft guidelines prepared for the State Stormwater Coordinating Committee, NSW EPA, Sydney, New South Wales.
- Stormwater Quality Management Committee (SQMC) 2003, *Best Management Practices – Surface Cleaning*. A community partnership sponsored by the Clarke County Regional Flood Control District, Nevada. Cited at <[www.lvstormwater.com/bmps.html](http://www.lvstormwater.com/bmps.html)>.
- United States Environmental Protection Agency (US EPA) 2001. *National Menu of Best Management Practices for Storm Water Phase II*. United States Environmental Protection Agency on-line guideline. Cited at: <[www.epa.gov/npdes/menuofbmps/menu.htm](http://www.epa.gov/npdes/menuofbmps/menu.htm)>.
- Victorian Stormwater Committee (VSC) 1999, *Urban Stormwater - Best Practice Environmental Management Guidelines*, CSIRO Publishing, Melbourne, Victoria.

## 2.2 Maintenance practices

### 2.2.10 Stormwater management on industrial and commercial sites

#### Description

Industrial and commercial premises have significant potential to pollute stormwater. For example:

- commercial areas are known to generate large loads of litter;
- industrial premises can contaminate stormwater through poor control of industrial processes or the transport, handling and storage of goods and wastes; and
- food preparation businesses may have poor facilities for waste handling and disposal.

In Western Australia, small to medium-sized industrial premises have been identified as representing a significant cumulative risk to the health of water resources in Perth (WRC, 2000; EMRC, 2002). Improving practices that potentially impact on stormwater and groundwater at these premises is a priority for water resource protection.

As several detailed guidelines are currently available that provide guidance on this topic, including several comprehensive Western Australian guidelines (see Additional Information), this section will:

- reference these guidelines; and
- briefly summarise key aspects that relate to stormwater management.

#### Applicability

Pollution prevention and other management activities for stormwater management are applicable to most commercial and industrial sites. Site-specific risks should be identified and appropriate management practices should be designed for the site. Attending suitable training, such as the courses provided by the Cleaner Production Training Program for Industry in Perth and the industry-specific seminars and workshops provided by the Green Stamp Program, can help people gain the skills necessary to undertake this process.

#### Recommended Practices

The Light Industry Project, Green Stamp Programs and the Centre of Excellence in Cleaner Production can provide training, support, case studies and further information.

##### Preparing the workplace

- ✓ Identify and assess stormwater-related risks on the site (e.g. activities that may contaminate stormwater). Various checklists and surveys have been developed to help people identify these risks (e.g. see Motor Trade Association of WA's self-assessment guides; EMRC, 2002; VSC, 1999). In some circumstances, a survey or checklist can also be used to raise awareness among staff of the potential for contamination of stormwater (VSC, 1999). Staff who may undertake risk assessments should receive training to ensure they have the necessary skills.
- ✓ Develop management plans or procedures to manage the identified risks (e.g. a Stormwater Management Plan, Waste Management Plan, Emergency Response Plan, etc.). Again, professional training is recommended to help those people developing these documents to access necessary skills and resources. For guidance on the content of a 'Stormwater Management Plan' for larger industrial or commercial sites, see Chapter 5 of this Manual.

- ✓ Train all staff to be aware of stormwater pollution, to undertake their roles in related management plans/procedures, report incidents and safely manage incidents.
- ✓ All stormwater-related actions in relevant plans or procedures should be subject to regular audits to ensure they are occurring. These may result in recommendations for improvement (e.g. modified procedures, new training, new equipment, etc.).
- ✓ For large sites with many potential sources of stormwater pollution or sites with significant risks to stormwater, it is recommended that an environmental management system (EMS) be developed, implemented and maintained. See Section 2.5.1 for guidance on this issue.
- ✓ Look for opportunities to recycle stormwater/roof water on-site as a way of minimising the use of scheme water and the export of stormwater and stormwater pollutants from the site. This water may be used for irrigation, vehicle washing, toilet flushing or industrial processes. A cost saving may be generated from this activity if the consumption of mains water is reduced.
- ✓ Develop and implement a Waste Management Plan to ensure that solid and liquid wastes are minimised and stored correctly to reduce the risk of stormwater contamination. This plan would explore opportunities for waste minimisation (e.g. ensuring the correct amounts of raw materials are purchased to decrease the amount of excess materials that are discarded) and the reuse of wastes (either on the site or within the region). For information about waste acceptance criteria and determination of the appropriate type of landfill for disposal of waste material, refer to the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2002). The Department of Environment regulates the transportation of wastes that may cause environmental or health risks. It does so through the application of the Environmental Protection (Controlled Waste) Regulations 2004. Controlled waste is generally defined as all liquid waste, and any waste that does not meet the acceptance criteria for a Class I, II or III landfill site. The *Guideline for Controlled Waste Generators* (DoE, 2004) specifies that a generator is a person whose activities produce, or apparatus result in the production of controlled waste. Staff should be aware of the Environmental Protection (Unauthorised Discharge) Regulations 2004, which include an on-the-spot infringement notice system for *minor* pollution offences. These powers can be delegated to local government officers. The new on-the-spot fines currently carry a penalty of \$250 to \$500, which increases to \$5,000 if the matter proceeds to court. The fines apply to commercial and industrial premises and cover the discharge of substances to stormwater or groundwater. These substances include hydrocarbons, solvents, degreaser detergent, dust, engine coolant, food waste, laundry waste, pesticides, paint, dyes, acids, alkali, sediment, sewage and substances containing heavy metals (Raine, 2004).
- ✓ Ensure all containers holding wastes or hazardous materials are designed to minimise the risk of stormwater contamination. This includes having lids on solid waste containers to prevent wind-blown litter, covering storage areas, using bunds around areas where liquid materials are stored, etc. Waste containers should be stored in bunded, undercover areas, on an impermeable surface and away from stormwater drains.
- ✓ Large quantities of potentially hazardous material should be stored within a bunded compound that is impervious to infiltration, able to safely contain at least



Figure 1. Green Stamp automotive premises, Balcatta. Correct storage of fuel and other chemicals in a bunded area. (Photograph: Department of Environment.)

110% of the volume of the largest container in the bund and 25% of the combined volume of all other liquids held within the compound. If located outside, the storage area should be roofed to prevent the collection of rainwater inside the bunded area (see EMRC, 2002, for more details).

- ✓ For storage of chemicals, all floor areas should be sealed to prevent infiltration and assist with the clean up of spills.
- ✓ In areas where accidental spills may occur (e.g. loading/unloading areas), ensure that appropriate spill response equipment is available and readily accessible at all times.
- ✓ Designated material handling areas need to be kerbed and graded to contain spills, stormwater and the liquid generated from at least 1 hour of typical fire-fighting activities. Speed humps or irregular surfaces that may cause accidents with containers should not be permitted in handling areas.
- ✓ Ensure stormwater from relatively clean areas (e.g. roofs) is kept separate from stormwater from potentially contaminated areas (e.g. uncovered work areas of industrial sites) to minimise the volume of stormwater that requires a high level of treatment.
- ✓ Prevent contaminated wastewater from floors and covered work areas from entering stormwater systems by using surface grades, bunds, or diversion drains to an impervious sump or wastewater treatment system.
- ✓ Wash-down pads should be designed to collect all water and residue in impervious collection sumps and have impervious bunds. The captured wastewater should be discharged to wastewater treatment facilities or removed by licensed waste contractors.
- ✓ Ensure suitable structural stormwater treatment devices are in place, and are regularly inspected and maintained in accordance with a maintenance plan. See Chapter 9 for information on structural controls.
- ✓ Obtain specialist advice on whether stormwater from various locations around the site needs to be treated and whether the stormwater can be discharged to the stormwater system (e.g. drains), soakwells, a hazardous waste treatment facility (via a licensed waste transport contractor) or sewer (approved in some rare circumstances only). This advice should be confirmed in writing from the Department of Environment and the local government and then documented in the site's Stormwater Management Plan.
- ✓ Consider the quality and quantity of stormwater discharges from the site during the design of new buildings and surrounding areas. Apply water sensitive design features where possible.
- ✓ Look for opportunities to re-engineer or redesign processes to take advantage of newer, cleaner and more efficient equipment that has a reduced risk of stormwater contamination.
- ✓ Use alternative materials for cleaning, coating, lubrication, and other production processes to prevent the generation of hazardous wastes and minimise the risk of stormwater being contaminated by these wastes.
- ✓ Stormwater drains within and around the site should be stencilled with messages to alert all staff that they drain to watercourses or wetlands (e.g. 'Rainwater only - flows to the Swan River'). See Section 2.3.4 for information about education/participation campaigns for industrial and commercial sites.

## Keeping the workplace clean

- ✓ Ensure surfaces that drain to stormwater are regularly cleaned using 'dry' methods.
- ✓ Only undertake washing, degreasing and cleaning activities in dedicated wash-down bays where the wastewater can be collected and prevented from mixing with stormwater. This includes vehicle washing using biodegradable detergents.
- ✓ Maintain machinery/vehicles to minimise the risk of leaks and store such machinery in cleaned areas so that regular inspections can quickly identify any discharges.
- ✓ Use spill trays under work areas where spills could occur.
- ✓ Control airborne sprays so those surfaces that generate or convey stormwater are not contaminated.
- ✓ Where possible, loading and unloading should take place in a covered area away from the vicinity of stormwater drains. Stormwater should be directed away from loading and unloading areas.
- ✓ For more information, see Section 2.2.8 Maintenance of vehicles, plant and equipment (including washing).

## Minimising the risk of accident/incident

- ✓ Ensure staff training includes safe material handling and storage procedures to minimise the risk of a spill. For large spills, contact the Department of Environment's Emergency Pollution Response Unit on (08) 9222 7123 (after hours 1800 018 800). Further information about emergency response is available via <<http://emergency.environment.wa.gov.au>>.
- ✓ In consultation with staff, develop and communicate an Emergency Response Plan to manage spills. One of the primary objectives of this plan is to ensure that spills do not leave the site via stormwater drains. For guidance on the content of this plan, see EMRC (2002).
- ✓ Ensure the site is equipped with suitable emergency spill equipment and absorbents and train staff on their use. Spill materials vary according to the nature of the work being undertaken, the location of the business (e.g. next to water bodies) and the types of liquids being handled. At a minimum, spill kits should include gloves and/or other protective clothing, suitable absorbent pads/powders/granules, shovels, brooms and dustpans.
- ✓ Clean up of spills should be immediate, automatic and routine in industrial premises, no matter how small. Under no circumstances should spills be washed away with water or buried on-site.

## Benefits and Effectiveness

Benefits associated with implementing these management practices may include:

- Reduced risks to, and impacts on, stormwater and groundwater quality.
- Improved workplace health and safety.
- Reduced risk of breaching environmental legislation and being prosecuted under this legislation.
- Cost savings as a result of cleaner production techniques.
- Reduced risk of complaints from stakeholders (e.g. neighbours, environmental groups).

- Enhanced corporate citizenry and public image.
- Reduced legal and financial liability with respect to issues such as site contamination.

In terms of the effectiveness of these practices, it is widely recognised that source control, cleaner production and pollution prevention techniques are cost-effective strategies for managing pollution on commercial and industrial premises. However, pollutant removal efficiency data for specific practices covered by this guideline are not available.

## Challenges

The following challenges may need to be addressed to improve implementation:

- The development of a Site Management Plan with a focus on pollution prevention for commercial industrial sites will require an initial investment of time and money, which could be recouped over time through more efficient business practices.
- A low level of environment regulation or enforcement (particularly for small to medium-sized enterprises) creates little to no incentive to comply with environmental legislation.
- There are a limited number of positive incentives for commercial or industrial premises to improve their stormwater-related environmental performance (e.g. opportunities for the company to gain positive publicity, reduced licence fees, grants for environmental works, subsidies and rebates).
- Few commercial benefits with customers that do not consider a business' environmental practices in their purchasing decision.
- Implementing training to address resistance to changes in work practices.
- Lack of expertise and/or knowledge of how to address the issues.
- Planning restrictions and restrictive lease arrangements.

## Cost

The cost required to identify, assess and manage stormwater-related risks will vary greatly depending on the activities being undertaken, the characteristics of the site, and the extent to which the stormwater-related management plans are implemented.

## Additional Information

The guidelines provided in Sections 2.4.2 and 2.5.1 are relevant to commercial and industrial premises. Section 2.4.2 explains how regulation (with enforcement of these regulations) can provide an effective incentive for improved stormwater management on commercial and industrial premises, while Section 2.5.1 explains the benefits of environmental management systems.

Section 2.2.8 is relevant for maintenance of vehicles and equipment (including washing).

Section 2.3.4 has information about education and participation campaigns for industrial and commercial premises.

The following resources provide guidance on undertaking sound environmental management on commercial and industrial sites, including cleaner production techniques and stormwater management practices:

- The Light Industry Project is a network of industry, State and local government, community groups, education and training providers. The project aims to provide small to medium-sized businesses with on-ground support, positive incentives and resources. Different levels of training and support are available, depending on the needs of particular businesses and industry sectors. Further information is available by telephoning (08) 9374 3301 or via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.wastewise.wa.gov.au](http://www.wastewise.wa.gov.au)>. The Light Industry Project office is at the Swan Catchment Centre, 80 Great Northern Highway, Middle Swan WA 6056.
- Green Stamp is an industry-specific environmental accreditation and education program that assists small to medium businesses to implement environmental best management practices. The program provides environmental assessments, training and support, including simple environmental management plans and industry-specific case studies and environmental guidelines. Green Stamp Programs are currently available through the following industry associations:
  - Motor Trade Association (MTA) of Western Australia. Resources include the *Environmental Products and Services Directory* and environmental guidelines such as *Asbestos Use and Disposal*, *Building New Premises*, *Bunds and Bunding*, *Cleaning up Spills*, *Cleaning Vehicles*, *Coolant Management*, *Degreasers and Detergents*, *Environmental Policy*, *Mobile Mechanics*, *New Environmental Laws*, *Oil Separators*, *Parts Washers*, *Preventing Oil Pollution*, *Purchasing Spill Kits*, *Solvent Thinner Recycling Systems*, *Wastewater Management for Body Repairers*, *Environmental Assessments for Body Repairers* and *Environmental Assessments for Mechanical Repairers*. Refer to the Examples/Case Studies section, below. Further information is available by telephoning the Automotive Industry Green Stamp Officer on (08) 9345 3466 or via <[www.greenstamp.com.au](http://www.greenstamp.com.au)>. Their office is at MTA House, 224 Balcatta Road, Balcatta WA 6914.
  - The Printing Industry Association. Resources include *Managing and Monitoring Environmental Impacts – A Simple Environmental Management Plan for Printing Businesses*, *Accreditation Criteria for Printing Businesses*, *Baseline Audit for Printing Businesses* and information sheets on *Chemical and Ink Management*, *Environmental Law*, *Protecting Stormwater Drains*, *Solid Waste Management* and *Wastewater Management*. These resources are available by telephoning the Printing Industry Green Stamp Coordinator on (08) 9278 0300. Further information is available via <[www.printnet.com.au](http://www.printnet.com.au)>.
  - Building Service Contractors Association (formerly the Master Cleaners Guild). The Building Service Contractor’s Association Green Stamp Coordinator is available by telephoning (08) 9278 0300 for further information.
  - Other industry associations are working with the Department of Environment to extend the Green Stamp Program to their industry sectors.
- Centre of Excellence in Cleaner Production, Curtin University of Technology, Western Australia. Refer to <<http://cleanerproduction.curtin.edu.au>> or telephone (08) 9266 4520 for cleaner production resources including case studies, checklists, environmental guidelines, technical references, training materials, details of training opportunities and postgraduate courses. *The Western Australian Business and Environment Manual - A Guide to Reducing Your Costs and Impacts* (2003) is a recommended reference.
- Department of Environment and Swan River Trust (2004) *Environmental Management and Cleaner Production Directory for Small and Medium Businesses*, DoE and SRT, Perth, Western Australia. This Directory includes case studies, details of training opportunities and lists State, national and international environmental management and cleaner production guidelines for small and medium businesses. Local governments, industry associations, catchment groups and other State agencies are encouraged to use this Directory to assist businesses to implement cleaner production initiatives and

adopt practices that protect stormwater quality. The Directory is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.

- Eastern Metropolitan Regional Council (2002). ‘Pollution Prevention/Cleaner Production Guidelines for Local Government’ in the *Local Government Natural Resource Management Policy Manual*, Eastern Metropolitan Regional Council, Perth, West Australia. The Manual is available at <[www.emrc.org.au](http://www.emrc.org.au)> under the Services/Environmental Services tab.
- WA Environmental Protection Authority (1999). *Guidance for the Assessment of Environmental Factors - Management of Surface Runoff from Industrial and Commercial Sites*, Draft guidance document No. 26. Environmental Protection Authority, Perth, Western Australia.
- Refer to relevant Water Quality Protection Notes, available from the Department of Environment via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>, or by telephoning (08) 9278 0300. For example:
  - *Mechanical Servicing and Workshops* (Water and Rivers Commission, 2002);
  - *Mobile Mechanical and Cleaning Services* (Draft) (DoE, 2004);
  - *Washdown of Mechanical Equipment* (WRC, 1998);
  - *Industrial Sites Near Sensitive Water Bodies* (WRC, 1999);
  - *Chemical Spills – Emergency Response Planning* (WRC, 2002);
  - *Stormwater Management at Industrial Sites* (WRC, 2002);
  - *Toxic and Hazardous Substances – Storage and Use* (WRC, 2002).
- WA Department of Minerals and Petroleum Resources - *Guidance Notes on Storage of Dangerous Goods – General Requirements for Premises Exempt from Licensing* (S305) (March 2003). These guidelines and further information about dangerous goods storage, handling and transport, relevant legislation and accredited training providers and consultants are available at <[www.doir.wa.gov.au/safetyhealthandenvironment](http://www.doir.wa.gov.au/safetyhealthandenvironment)>.

## Examples / Case Studies

Refer to the Light Industry Project and Green Stamp Programs, outlined in the Additional Information Section and Section 2.3.4.

The case study provided in Section 2.4.2 is relevant to this management practice, as it demonstrates the stormwater-related outcomes that can be achieved at vehicle service facilities *where there is a strong incentive to improve*. In the case study provided, positive and negative incentives were used by a regulator to promote behavioural change.

## Other

Australian and international case studies are also available from:

- The Centre of Excellence in Cleaner Production, Curtin University of Technology, Western Australia. Refer to <<http://cleanerproduction.curtin.edu.au>> or telephone (08) 9266 4520.
- Section 1.6 – Case Studies in the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.

## References and Further Information

- Centre of Excellence in Cleaner Production 2003, *The Western Australian Business and Environment Manual - A Guide to Reducing Your Costs and Impacts*, Centre of Excellence in Cleaner Production, Perth, Western Australia. Cited at: <<http://cleanerproduction.curtin.edu.au>> (August, 2003).
- Department of Environmental Protection 2002, *Guidelines for Acceptance of Solid Waste to Landfill*, Department of Environmental Protection, Perth, Western Australia.
- Department of Environment 2004, *Guideline for Controlled Waste Generators, Controlled Waste Guideline Series: Guideline No. 1*, Department of Environment, Perth, Western Australia.
- Department of Environment and Swan River Trust 2004, *Environmental Management and Cleaner Production Directory for Small and Medium Businesses*, DoE and SRT, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.
- Eastern Metropolitan Regional Council (EMRC) 2002, 'Pollution Prevention/Cleaner Production Guidelines for Local Government', in *Local Government Natural Resource Management Policy Manual*, Eastern Metropolitan Regional Council, Perth, Western Australia.
- Green Stamp Program / Motor Trade Association of Western Australia, which includes Environmental Guidelines for automotive businesses and practices (<[www.greenstamp.com.au](http://www.greenstamp.com.au)>). Information about other Green Stamp Programs is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>.
- Raine, K. 2004, Ken Raine, Manager, Response and Audit, Department of Environment, Internal Department of Environment article (7 April 2004).
- Taylor, A.C. and Wong, T.H.F. 2002c, *Non-structural Stormwater Quality Best Management Practices - A Literature Review of Their Value and Life-cycle Costs*, Technical Report No. 02/13, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria. Available via <[www.catchment.crc.org.au](http://www.catchment.crc.org.au)> and <[www.clearwater.asn.au/infoexchange.cfm](http://www.clearwater.asn.au/infoexchange.cfm)>.
- United States Environmental Protection Agency (US EPA) 2001, *National Menu of Best Management Practices for Storm Water Phase II*. United States Environmental Protection Agency on-line guideline. Cited at: <[www.epa.gov/npdes/menuofbmps/menu.htm](http://www.epa.gov/npdes/menuofbmps/menu.htm)>.
- Victorian Environmental Protection Authority (VEPA) 2003, *Preventing Stormwater Pollution - A Guide for Industry*, Stormwater-related fact sheet. Cited at <[www.epa.vic.gov.au](http://www.epa.vic.gov.au)> (August 2003).
- Victorian Stormwater Committee (VSC) 1999, *Urban Stormwater - Best Practice Environmental Management Guidelines*, CSIRO Publishing, Melbourne, Victoria.
- WA Department of Minerals and Petroleum Resources 2003, *Guidance Notes on Storage of Dangerous Goods – General Requirements for Premises Exempt from Licensing (S305 REV 3)*.
- WA Environmental Protection Authority 1999, *Guidance for the Assessment of Environmental Factors - Management of Surface Runoff from Industrial and Commercial Sites*, Draft guidance document No. 26, Environmental Protection Authority, Perth, Western Australia.
- Water and Rivers Commission 1998, *Washdown of Mechanical Equipment*, Water Quality Protection Note, August 1998, Water and Rivers Commission, Perth, Western Australia.
- Water and Rivers Commission 1999, *Industrial Sites Near Sensitive Water Bodies*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission (WRC) 2000, *Swan-Canning Industry Survey Report – Pilot Survey Findings*, Water and Rivers Commission, Perth, Western Australia.

Water and Rivers Commission 2002, *Chemical Spills – Emergency Response Planning*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Mechanical Servicing and Workshops*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Radiator Repairers and Reconditioners*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Stormwater Management at Industrial Sites*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Water and Rivers Commission 2002, *Toxic and Hazardous Substances – Storage and Use*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

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## 2.3 Educational and participatory practices

### 2.3.1 Capacity building programs for local government and stormwater management industry professionals

#### Description

Capacity building is a ‘holistic approach to knowledge building and transfer, identifying issues of relevance and benefit to foster professional skill development, competency, innovation, creativity, confidence, certainty and clarity. Capacity building is also a means to facilitate network building, linkages and training for continuous improvement’ (Clearwater, 2002, p. 2).

Stormwater-related capacity building programs can be run at a variety of scales, from a program that covers a small local government area to one that covers an entire State.

Providing people with the information and contacts they need to make better decisions is an essential part of promoting best practice stormwater management.

#### Applicability

These programs are applicable to local government authorities, metropolitan regional councils and stormwater management industry associations.

Refer to the Recommended Practices section for the potential target audiences, who should be involved in the scoping stage of the program.

#### Recommended Practices

The Clearwater program in Victoria and the Urban Water Cycle Management Capacity Building Program in New South Wales are good examples of stormwater management capacity building programs (refer to the Examples/Case Studies section for further information).

Recommended steps to developing a stormwater-related capacity building program include:

- ✓ Scoping the program by identifying the capacity building requirements for the target audience. For example, specialist market researchers may be engaged to survey the target audience (through methods such as focus groups, workshops and phone surveys) to identify current levels of stormwater knowledge and awareness, training and development needs, barriers to change, potential education and networking opportunities, including existing communication networks.
- ✓ Using the information from the scoping step to identify key project areas.
- ✓ Developing project plans for each of the key project areas. These plans detail how major projects will be delivered (e.g. training events, information registers, websites and guidelines), including details such as the target audience, objectives, expected outputs, expected outcomes, method of evaluation, timing and responsibilities.
- ✓ Implementing these project plans.
- ✓ Communicating with stakeholders *throughout* this process. Opportunities for communication include newsletters (paper and electronic), websites, workshops and travelling ‘road shows’, where stakeholders are introduced to the capacity building program, new projects are advertised (e.g. upcoming training events or guidelines), and new products are explained.

- ✓ Evaluating the program. An approach to monitoring and evaluation should be planned at the beginning of the program's development and executed throughout its delivery. For advice on designing a suitable monitoring and evaluation plan, see Taylor and Wong (2002d).

The following potential target audiences should be involved in the initial scoping exercise (i.e. step number one above):

- elected members (particularly in small to medium-sized local government);
- senior managers in local government, State government and relevant water service providers;
- town planners, engineers, ecologists, architects, landscape architects and staff responsible for the maintenance of stormwater assets; and
- the construction and stormwater management industries (both in government and the private sector).
- local catchment groups, industry associations and other existing communication networks, where applicable.

In large urban areas covering several local government districts, there are potential benefits associated with combining available resources to form a major regional capacity building program (e.g. jointly funded by State and local government).

## Benefits and Effectiveness

The potential benefits of a capacity building program include:

- increased rate of uptake of stormwater best practices by the public and private sector;
- increased understanding of the need for stormwater management initiatives (e.g. strict town planning controls and stable funding mechanisms), particularly by senior managers and elected officials;
- widely communicated results of other successful projects;
- enhanced communication networks amongst stakeholders that will exist long after the capacity building program has officially finished; and
- identification of common needs (e.g. a specific guideline or training module) and the facilitation of a cost-effective, high-quality regional project that most organisations could not fund on their own.

Best practice stormwater-related capacity building programs may be highly effective if designed, delivered and evaluated in accordance with the steps highlighted in this guideline.

## Challenges

The primary challenge for running a capacity building program is cost. Some of these costs could be recovered by charging participants to attend specific training events and to access products, although this option is rarely chosen.

Stakeholder needs may change over time. For example, in the early stages of a program, stakeholders may require basic information and knowledge. As stakeholders become more experienced, other issues, such as funding and the regulatory framework, may become more prominent. Bold initiatives like strict town planning controls, enforcement programs, new funding arrangements and new organisational structures may not be implemented unless senior managers, elected officials and the broader community understand

the need for these measures. A capacity building program can help to ensure this base level of knowledge is obtained, particularly within professional stakeholder groups.

## Cost

Stormwater-related capacity building programs are scalable. As an indication of cost, the State-wide Clearwater stormwater capacity building program in Victoria is funded at a level of \$1,000,000 over 2 years (J. White, pers. comm., 2003).

## Additional Information

For further guidance about how to undertake specific educational events (e.g. training programs), see Sections 2.3.2 to 2.3.5 in the Educational and Participatory Practices section of this chapter. Chapter 8: *Education and awareness for stormwater management* provides additional case studies and guidance on how to design a community education and awareness program.

For information on the effectiveness of educational and participatory approaches to stormwater management, see Taylor and Wong (2002c).

For more information about capacity building, see the Implementation chapter of this Manual.

The following *behaviour change* resources are recommended when designing the program:

- Community Change (Victoria, Australia) via <[www.communitychange.com.au](http://www.communitychange.com.au)>.
- Social Change Media (New South Wales, Australia), the home page is available via <<http://media.socialchange.net.au>> and *The Seven Door Social Marketing Approach* (Robinson, undated) is available via <<http://media.socialchange.net.au/strategy>>.
- Community Based Social Marketing (Canada) via <[www.cbsm.com](http://www.cbsm.com)>.
- *Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing* (Mckenzie-Mohr & Smith, 1999). Further information is available from Community Based Social Marketing via <[www.cbsm.com](http://www.cbsm.com)>.

The *Facilitation Toolkit: A practical guide for working more effectively with people and groups* (Keating, 2003) is a recommended resource to use when facilitating workshops, seminars or group meetings. The toolkit is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300. See also the Coastal Cooperative Research Centre's *Citizen Science Toolbox* (Australia) for advice about particular facilitation techniques (<[www.coastal.crc.org.au/toolbox/index.asp](http://www.coastal.crc.org.au/toolbox/index.asp)>).

## Examples / Case Studies

### The Victorian Clearwater Capacity Building Program and Information Exchange

The Clearwater capacity building program is a Statewide targeted education and training program to support local government and industry professionals in the sustainable management of urban stormwater. It is a joint initiative of the Municipal Association of Victoria (MAV) and the Stormwater Industry Association of Victoria (SIAV), made possible through the Victorian Stormwater Action Program (Clearwater, 2002 and 2003).

The four key goals of the program are to:

1. Identify capacity building requirements for local government and stormwater industry professionals in urban stormwater best practice.

2. Develop a suite of tailored capacity building training/education packages promoting urban stormwater best practice to local government and training professionals.
3. Effectively deliver tailored capacity building training/education packages promoting urban stormwater best practice to the target audiences.
4. Effectively communicate and promote the program to the target audiences and key stakeholders (i.e. community, industry, government and non-government organisations).

The vision of the program is to ‘achieve best practice urban stormwater management and sustainable urban development’. Its mission is to ‘effectively create an environment to facilitate cultural change in the adoption of best practice environmental management of urban stormwater by local government and industry professionals’.

The program has a strong emphasis on case studies and guidance on best practice approaches, and is careful to acknowledge and build upon existing cultures, knowledge, experience and technical skills. A number of planning and focus group workshops were held at locations across Victoria, where stakeholders were asked to:

- nominate key areas of need with respect to training, professional development, technical/information kits or seminars;
- provide input and give direction to the development of the capacity building program;
- suggest what resources or support stakeholders need in order to implement best practice urban stormwater management; and
- nominate who can be involved from their organisation (Clearwater, 2002).

This series of workshops helped to develop a program of education and training events. Key project areas include water sensitive urban design, town planning tools, regulation and enforcement, leadership and commitment. Specific project plans are being developed for each of these four areas.

To respond to the needs of surveyed stakeholders, a ‘stormwater information exchange’ was established and a travelling ‘road show’ was delivered at four areas around Victoria, to showcase work being done through the program.

The *Clearwater information exchange* is a web-based database for urban stormwater management initiatives, available via <[www.clearwater.asn.au](http://www.clearwater.asn.au)>. It aims to provide up-to-date and relevant information on topics including: tools and resources; research; reports; case studies (including contact details for further information); interstate programs and resources; partnership projects; contacts; and relevant websites.

## The New South Wales Urban Water Cycle Management Capacity Building Program

The New South Wales Urban Water Cycle Management Capacity Building Program is a component of the Lower Hunter and Central Coast Regional Environmental Management Strategy (LHCCREMS) in the Newcastle area.

The LHCCREMS is an innovative and successful regional initiative currently being implemented by the seven local governments of the Lower Hunter and Central Coast Region. The LHCCREMS seeks to facilitate a regional approach by actively encouraging greater cooperation between local governments, industry and community groups and other relevant authorities (LHCCREMS, 2003).

The LHCCREMS's Water Sensitive Urban Design Capacity Building Program for local governments and catchment managers earned LHCCREMS five awards in the 2001 Local Government and Shires Association Excellence in the Environment Awards, including divisional winner and overall State winner for both the Built Environment and Stormwater Management categories. The project developed a Water Sensitive Urban Design Capacity Building CD and Toolkit for local governments, which contains a range of reports, presentations, and video-based training modules and tools.

A comprehensive, interactive training tool for use by all local governments throughout NSW may soon be available.

The capacity building program led to the development of regional planning and management tools in the Lower Hunter area. *Water Smart Model Planning Provisions for the Lower Hunter and Central Coast Region* and a *National Design Guide for Water Sensitive Urban Design* are two important documents for local governments and industry practitioners that have attracted interest and attention from all levels of government and organisations across Australia.

A *Stormwater Extension Officer program* has also been established as a joint initiative between LHCCREMS and the NSW EPA's Stormwater Trust. The primary role of the extension officer is to help 16 local governments within the Central Coast and Hunter region build capacity to effectively manage stormwater. The position was funded over 18 months. Further information is available via <[www.lhccrems.nsw.gov.au](http://www.lhccrems.nsw.gov.au)>.

### The HIA GreenSmart® Program

The HIA GreenSmart® Program is a national, industry-based capacity building program run by the Housing Industry Association of Australia within each State, in cooperation with the Federal government (Department of Environment and Heritage), Greening Australia and industry groups. The program aims to promote environmentally responsible land-development and building practices. The program focuses on energy efficiency, water efficiency, waste management and stormwater management. It involves training, accreditation of professionals (builders), demonstration sites and promotional activities (e.g. annual awards). For more information, see <[www.greensmart.com.au](http://www.greensmart.com.au)> or telephone (08) 9244 3222.

## References and Further Information

Clearwater 2003, *Stormwater Information Exchange Kit*, Clearwater Program, Melbourne, Victoria. Contains case study information on Victorian stormwater projects, June 2003. See <[www.clearwater.asn.au](http://www.clearwater.asn.au)>.

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Keating, C. 2003, *Facilitation Toolkit: A practical guide for working more effectively with people and groups*, Department of Environmental Protection, Water and Rivers Commission and Department of Conservation and Land Management, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300.

Lower Hunter and Central Coast Regional Environmental Management Strategy (LHCCREMS) 2003. The project's website at <[www.lhccrems.nsw.gov.au](http://www.lhccrems.nsw.gov.au)>, retrieved on 1 August 2003.

Lower Hunter Central Coast Region Environmental Management Strategy, Sydney Coastal Councils Group, Western Sydney Regional Organisation of Councils and Upper Parramatta River Catchment Trust 2003, *Water Smart Model Planning Provisions for the Lower Hunter and Central Coast Region*, LHCCREMS, NSW Australia. Available via <[www.lhccrems.nsw.gov.au](http://www.lhccrems.nsw.gov.au)>.

McKenzie-Mohr, D. and Smith, W. 1999, *Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing*, New Society Publishers, Canada. Further information is available from Community Based Social Marketing via <[www.cbsm.com](http://www.cbsm.com)>.

Robinson, L. (undated), *The Seven Doors Social Marketing Approach*. Retrieved: 10 January 2005 from <<http://media.socialchange.net.au/strategy>>.

Schueler, T. 2000, 'On Watershed Education', in *The Practice of Watershed Protection*, Schueler, T.R. and Holland, H.K. (eds), Centre for Watershed Protection, Ellicott City, Maryland, pp. 629-635.

Social Change Media (undated). Retrieved: 10 January 2005 from <<http://media.socialchange.net.au>> and <<http://media.socialchange.net.au/strategy>>.

Taylor, A.C. and Wong, T.H.F. 2002c, *Non-Structural Stormwater Quality Best Management Practices - A Literature Review of Their Value and Life-cycle Costs*, Technical Report No. 02/13, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria. Available via <[www.catchment.crc.org.au](http://www.catchment.crc.org.au)> and <[www.clearwater.asn.au/infoexchange.cfm](http://www.clearwater.asn.au/infoexchange.cfm)>.

Taylor, A.C. and Wong, T.H.F. 2002d, *Non-structural Stormwater Quality Best Management Practices - Guidelines for Monitoring and Evaluation*, Working paper No. 02/6, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria. Available via <[www.catchment.crc.org.au](http://www.catchment.crc.org.au)>.

## 2.3 Educational and participatory practices

### 2.3.2 Intensive training of landowners on aspects of stormwater management

#### Description

This best management practice typically involves a series of free intensive training workshops for volunteer residents involving lawn and garden care activities. The aim is to promote alternative lawn and garden care practices to minimise stormwater pollution.

Home gardens can have a significant adverse impact on stormwater and groundwater quality. Potential pollutants include nutrients, pesticides, sediments and organic matter (e.g. manure and grass clippings).

Intensive training programs may focus on water conservation, plant selection, fertiliser use, weed and pest management, irrigation practices, stormwater and shallow groundwater reuse, composting and soil amendment.

The Swan River Trust gardening workshops and the Living Smart sustainable living workshops are successful Western Australian examples. Other examples include the Master Gardener program in the United States. Refer to the Examples/Case Studies section for further information.

#### Applicability

These programs are applicable to all areas, however they are particularly applicable in the following situations:

- areas with sandy soils that have low nutrient and moisture retention capabilities;
- areas draining to sensitive water bodies (e.g. wetlands and waterways with conservation values, or catchments that are under stress from nutrient inputs, such as the Peel-Harvey and Swan-Canning);
- drinking water catchments;
- areas where gardens are close to water bodies;
- areas with large gardens and lawns; and
- areas subject to erosion (e.g. due to steep slopes).

#### Recommended Practices

Use proven *behaviour change* techniques, such as commitments/goal setting, prompts (to address forgetting), develop social norms and consider incentives. These techniques, particularly commitments/goal setting, have been used successfully in the Living Smart workshops in Western Australia and the Master Gardeners program in the United States. Refer to the Additional Information section for a list of recommended behaviour change resources.

For example, the Master Gardener program approach is outlined below:

Attendees who demonstrate an interest in environment-sensitive lawn and garden care can enrol their property as ‘volunteer gardens’ to demonstrate best practice techniques.

Participating landowners may sign an agreement to implement a variety of best management practices and keep a log of their activities over a full year.

Each volunteer may be assigned a personal Master Gardener, who is also a volunteer but has received prior training in alternative lawn and garden care techniques. The Master Gardener visits the landowner and sets aside regular times to discuss their progress.

Participants who successfully complete a year in the program can earn the title of ‘demonstration garden’, where they place a sign on the property to highlight that an alternative approach is being used. Participants are also encouraged to network within their local residential community to promote the practices they have learned and adopted. Participants may also undergo additional intensive training to become Master Gardeners themselves.

Changes in the knowledge and self-reported behaviour of participants are evaluated through regular surveys and through the logs kept by volunteers.

The training may also extend to water conservation, waste management practices and integrated pest management, where the application of insecticides and herbicides is minimised through alternative garden and lawn management techniques.

To engage the community, it may be advantageous for the program to address a range of *sustainable living* issues, e.g. stormwater management, water conservation, water sensitive gardening, waste minimisation and energy efficiency. Examples of sustainable living programs are provided in the Examples / Case Studies section.

## Benefits and Effectiveness

These programs can specifically target key sources of pollution, audiences and landowners from geographic areas. The program can also evolve as new pollutant priorities and management practices emerge. The programs can be applied in established areas and are relatively cost effective to run. Unlike the equivalent structural measures, they are not associated with a maintenance requirement for several decades (although maintenance of the training program is needed over time).

Supporting earlier work by Schueler (2000), the US EPA (2001) reviewed the effectiveness of non-point source education programs and concluded ‘from evaluations of several market surveys, it appears that media campaigns and intensive training can each produce up to a 10 to 20 percent (self reported) improvement in selected behaviours. A combination of both outreach techniques is probably needed in most watersheds, as each complements the other’ (p. 29).

Taylor and Wong (2002c) reviewed a number of US case studies and reported that intensive training programs involving lawn and garden care practices can produce:

- 26% - 41% increase in knowledge<sup>17</sup>.
- 17% increase in desirable attitudes.
- 10% - 75% (with the range 20% - 40% being common and an average of the most reliable data around 29%) increase in the number of people undertaking a specific desirable behaviour (based on *self-reported* data).
- 40% increase in the number of desirable practices adopted (based on *self-reported* data).
- For lawn care training, total nitrogen and pesticide loads applied to lawns can be reduced by approximately 40% and 25%, respectively.

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<sup>17</sup> That is, 26% – 41% of the surveyed population increased their knowledge in a certain area (e.g. they knew the best season and weather conditions to apply fertiliser).

Taylor and Wong (2002c) also reported that combined awareness and training programs (e.g. catchment-wide awareness and intensive lawn care training initiatives) are capable of producing:

- A 20% - 29% increase in the number of participants undertaking a desirable behaviour (again based on *self-reported* data).
- Event mean concentrations of common lawn herbicides in stormwater may be reduced by 56% - 86% over several years.

Taylor and Wong (2002c) concluded that there is strong evidence that intensive and interactive training is a superior method for changing lawn and garden care behaviour compared with seminars and publications. For example, an independent investigation was undertaken on the effectiveness of these three extension methods as part of the Florida Yards and Neighbourhoods Program. Intensive training involving interactive workshops and mentoring (e.g. consistent with the Master Gardener Program) increased the number of desirable lawn care practices adopted by participants by approximately 36%, compared to 24% for seminars and 15% for publications. The relative difference between the effects of these three methods is unlikely to be distorted by any bias associated with self-reported behavioural change.

The Examples/Case Studies section outlines the benefits and effectiveness of particular programs.

## Challenges

The primary challenge with this BMP is that it is a voluntary measure, relying upon individuals to volunteer their time to participate in the program. Significant effort would be required to communicate the needs for participation in such a program (e.g. why nutrient management on residential properties is an issue on the Swan Coastal Plain), and the benefits of doing so, both in terms of the broader community and the individual.

The programs should be delivered free of charge to attract a significant number of participants, so funding must be sourced from government agencies (i.e. rather than a 'polluter pays' arrangement).

## Cost

Taylor and Wong (2002c) reported that intensive training programs such as the US Master Gardener Programs cost approximately AUD\$15,326 - AUD\$19,157 per year to run, or AUD\$0.23 per person per year (when the costs are spread over the entire population of the programs' area of influence), or AUD\$7.76 - AUD\$15.52 per hectare of lawn managed through the programs.<sup>18</sup>

Equivalent Australian estimates are not available, but could be calculated during the design of a program.

## Additional Information

Chapter 8: *Education and awareness for stormwater management* provides additional case studies and guidance on how to design a community education and awareness program.

The following *behaviour change* resources are recommended when designing the program:

- Community Change (Victoria, Australia) via <[www.communitychange.com.au](http://www.communitychange.com.au)>.
- Social Change Media (New South Wales, Australia), the home page is available via <<http://media.socialchange.net.au>> and *The Seven Door Social Marketing Approach* (Robinson, undated) is available via <<http://media.socialchange.net.au/strategy>>.

<sup>18</sup> Based on a currency conversion rate of US\$1 = AUD\$1.92.

- Community Based Social Marketing (Canada) via <[www.cbsm.com](http://www.cbsm.com)>.
- *Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing* (McKenzie-Mohr & Smith, 1999). Further information is available from Community Based Social Marketing via <[www.cbsm.com](http://www.cbsm.com)>.

The *Facilitation Toolkit: A practical guide for working more effectively with people and groups* (Keating, 2003) is a recommended resource about facilitating workshops, seminars or group meetings. The toolkit is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300. See also the Coastal Cooperative Research Centre's *Citizen Science Toolbox* (Australia) for advice about particular facilitation techniques (available via <[www.coastal.crc.org.au/toolbox/index.asp](http://www.coastal.crc.org.au/toolbox/index.asp)>).

The *Sustainable Living in Western Australia* website, available via <[www.sustainableliving.wa.gov.au](http://www.sustainableliving.wa.gov.au)> (Government of Western Australia, 2004-2005), contains links to Western Australian resources for sustainable practices including water conservation, household waste management and gardening.

Refer to Section 2.2.7 for further information about recommended best management practices for gardens. The following guidelines, programs and sources of information are some of the recommended resources:

- *Free gardening workshops* - Swan River Trust. These feature information and guidance on fertilise wise and sustainable gardening practices. Telephone (08) 9278 0900 for further information, or refer to <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)>.
- *Fertilise Wise Guides* – The Phosphorus Action Group's Fertilise Wise Guides advise gardeners on appropriate fertiliser types and application rates for soils in the Perth region. For further information and advice about the guides and other available resources, please telephone the Phosphorus Awareness Project Coordinator on (08) 9458 5564. You may also access Fertilise Wise information via the South East Regional Centre for Urban Landcare website <[www.sercul.org.au/pag.html](http://www.sercul.org.au/pag.html)>.
- *Local Plants Guides* – The North Metropolitan Catchment Group's (formerly the North East Catchment Committee, NECC) *Local Plants Community Education Strategy* provides strategies that local government authorities can undertake to promote and encourage the use of local plants within their communities, as well as providing information and resources to the community to aid in its implementation. This includes a set of Grow Local Plants brochures covering suitable species for five soil regions on the Swan Coastal Plain (matching the Fertilise Wise Guide brochures). Comprehensive lists of plants that are suitable for particular uses, such as street trees and hedging, will also be available. Local government authorities will be able to print the relevant brochures for their region in conjunction with conducting one or more activities outlined in the strategy. For further information, telephone the Biodiversity Coordinator at the North Metropolitan Catchment Group (NMCG) on (08) 9271 7922.
- Guidelines on various aspects of saving water when designing and maintaining lawns and gardens (e.g. *Waterwise Garden Centres*, *Waterwise Garden Irrigators*, *New Gardens*, *New Lawns*, *Waterwise Guide to Irrigation*, *Watering Zones*, *Waterwise Guide to Lawns*, *Waterwise Garden Designs*, *Common Plants*) posted on the Being Waterwise page of the WA Water Corporation's website <[www.watercorporation.com.au/savingwater](http://www.watercorporation.com.au/savingwater)>.
- Section 3.19 – Landscaping, Gardens, Turf and Grassed Areas in the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). The directory is designed for small and medium businesses. However, many of the resources are applicable to home gardens. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>, <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning (08) 9278 0300.

Growing local plants may protect water resources, as they require minimal water, pesticides and fertilisers. Further information is available from the following resources:

- To select Perth plants suitable for your soil type, go to the APACE WA website <<http://web.argo.net.au/apace/soiltypes.htm>> or by telephoning APACE on (08) 9336 1262.
- *Purchasing Local Native Plants* – Go to the Everlasting Concepts website (<[www.everlastingconcepts.com.au](http://www.everlastingconcepts.com.au)>), which provides contact details for nurseries throughout WA that stock WA native plants. The website also provides information on how to grow native plants. In addition, the Friends of Kings Park hold several native plant sales throughout the year. Information about the Friends of Kings Park and plant sales is available via <[www.kpbg.wa.gov.au](http://www.kpbg.wa.gov.au)>. Select ‘Growing Plants’ / ‘Community Involvement’ / ‘Friends of Kings Park’ / ‘Coming Events’.
- *Wildflower Society of Western Australia* – The Society provides a range of resources (e.g. books) and advice about planting local native plants. Refer to their website at <<http://members.ozemail.com.au/~wildflowers>>.
- *Growing Locals – Gardening with Local Plants in Perth* by Robert Powell and Jane Emberson (1996). This book can be purchased by telephoning the WA Naturalists Club on (08) 9228 2495 or via <[www.wanats.iinet.net.au](http://www.wanats.iinet.net.au)>.
- *Free Gardening Advisory Service* - Botanic Gardens and Parks Authority (08) 9480 3672 <[www.bgpa.wa.gov.au](http://www.bgpa.wa.gov.au)>. Select ‘Growing Plants’ / ‘Community Involvement’ / ‘Master Gardeners’. Note: this service is different to the United States Master Gardeners program, referred to in the Recommended Practices section.
- *Designing and maintaining gardens* - Advice about how to grow local native plants, deal with pests and diseases effectively and responsibly, use less water and fertiliser, save time and money and attract Western Australian wildlife into your garden. Available via <[www.greatgardens.info](http://www.greatgardens.info)>.
- Section 3.16 - Growing Local Plants to Protect Water Resources in the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004). Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>, <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

Section 2.3.4 has useful information about the benefits of community participation programs versus traditional education programs.

## Examples / Case Studies

### Gardening Workshops in Western Australia

The Swan River Trust, Water Corporation and Nursery and Garden Industry WA sponsored free gardening workshops throughout the Swan and Canning Catchment during spring 2003 and autumn and spring 2004. These featured information and guidance on fertilise wise and sustainable gardening practices. During spring 2003, over 1900 people attended one of 21 workshops (Landcare Solutions, 2004). Another 15 workshops were held in Autumn 2004, which were attended by 1235 people. The age range of workshop participants in the Autumn 2004 series was 32-35% were more than 50 years old, 56-57% were 30-50 years old and 8-12% were less than 30 years old (Landcare Solutions, 2004). Surveys conducted at the end of each Autumn 2004 workshop demonstrated a considerable increase in participant understanding of catchment friendly gardening (Landcare Solutions, 2004). For more information, go to the Swan River Trust website <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or contact the Trust office during work hours on (08) 9278 0900. In addition, four workshops were held in the Peel Catchment during autumn 2004. These workshops were sponsored by the Shires of Augusta-Margaret River and Busselton, Town of Kwinana and City of Mandurah, with assistance from Water Corporation and Natural Heritage Trust.



*Figure 1. A display garden is set up at each Great Gardens workshop to promote local native plants. (Photograph: Garry Heady, Heady Enterprises.)*



*Figure 2. The mayor of South Perth opening a Great Gardens workshop. Local governments host all Great Gardens workshops to maximise local ownership. (Photograph: Garry Heady, Heady Enterprises.)*

## Sustainable Living Programs in Western Australia

Examples of sustainable living programs in Western Australia include: the Living Smart Program developed by The Meeting Place Community Centre, City of Fremantle, Murdoch University and Southern Metropolitan Regional Council (SMRC) (contact (08) 9432 9914 or <[www.freofocus.com/projects/html/living\\_smart.cfm](http://www.freofocus.com/projects/html/living_smart.cfm)>); the Creating Communities program (contact (08) 9284 0910 or <[www.creatingcommunities.com.au](http://www.creatingcommunities.com.au)>); and the Green Houses Program (energy and water conservation only) by SMRC and Murdoch University (contact (08) 9316 3988 or <[www.smrc.com.au/greenhouses](http://www.smrc.com.au/greenhouses)>).

The Living Smart and Green Houses programs use proven goal-setting techniques and recognise that information alone is not enough to achieve sustained behaviour change. For example, as a result of attending the Living Smart pilot program:

- Participants significantly increased their environmental knowledge and the number and frequency of sustainable behaviours.
- 63% of participants said it was very important for them to reach their goal and the majority thought setting goals increased their motivation and made them more likely to act.
- In all topics (including Simple Smart Lifestyles, Goal Setting, Waste Smart, Smart Gardens, Power Smart, Water Smart, Health Smart, Move Smart and Take Action), participants increased their effort towards sustainable practices by 17-22%.
- 68% said that the program changed the way they think about lifestyle and environmental issues.
- Half of the participants felt that what they learned in the program would influence them for a very long time and 41% said it would influence them forever (Sheehy, 2004).

Sustainable living programs provide additional benefits for communities. For example, as a result of attending the Living Smart pilot program, 91% of participants felt more a part of the community, 95% increased their knowledge of community resources and services and 82% increased their sense of wellbeing (Sheehy, 2004).

Communication techniques include workshops, self-paced learning via booklets, ongoing dialogue (newsletters and meetings) and/or websites.

## Chesapeake Bay Residential Watershed Program (United States)

The Chesapeake Bay Residential Watershed Water Quality Management Program (Virginia Cooperative Extension, 2001) was an intensive training program that involved recruitment of residents from selected neighbourhoods, lawn care seminars by trained extension agents, home visits and data collection by trained Master Gardener volunteers, and demonstration lawns. The program included pre- and post-participation surveys to assess changes in people's attitudes, knowledge and self-reported behaviour.

From 1990 to 2001, approximately 3,600 residents participated in the program in 18 counties and cities in Virginia, with an estimated area of lawn managed through the program in 2001 of 158 hectares.

Results reported by Virginia Cooperative Extension (2001) and Aveni (2002) included the following:

- Soil testing by participants increased from 25% to almost 100% following participation in the program.
- Composting grass clippings increased from 22% - 54% to 50% - 71% following participation.
- The proportion of people who knew how much fertiliser they applied to their lawn each year increased from 25% to 66% following participation.
- The proportion of people fertilising their lawn during autumn (as promoted) increased from 55% to 77% following participation.
- The proportion of people who aerated their lawns increased from 12% - 50% to 75% - 100% following participation.
- Estimates derived from self-reported behavioural change data indicated that the load of total nitrogen and total phosphorus applied to residential lawns was reduced by approximately 49 – 98 kg/ha/year as a result of participation in the program.

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## 2.3 Educational and participatory practices

### 2.3.3 Encouraging participation by the community in stormwater management

#### Description

Stormwater-related community participation programs seek to:

- engage the community so they understand the problem, and can participate in the development and implementation of solutions;
- treat community members as people who, given support and time, can quickly build knowledge and positively contribute to the formulation of new and sustainable approaches to stormwater management; and
- foster ownership of the stormwater-related problem by the local community.

This section recommends an increased focus on public participation in urban stormwater management (e.g. involving the community in deliberative decision-making processes), as opposed to traditional community education approaches (e.g. distribution of education materials).

Traditional community educational approaches may be considered ‘top-down’, i.e. consultative rather than participatory, delivered by experts from outside the site of intervention. Public participation is ‘bottom-up’, concerned with spreading control and ownership as widely as possible throughout the community and ‘developing a partnered or shared analysis of both the problem and the solution’ (Ryan and Brown, 2000, p. 10).

Ryan and Brown (2000) promote public participation and consensus as ‘the key vehicles for improving the management of urban stormwater through social action’ (p. 10).

#### Applicability

This technique is widely applicable to stormwater-related activities that seek to alter people's behaviour. Advocates of the participatory approach challenge the effectiveness of traditional ‘top-down’ education methods in changing people’s behaviour, and urge people to consider moving towards a more participatory approach.

The technique can be applied to common stormwater-related activities such as:

- the development of management plans;
- education and participation programs (e.g. programs within a catchment to protect the health of a local waterway or wetland and anti-litter campaigns within a commercial district); and
- specific activities such as stormwater drain stencilling and clean-up activities.



*Figure 1. Clean Drains - River Gains drain stencilling at Blue Gum Lake, Booragoon. (Photograph: South East Regional Centre for Urban Landcare.)*

## Recommended Practices

The development of a stormwater management plan in a catchment or local government area could adopt a participatory approach. For example, awareness could be raised in the community then volunteers could be sought to participate in development of the plan. Participation techniques such as citizen juries can be used to:

- select a group of citizens that is representative of the community;
- deliberate and agree on priority issues to be managed; and
- jointly develop sustainable solutions.

‘Expert witnesses’ can also be used to provide technical information and advice to community members as needed. Involvement of sections of the community should also be sought during implementation of the plan.

Resources for planning public participation in decision-making and designing behaviour change programs are provided in the Additional Information section.

## Benefits and Effectiveness

Participation programs produce environmental benefits (e.g. waterway health) and social benefits (e.g. through building the capacity of individuals and groups).

Taylor and Wong (2002c) found that participation programs which promote widespread ownership of the stormwater pollution issue, and encourage community participation to develop and implement a solution, are more effective at changing behaviour than programs that rely on traditional forms of education. However, the success of a participatory approach depends on the capacity of the community to develop and implement the solutions. This is supported by other research, for example, ‘a comprehensive review of the literature finds very little evidence of the success of traditional ("top down") community education activities...’ (Ryan and Brown, 2000, p. 7).

In a literature review on *littering* behaviours and intervention strategies, Reeve *et al.* (2000) also stress the importance of a participatory approach, stating ‘there is ample evidence from the literature that community participation in the design and management of public space, together with the coupling of local litter education with community involvement strategies, is still one of the best ways to obtain the sense of local ownership and relevance that enables social norms against littering to be effective’ (p. 30).

This view is supported by Curnow *et al.* (2002) who include involvement of the community (e.g. involving users of public areas in the design and placement of litter bin facilities) as one of eight principles for effecting change to reduce littering in public places.

## Challenges

Taylor and Wong (2002c) report that genuine participation programs for stormwater management are still relatively rare in Australia, with the exception of stormwater drain stencilling. One of the likely reasons for this is that increased resources (especially time) are often required to shift the emphasis from traditional educational approaches to ones with extensive community involvement. Participatory programs require partnerships between agencies and community members/groups (Drucker, 1986), which take time to build and require a significant investment of enthusiasm, time and trust.

In most cases, community participation requires capacity building, which involves a transfer (or flow between) of knowledge, skills and resources from agencies to the community. An agency should ensure the community is well informed of the issues if they become involved in the decision-making processes. This type of process is initially time consuming and resource intensive. Also, a change in representation from the community can result in a loss of knowledge (and leadership), often requiring a re-education of new community members.

Adopting a participatory approach to effect behavioural change represents a significant change of direction for many urban stormwater managers in Australia, who frequently rely on traditional education methods such as pamphlets, advertisements, fact sheets and newsletters. It also shifts the focus of control for urban stormwater management away from professional technical managers (e.g. engineers in a local government) towards the community. This shift in control may be unsettling for some individuals and organisational cultures.

## Cost

The cost of adopting a participatory approach will vary depending upon the project and the degree of participation. Costs would however be expected to be greater than those associated with traditional forms of stormwater-related education. For example, a citizen jury may be used to facilitate a deliberative and participatory approach to decision-making. Such juries may involve 15 people for two to four days per sitting. Jurors and facilitators are paid for their time. Additional costs include the hire of the venue, the provision of background information, costs associated with the involvement of expert witnesses, documentation of the results, and administration. This method could cost up to \$10,000 per sitting.

## Additional Information

Chapter 8: *Education and awareness for stormwater management* provides additional case studies and guidance on how to design a community education and awareness program.

Recommended resources for *community participation in decision-making* include:

- The Coastal Cooperative Research Centre's *Citizen Science Toolbox* (Australia), available via <[www.coastal.crc.org.au/toolbox/index.asp](http://www.coastal.crc.org.au/toolbox/index.asp)>.
- The Western Australian Department of the Premier and Cabinet's *Consulting Citizens: A resource guide* (DPC, 2002) and *Consulting Citizens: Planning for success* (DPC, 2003). Available via <[www.citizenscape.wa.gov.au/docs/blue\\_guide.pdf](http://www.citizenscape.wa.gov.au/docs/blue_guide.pdf)> and <[www.citizenscape.wa.gov.au/docs/red\\_guide.pdf](http://www.citizenscape.wa.gov.au/docs/red_guide.pdf)> or by telephoning (08) 9222 9888.

The following *behaviour change* resources are recommended for designing the program:

- Community Change (Victoria, Australia) via <[www.communitychange.com.au](http://www.communitychange.com.au)>.
- Social Change Media (New South Wales, Australia), the home page is available via <<http://media.socialchange.net.au>> and *The Seven Door Social Marketing Approach* (Robinson, undated) is available via <<http://media.socialchange.net.au/strategy>>.
- Community Based Social Marketing (Canada) via <[www.cbsm.com](http://www.cbsm.com)>.
- *Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing* (Mckenzie-Mohr & Smith, 1999). Further information is available from Community Based Social Marketing via <[www.cbsm.com](http://www.cbsm.com)>.

The *Facilitation Toolkit: A practical guide for working more effectively with people and groups* (Keating, 2003) is a recommended resource to use when facilitating workshops, seminars or group meetings. The toolkit is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300.

The *Sustainable Living in Western Australia* website, available via <[www.sustainableliving.wa.gov.au](http://www.sustainableliving.wa.gov.au)> (Government of Western Australia, 2004-2005), contains links to Western Australian resources for sustainable practices including water conservation, household waste management, gardening and growing local native plants.

Refer to the Examples / Case Studies provided in Section 2.3.2, as these intensive training programs use proven goal-setting techniques and recognise that information alone is not enough to achieve sustained behaviour change. Communication techniques include workshops, self-paced learning via booklets, on-going dialogue (newsletters and meetings) and/or websites.

For focused participation programs involving new estates, refer to Section 2.3.5.

## Examples / Case Studies

### Bronte Catchment Project (NSW)

The Bronte Catchment Project in Waverley, Sydney, is a good example of how a ‘bottom-up’, participatory and deliberative approach to urban water management can produce enhanced results. This was a local stormwater management project involving community development activities, deliberative decision-making processes (e.g. a citizen jury and citizens’ Telepoll) and a review of the local government’s activities and processes. The project:

- used social research, community development and active learning techniques to profile community barriers to participation;
- strengthened environmental education initiatives with participatory strategies;
- tested new deliberative decision-making processes in environmental management;
- built democratic and environmental capacity across the catchment; and
- demonstrated the critical importance of Council and community commitment to participation in environmental management (Elton Consulting, undated).

The project involved three primary components:

- the development, implementation and evaluation of targeted stormwater education campaigns;
- installation of gross pollutant control devices; and
- physical and observational monitoring of pollutants and behaviours within the catchments.

The project delivered positive changes in people's stormwater-related environmental attitudes and values, knowledge about urban stormwater pollution, and self-reported behaviour (Elton Consulting, undated).

The elected leaders of Waverley Council (e.g. the Mayor) and its officers have publicly spoken about the success of the project and have even created an ongoing consultative role for the citizens involved in the participatory process.

Further information is available from the New South Wales Environmental Protection Authority via <[www.epa.nsw.gov.au/stormwater/casestudies/index.htm](http://www.epa.nsw.gov.au/stormwater/casestudies/index.htm)> and Elton Consulting via <[www.elton.com.au/bronte.htm](http://www.elton.com.au/bronte.htm)>.

## Clean Drains - River Gains (WA)

Clean Drains – River Gains is a campaign by the South East Regional Centre for Urban Landcare (SERCUL) to reduce nutrients and other contaminants in receiving water bodies. The campaign aims to raise awareness about the link between stormwater drains and natural waterways, as well as providing information on positive behavioural changes that will reduce stormwater pollution. The campaign delivers its message through activities such as stormwater drain stencilling with the Clean Drains - River Gains slogan, letterbox drops in residential, commercial and industrial areas, displays at community events, shopping centres and libraries, and through products including posters, postcards, pamphlets, a website, re-useable shopping bags and stencils. Businesses, local governments and community groups are encouraged to hire the stencils for stormwater drain stencilling in their area.

For further information, contact the Clean Drains - River Gains Campaign, care of SERCUL, 69 Horley Road, Beckenham WA 6107, via <[www.sercul.org.au](http://www.sercul.org.au)> or by telephoning (08) 9458 5564.

## Stormwater Education Strategy (WA)

The North Metropolitan Catchment Group (NMCG, formerly the North East Catchment Committee, NECC) has prepared a *Stormwater Education Strategy* (NECC, 2004) for the Western Region of Councils (WESROC), which includes Cottesloe, Mosman Park, Peppermint Grove, Subiaco, Nedlands, Claremont and Cambridge.

The strategy targets community and industry groups and schools, and outlines the effectiveness of stormwater education strategies in the Eastern States and overseas.

Further information is available from NMCG on 9271 7922 or via <<http://members.westnet.com.au/bbcg>>.

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## 2.3 Educational and participatory practices

### 2.3.4 Education and participation on campaigns for commercial and industrial premises

#### Description

Education and participation campaigns for commercial and industrial premises should be tailored for each target audience. Planning should include development of the procedures for surveying the target audience, designing (involving the target audience where possible) and delivering the campaign (incorporating site assessments and incentives/disincentives), and evaluation.

The campaigns may focus on pollutants, behaviours, and best practice techniques and technologies that are most important for the area within which the campaign is operating.

The Light Industry Project, Green Stamp Programs and the Centre of Excellence in Cleaner Production's training programs are good examples of successful education and participation programs for commercial and industrial premises in Western Australia. For further information about these programs, including the training and support available, refer to the Examples/Case Studies section.

Industrial and commercial premises can pose significant risks to stormwater and shallow groundwater due to the activities they undertake and the types of materials being handled and stored on site. Promoting sound management practices and technologies, and ensuring a high degree of compliance (either through education, incentives or regulation) should be a high priority in any urban stormwater management program.

#### Applicability

These campaigns or programs are applicable to all commercial and industrial areas, however they are particularly applicable in the following situations:

- areas with sandy soils that have low nutrient and moisture retention capabilities;
- areas draining to sensitive water bodies (e.g. conservation category wetlands, or catchments that are under stress from nutrient inputs, such as the Peel-Harvey and Swan-Canning);
- drinking water catchments;
- areas where premises are close to water bodies; and
- areas that are not sewered (e.g. parts of the Canning catchment). This may elevate the risks of adverse impacts from illegal discharges of wastes to stormwater or shallow groundwater.

#### Recommended Practices

Use proven *behaviour change* techniques, such as commitments/goal setting, prompts (to address forgetting), develop social norms and consider incentives. Refer to the Additional Information section for a list of recommended behaviour change resources.

Targeted education and participation programs should be applied on a priority basis. An investigation should be undertaken to determine those premises that pose the greatest risk to the health of water bodies. For example, this has been undertaken for industrial premises on the Swan Coastal Plain (see Water and Rivers Commission, 2000b).

Campaigns should specifically tailor messages to a particular target audience (i.e. based on the type of business or industry sector). To maximise the impact of the campaign, consider complementary use of site assessments, incentives (e.g. positive recognition, assistance) and disincentives (e.g. penalties).

The design of the campaign should draw upon knowledge gained from executing similar campaigns (e.g. those involving similar target audiences, promoting similar forms of behaviour, and involving similar timeframes and budgets). Similar case studies should be carefully studied at the beginning of a new project. Leading stormwater managers in other Australian States and research institutions should be briefly consulted to identify the existence of similar case studies.

It is important to understand the knowledge and attitudes of the target audience, as well as the context in which they conduct their work. Typically, social scientists will survey the target audience to answer these questions prior to the campaign being designed. This survey can also act as a baseline monitoring event, to help evaluate the overall effectiveness of the campaign.

Such surveys can identify critical pieces of information, such as the need to develop education materials in several languages, the need to address specific knowledge gaps or attitudes, and the need to deliver educational messages in a form that is compatible with the work environment of the target audience.

Ideally, such campaigns will take a ‘participatory approach’ and seek to involve the target audience in the design and delivery of the campaign. Campaigns that are able to enhance the participatory element of the program are generally more successful than those that rely upon traditional forms of education.

Educational materials designed for commercial and industrial premises may include posters, flyers, checklists, brochures, fact sheets, guidelines, magnets, calendars, caps, T-shirts, drain stencils, procedures, training materials (e.g. videos), signs, etc.



Figure 1. Industrial site drain stencil. (Photograph: Colin Ceresa, ARRIX.)

Educational events may also be used, such as training sessions, trade displays and field days (to highlight best management practices and technologies), and free lunches or barbecues (where educational messages are communicated).

Incentives to change behaviour could include promotional give-aways (e.g. spill clean-up kits, signs, T-shirts), free educational events (as described above), recognition in the local media, awards schemes with associated publicity, cash grants, assistance from environmental specialists (e.g. to conduct site assessments and recommend solutions to identified problems), listing in a ‘green business directory’, licence fee reductions and free waste disposal.

Due to the specific needs of commercial and industrial businesses, education campaigns will often include a site assessment. Free site assessments are undertaken by suitably qualified specialists to highlight to the business owner where improvements may or should be made. Typically, an amnesty from prosecution under environmental law is provided to participating businesses for a given period (e.g. three months).

Working through the relevant industry associations is highly recommended. For example, this approach has been successful for the Green Stamp Program, where the relevant industry associations are directly involved in designing the program and promoting active involvement by members.

Refer to the Examples / Case Studies Section. These examples highlight the different approaches that may be taken.

## Benefits and Effectiveness

Businesses that are more aware of environmental issues as a result of an educational campaign may be willing to partner with local governments, catchment groups and water service providers, and sponsor waterway health-related programs and activities that reach a wider audience in the community (e.g. broad awareness campaigns, clean-up events, waterway rehabilitation projects). Businesses may receive positive publicity in return for the donation of money, materials, personnel or use of their facilities (US EPA, 2001b).

Taylor and Wong (2002c) reviewed a number of education and behaviour change programs for industrial and commercial premises (e.g. campaigns involving media, site assessments and one-to-one discussions) and concluded that they can deliver:

- 5% - 15% increase in environmental knowledge/awareness.
- 58% increase in the number of people undertaking at least one desirable behaviour (e.g. storage of materials, waste disposal practices, staff training and/or environmental management systems).
- 26% - 40% increase in the number of people undertaking a specific desirable behaviour (e.g. 40% of respondents reported changes to the storage of materials, 34% of respondents reported changes to waste disposal practices, 29% of respondents reported changes to environmental management systems and 26% of respondents reported changes to staff training).

## Challenges

If the proposed education campaign is purely voluntary and promotes behavioural change that is difficult or costly to implement, its effectiveness may be limited. The campaign should try to create an environment where environmental compliance is promoted through incentive mechanisms and then regulatory enforcement approaches if necessary. For example, an anti-litter education campaign focusing on the waste behaviours of traders in a small commercial shopping centre may discover during its pre-campaign survey of traders that the public litter bin infrastructure is inadequate, as are the waste receptacles the traders use to store their solid waste. Fixing these infrastructure problems as a part of the campaign may be necessary to facilitate behavioural change in the centre (in addition to the promotion of desired waste management behaviours).

The willingness of businesses to participate is important to the success of the campaign, so planning should include consideration of the resources and interests of participants. Where a campaign is followed up by a regulatory approach, ensure businesses have enough time to implement new initiatives.

These types of campaigns are typically government funded. Acquiring the funds to run the campaign may be a significant challenge.

## Cost

The cost associated with developing an educational campaign for commercial or industrial premises depends greatly upon the type and quantities of materials produced, the human resource demands and the scope of the campaign. Where campaigns include surveys of the target audience, site assessments of premises, and one-to-one discussions with business owners, the time demands on staff running the campaign can be considerable.

Some indicative costs are given for the New South Wales and South Australian case studies, below.

## Additional Information

Refer to Section 2.2.10 for recommended best management practices related to commercial and industrial premises. Section 2.2.8 is relevant for maintenance of vehicles, plant and equipment (including washing).

Chapter 8: *Education and awareness for stormwater management* provides guidance on how to design an education and awareness program, including programs for commercial and industrial premises.

The following *behaviour change* resources are recommended when designing the program:

- Community Change (Victoria, Australia) via <[www.communitychange.com.au](http://www.communitychange.com.au)>.
- Social Change Media (New South Wales, Australia), the home page is available via <<http://media.socialchange.net.au>> and *The Seven Door Social Marketing Approach* (Robinson, undated) is available via <<http://media.socialchange.net.au/strategy>>.
- Community Based Social Marketing (Canada) via <[www.cbsm.com](http://www.cbsm.com)>.
- *Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing* (Mckenzie-Mohr & Smith, 1999). Further information is available from Community Based Social Marketing via <[www.cbsm.com](http://www.cbsm.com)>.

The *Facilitation Toolkit: A practical guide for working more effectively with people and groups* (Keating, 2003) is a recommended resource to use when facilitating workshops, seminars or group meetings. The toolkit is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300. See also the Coastal Cooperative Research Centre's *Citizen Science Toolbox* (Australia) for advice about particular facilitation techniques (available via <[www.coastal.crc.org.au/toolbox/index.asp](http://www.coastal.crc.org.au/toolbox/index.asp)>).

Water Quality Protection Notes and the *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004) are recommended resources that may be used to develop education and participation campaigns.

Refer to relevant Water Quality Protection Notes, available from the Department of Environment via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)>, or by telephoning (08) 9278 0300. For example:

- *Mechanical Servicing and Workshops* (Water and Rivers Commission, 2002);
- *Mobile Mechanical and Cleaning Services* (Draft) (DoE, 2004);
- *Washdown of Mechanical Equipment* (WRC, 1998);
- *Industrial Sites Near Sensitive Water Bodies* (WRC, 1999);
- *Chemical Spills – Emergency Response Planning* (WRC, 2002);
- *Stormwater Management at Industrial Sites* (WRC, 2002);
- *Toxic and Hazardous Substances – Storage and Use* (WRC, 2002).

The *Environmental Management and Cleaner Production Directory for Small and Medium Businesses* (DoE and SRT, 2004) lists Western Australian, interstate and international environmental management and cleaner production resources for commercial and industrial premises. The Directory is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.swanrivertrust.wa.gov.au](http://www.swanrivertrust.wa.gov.au)> or by telephoning the Swan River Trust on (08) 9278 0900.

Section 2.3.3 is designed for the general community, rather than industrial and commercial premises. However, this section has useful information about the benefits of participation programs versus traditional education programs.

## Examples / Case Studies

### The Light Industry Project and Green Stamp Programs, Western Australia

The Light Industry Project is a network of industry, State and local government, community groups, education and training providers. The project aims to provide small to medium-sized businesses with on-ground support, positive incentives and resources. Different levels of training and support are available, depending on the needs of particular businesses and industry sectors. Further information is available by telephoning (08) 9374 3301 or via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> and <[www.wastewise.wa.gov.au](http://www.wastewise.wa.gov.au)>. The Light Industry Project office is at the Swan Catchment Centre, 80 Great Northern Highway, Middle Swan WA 6056.

The Swan River Trust and a number of local governments began the Swan-Canning Industry Project in 1996. The project was initiated to evaluate the environmental risks and impacts of small to medium-sized business in the Swan and Canning catchment. The Swan-Canning Industry Survey was conducted in 1997 and 1998, involving on-site inspection and assessment of 522 light industrial premises in the metropolitan area. The Swan-Canning Industry Working Group developed a number of recommendations that are published in the *Swan-Canning Industry Survey Final Report* (WRC, 2000a) to address these issues.

Green Stamp is an industry-specific environmental accreditation and education program that assists small to medium businesses to implement environmental best management practices. The program provides environmental assessments, training and support, including simple environmental management plans and industry-specific case studies and environmental guidelines. Green Stamp Programs are currently available through the following industry associations:

- Motor Trade Association (MTA) of Western Australia. Resources include the *Environmental Products and Services Directory* and guidelines such as *Asbestos Use and Disposal*, *Building New Premises*, *Bunds and Bunding*, *Cleaning up Spills*, *Cleaning Vehicles*, *Coolant Management*, *Degreasers and Detergents*, *Environmental Policy*, *Mobile Mechanics*, *New Environmental Laws*, *Oil Separators*, *Parts Washers*, *Preventing Oil Pollution*, *Purchasing Spill Kits*, *Solvent Thinner Recycling Systems*, *Wastewater Management for Body Repairers*, *Environmental Assessments for Body Repairers* and *Environmental Assessments for Mechanical Repairers*. Further information is available by telephoning the Automotive Industry Green Stamp Officer on (08) 9345 3466 or via <[www.greenstamp.com.au](http://www.greenstamp.com.au)>. Their office is at MTA House, 224 Balcatta Road, Balcatta WA 6914. Further information about the Motor Trade Association of WA's Green Stamp Program is available in Chapter 8: *Education and Awareness for Stormwater Management*.
- The Printing Industry Association. Resources include *Managing and Monitoring Environmental Impacts – A Simple Environmental Management Plan for Printing Businesses*, *Accreditation Criteria for Printing Businesses*, *Baseline Audit for Printing Businesses* and information sheets on *Chemical and Ink Management*, *Environmental Law*, *Protecting Stormwater Drains*, *Solid Waste Management* and *Wastewater Management*. You can telephone the Printing Industry Green Stamp Coordinator on (08) 9278 0300. Further information is available via <[www.printnet.com.au](http://www.printnet.com.au)>.

- Building Service Contractors Association (formerly the Master Cleaners Guild). The Building Service Contractors Association Green Stamp Coordinator is available by telephoning (08) 9278 0300 for further information.
- Other industry associations are working with the Department of Environment to extend the Green Stamp Program to their industry sectors.

The Green Stamp Program was originally developed by the Department of Environment and the Motor Trade Association of Western Australia to encourage automotive businesses to comply with environmental laws and to reward those going beyond their legislative requirements. Due to the success of the Program in Western Australia, it is now being implemented nationally as a part of the Federal Government's National Eco-efficiency Program.

### Clean Drains - River Gains, Western Australia

Clean Drains – River Gains is a campaign by the South East Regional Centre for Urban Landcare (SERCUL) to reduce nutrients and other contaminants in receiving water bodies. The campaign aims to create behavioural changes through awareness raising and educational activities such as stormwater drain stencilling, displays, letterbox drops and products including posters, postcards, pamphlets, a website and stencils. Businesses, local governments and community groups may hire the stencils for stormwater drain painting on commercial and industrial premises.

For further information, contact the Clean Drains - River Gains Campaign, care of SERCUL, 69 Horley Road, Beckenham WA 6107, via <[www.sercul.org.au](http://www.sercul.org.au)> or by telephoning (08) 9458 5564.

### Manly, New South Wales - 'The Great Estate' Stormwater Environmental Education Program

Taylor and Wong (2002c) reported preliminary results from Smith (2002a and 2002b) and Smith and Simmons (2002) involving a study of the small (11.2 ha) Balgowlah industrial estate in Manly, Sydney. The study included an evaluation of the effectiveness of industry education and auditing as non-structural best management practices to promote improved housekeeping practices and reduce stormwater pollution.

The Great Estate Stormwater Environmental Education Program involved face-to-face discussions with operators of premises within the industrial estate, audits and promotion of improved housekeeping practices such as material handling and stockpiling. An Education Officer was appointed for 12 months to undertake this work from March 2001 to March 2002.

Substantial opportunities were taken by the occupants of the estate to improve the management of material storage. For example, in one of the estate's three sub-catchments, 1,260 m<sup>2</sup> (or 21% of the total area) used for stockpiling was converted from an uncovered area to a roofed area. The approximate cost of education and auditing activities over 12 months was AUD\$70,000 (McManus, 2002).

Reductions in annual pollutant loads that could *potentially* be attributed to education, auditing and better industrial housekeeping were approximately 8% (total suspended solids), 40% (total nitrogen), 49% (total phosphorus), 42% (copper), 72% (lead) and 83% (zinc).

Further information is available from Manly Council via <[www.manly.nsw.gov.au/greatestate](http://www.manly.nsw.gov.au/greatestate)>.

### South Australia - Be Stormwater Smart

Laris (2001) reported on the effects of the South Australian Be Stormwater Smart Project. The project aimed to reduce stormwater pollution by raising awareness about stormwater issues, particularly in the commercial, industrial and local government sectors. Pollution Prevention Project Officers within each of

the host local governments visited non-residential premises (e.g. small to medium-sized businesses) to promote practices to minimise stormwater pollution. No enforcement activities were involved for this project.

By mid April 2001, 319 premises were visited at least once, with sufficient funding to allow 20 - 30 sites to be visited each quarter (Laris, 2001). The annual running cost was approximately AUD\$180,000, not including in-kind support from three host local governments (Labaz, 2002).

The effect of the project on the levels of awareness, self-reported behaviour and actual behaviour of participants was evaluated through telephone surveys, face-to-face and telephone interviews and site assessments. The evaluation strategy included the validation of *self-reported* behavioural changes, involving a number of site visits after the telephone survey.

The project was successful in changing behaviour and, in particular, ‘the great majority of businesses visited by the project and initially assessed as unsatisfactory do make significant changes towards compliance’ (Laris, 2001, p. 7). The case study is important, as it is one of the few documented projects to make a sound attempt to validate self-reported behaviour, and convincingly demonstrate that positive behavioural change occurred (Taylor and Wong, 2002c).

Further information is available from the North Adelaide and Barossa Catchment Water Management Board via <[www.nabcatchment.net/projects/be\\_stormwater\\_smart.shtml](http://www.nabcatchment.net/projects/be_stormwater_smart.shtml)> and <[www.nabcatchment.net/action/projects.shtml](http://www.nabcatchment.net/action/projects.shtml)>.

## Other

Chapter 8: *Education and awareness for stormwater management* provides guidance on how to design an education and awareness program, including case studies that may be relevant to commercial and industrial premises. Other case studies can be identified through publications such as Taylor and Wong (2002c), Lehner *et al.* (1999) and US EPA (2001).

## References and Further Information

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Water and Rivers Commission 1999, *Industrial Sites Near Sensitive Water Bodies*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

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Water and Rivers Commission 2002, *Toxic and Hazardous Substances – Storage and Use*, Water Quality Protection Note, Water and Rivers Commission, Perth, Western Australia. Available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning the Department of Environment on (08) 9278 0300.

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## 2.3 Educational and participatory practices

### 2.3.5 Focused stormwater education involving new estates

#### Description

This best management practice involves engagement of a temporary Stormwater Management / Environmental Officer for a large residential estate land development. The officer may be employed on a part or full-time basis (depending on the size of the estate) and may play a role in:

- ensuring stormwater quality during construction/building (e.g. helping to maintain the integrity of structural controls such as infiltration systems, educating builders and sub-contractors while they are on-site, monitoring erosion and sediment controls, and monitoring construction practices);
- promoting water sensitive gardening practices, as new landowners begin to landscape their properties;
- educating new landowners about sustainable practices for washing cars, car maintenance (e.g. changing oil), composting, disposing of animal wastes, disposal of swimming pool discharges, bin washing, and how to keep materials such as lawn clippings and sediment out of the stormwater management system;
- undertaking manual litter collections in areas such as parks (as psychological studies indicate that if you keep a public place clean it promotes reduced rates of littering);
- promoting positive stormwater initiatives that occur on the estate via local media (i.e. provide positive feedback to reinforce desired forms of behaviour);
- educating mobile businesses about stormwater management when they are on-site (e.g. dog washing franchises, external house and roof cleaners and car servicing businesses); and
- explaining to new landowners about the purpose of, and how to look after, permanent water sensitive urban design features in the estate (e.g. not driving on grassed swales).

#### Applicability

This practice is suitable for large residential estates/land developments, particularly in the following situations:

- areas with sandy soils that have low nutrient and moisture retention capabilities;
- areas draining to sensitive water bodies (e.g. conservation category wetlands, or catchments that are under stress from nutrient inputs, such as the Peel-Harvey and Swan-Canning);
- drinking water catchments;
- areas where gardens are close to water bodies;
- areas subject to erosion (e.g. due to steep slopes); and
- areas with large gardens and lawns.

The role could be valuable in protecting infiltration systems during construction and educating residents on water sensitive management practices at the building stage, when there is the greatest potential to adopt measures such as waterwise and fertilise wise gardening, and the reuse of shallow groundwater or roof water.

## Recommended Practices

Use proven *behaviour change* techniques, such as commitments/goal setting, prompts (to address forgetting), develop social norms and consider incentives. Refer to the Additional Information section for a list of recommended behaviour change resources.

This role could be undertaken by a local environmental group (e.g. staff from the group may be funded by the developer and/or local government), which would help to build expertise and skills in the region. Developer funding may be applicable if the Stormwater Management / Environmental Officer is exclusively engaged for a particular development. However, funding or employment by local government or a catchment management authority may be advantageous, so that the officer could be engaged over a much larger area.

The role would start immediately prior to construction and continue for at least six months after the development has effectively finished (i.e. the vast majority of potential residents are living in the estate).

A specific 'role description' should be developed for the position by the developer and local government as part of a site-based stormwater management plan. The role description would be specifically worded so that an enforcement officer could easily check that each element of the role had been delivered.

To engage the community, it may be advantageous for the officer to address a range of *sustainable living* issues, e.g. stormwater management, water conservation, water sensitive gardening, waste minimisation and energy efficiency. Examples of sustainable living programs are provided in the Examples / Case Studies section.

## Benefits and Effectiveness

The officer may provide valuable marketing benefits to the developer and help to build human and social capital by:

- welcoming new residents to the estate;
- fostering a positive sense of community (e.g. psychological studies show that if you can foster a positive sense of community it promotes reduced rates of littering);
- running basic education and participation events (e.g. stormwater-related training courses like the Swan River Trust's gardening workshop program in Western Australia and the Master Gardener Program in the United States), activities for children, clean-up events and drain stencilling); and
- helping to establish an *ongoing* environmental group for the catchment area (i.e. to keep the momentum going after the officer's tenure expires).

In terms of potential pollutant removal efficiencies, the effectiveness of this best management practice is currently unknown. A conservative estimate of the post-construction 'pollutant removal efficiency' is approximately 20% for typical stormwater pollutants in a residential development<sup>19</sup>.

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<sup>19</sup> That is, the BMP can be expected to reduce the event mean concentration of typical pollutants in stormwater by approximately 20% during the post-construction stage of the development.

## Challenges

This best management practice is difficult to evaluate and success is largely dependent on the skills and commitment of the Stormwater Management / Environmental Officer.

The program would operate for a limited period only. After this time, continuing education should be undertaken via local or State government initiatives.

## Cost

The cost should be determined on a case-by-case basis. However, it is relatively easy to estimate. Principal costs include the officer's time, transport, and consumables (e.g. educational products, advertisements).

When the many potential benefits are compared to costs on a 'life cycle cost basis' and compared to structural alternatives, this BMP represents an attractive option particularly for large greenfield estates.

## Additional Information

Enforcement would need to occur to ensure the BMP was *fully* implemented. This could occur via the development's approval conditions and through regular site inspections by local government officers.

Refer to Section 2.1.1 for further information about best management practices on construction sites. Refer to Section 2.2.7 for further information about best management practices for gardens.

Section 2.3.2 addresses intensive training of landowners on aspects of stormwater management and Section 2.3.3 has information about encouraging participation by the community in stormwater management. Refer to Section 2.3.4 for useful information about the benefits of community participation programs versus traditional education programs.

The Examples / Case Studies part of Section 2.3.3 has information about the South East Regional Centre for Urban Landcare's Clean Drains - River Gains campaign to reduce nutrients and other contaminants in receiving water bodies. For further advice, contact the South East Regional Centre for Urban Landcare (SERCUL), 69 Horley Road, Beckenham WA 6107, via <[www.sercul.org.au](http://www.sercul.org.au)> or by telephoning (08) 9458 5564.

Chapter 8: *Education and awareness for stormwater management* provides guidance on how to design an education and awareness program.

The following *behaviour change* resources are recommended when designing the program:

- Community Change (Victoria, Australia) via <[www.communitychange.com.au](http://www.communitychange.com.au)>.
- Social Change Media (New South Wales, Australia), the home page is available via <<http://media.socialchange.net.au>> and *The Seven Door Social Marketing Approach* (Robinson, undated) is available via <<http://media.socialchange.net.au/strategy>>.
- Community Based Social Marketing (Canada) via <[www.cbsm.com](http://www.cbsm.com)>.
- *Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing* (Mckenzie-Mohr & Smith, 1999). Further information is available from Community Based Social Marketing via <[www.cbsm.com](http://www.cbsm.com)>.

The *Facilitation Toolkit: A practical guide for working more effectively with people and groups* (Keating, 2003) is a recommended resource to use when facilitating workshops, seminars or group meetings. The

toolkit is available via <[www.environment.wa.gov.au](http://www.environment.wa.gov.au)> or by telephoning (08) 9278 0300. See also the Coastal Cooperative Research Centre's *Citizen Science Toolbox* (Australia) for advice about particular facilitation techniques (available via <[www.coastal.crc.org.au/toolbox/index.asp](http://www.coastal.crc.org.au/toolbox/index.asp)>).

The *Sustainable Living in Western Australia* website, available via <[www.sustainableliving.wa.gov.au](http://www.sustainableliving.wa.gov.au)> (Government of Western Australia, 2004-2005), contains links to Western Australian resources for sustainable practices including water conservation, household waste management, gardening and growing local native plants.

## Examples / Case Studies

No detailed case studies are available for residential estates. However, the initiative has been applied in the United States. A similar initiative has been successfully applied in an industrial estate in Manly, New South Wales (Taylor and Wong, 2002c). Refer to the Examples / Case Studies part of Section 2.3.4.

Examples of sustainable living programs in Western Australia include: the Living Smart Program developed by The Meeting Place Community Centre, City of Fremantle, Murdoch University and Southern Metropolitan Regional Council (SMRC) (contact (08) 9432 9914 or <[www.freofocus.com/projects/html/living\\_smart.cfm](http://www.freofocus.com/projects/html/living_smart.cfm)>); the Creating Communities program (contact (08) 9284 0910 or <[www.creatingcommunities.com.au](http://www.creatingcommunities.com.au)>); and the Green Houses Program (energy and water conservation only) by SMRC and Murdoch University (contact (08) 9316 3988 or <[www.smrc.com.au/greenhouses](http://www.smrc.com.au/greenhouses)>).

These programs use proven goal-setting techniques and recognise that information alone is not enough to achieve sustained behaviour change. For example, as a result of attending the Living Smart pilot program:

- Participants significantly increased their environmental knowledge and the number and frequency of sustainable behaviours.
- 63% of participants said it was very important for them to reach their goal and the majority thought setting goals increased their motivation and made them more likely to act.
- In all topics, participants increased their effort towards sustainable practices by 17-22%.
- 68% said that the program changed the way they think about lifestyle and environmental issues.
- Half of the participants felt that what they learned in the program would influence them for a very long time and 41% said it would influence them forever (Sheehy, 2004).

Sustainable living programs provide additional benefits for communities. For example, as a result of attending the Living Smart pilot program, 91% of participants felt more a part of the community, 95% increased their knowledge of community resources and services and 82% increased their sense of wellbeing (Sheehy, 2004).

Communication techniques include workshops, self-paced learning via booklets, ongoing dialogue (newsletters and meetings) and/or websites.

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## 2.4 Funding, policy, regulatory and enforcement practices

### 2.4.1 Funding programs for stormwater management

#### Description

Effective stormwater management requires substantial resources. For example, Taylor and Wong (2002b) surveyed leading stormwater management agencies in Australia and overseas and found:

- On average, leading Australian stormwater management agencies responsible for minor and major/trunk drainage spent approximately \$18.52 per person per year on stormwater management (in 2001 dollars).
- Compared to equivalent Australian agencies, leading US agencies that were surveyed spent approximately 3.8 times as much (per capita) on stormwater management.

In Australia, resources are typically obtained from:

- Short-term grants (e.g. Natural Heritage Trust, Swan-Canning Cleanup Program Funding, NSW Stormwater Trust, Victorian Stormwater Action Program, etc.);
- Consolidated revenue or general rates (e.g. a local government may fund stormwater management initiatives through its general rate base);
- Environmental levies (e.g. a local government may charge a separate levy as part of its rates, to fund specific environmental initiatives); and
- Stormwater-related fees (e.g. a local government or regional stormwater authority may charge properties a fee to use downstream stormwater drainage infrastructure).

There is compelling evidence from case studies, particularly from North America, that establishing a dedicated and stable source of funding for stormwater management ensures long-term viability of programs and public support. For example, Lehner *et al.* (1999) surveyed 100 stormwater case studies in the US and concluded that there were six ‘foundations of success’ in relation to stormwater management projects:

1. Focusing on pollution prevention (e.g. using non-structural and structural source controls);
2. Preserving and utilising natural features and processes (e.g. using vegetated buffers, ‘cluster development’ principles);
3. Providing strong incentives, routine monitoring and consistent enforcement to establish accountability;
4. Establishing a dedicated source of funding to ensure long-term viability of programs and public support;
5. Providing strong leadership to provide a catalyst for success; and
6. Providing effective administration.

In areas of Australia where major stormwater-related grants programs have been in existence for several years and then removed, local government authorities are increasingly establishing their own dedicated funding mechanisms. These often take the form of an environmental levy or a property-based stormwater fee (known as a ‘stormwater utility’ in the US).

The US Centre for Watershed Protection (2000) describes a ‘stormwater utility’ as a method of stormwater financing, where property owners are charged a modest fee for using the stormwater drainage network. The revenue gained from these fees is used to finance capital and operating expenses that are needed for local stormwater quality and quantity management.

The US Centre for Watershed Protection (2000) also reported that the American Public Works Association considers stormwater utilities as the ‘most dependable and equitable approach available to local government to finance stormwater management’. Such funding arrangements were rare in the early 1990s, but are now an important revenue raising mechanism in several hundred cities and counties across the US.

## Applicability

A stable and dedicated funding mechanism for urban stormwater management is needed in all urban areas, particularly those experiencing rising stormwater costs and community expectations.

Exploration of funding options should occur early in the development of a region’s stormwater management program (e.g. as a critical management action in the region's stormwater management plan). As mentioned below, awareness of stormwater-related issues within the community would need to be significantly raised before a funding mechanism can be established. In this context, ‘community’ includes all key stakeholders (e.g. elected officials, environmental groups, ratepayer associations, etc.).

## Recommended Practices

One method of creating secure and stable funding for stormwater management is through the establishment of an environmental levy or a property-based stormwater fee (known as a ‘stormwater utility’ in the US). The US Centre for Watershed Protection (2000) provides the following five-step plan for successfully creating a ‘stormwater utility’.

- ✓ Accurately estimate revenue requirements.
- ✓ Determine an administrative structure for stormwater management (e.g. determine the scope of activities needed to manage stormwater and identify the administrative units best suited to perform each task).
- ✓ Devise a fee structure and a billing system. For example, a fee schedule may be structured according to the amount of directly connected impervious area on the property.
- ✓ Implement a public information program. Public involvement during and after the establishment of the stormwater utility is believed to be essential for its successful implementation. Through participation processes, the community could also be involved in designing the stormwater utility.
- ✓ Adopt stormwater utility ordinances. This step ensures that the utility has a statutory basis, if challenged.

## Benefits and Effectiveness

Funding is obviously essential for sound urban stormwater management. However, the type of funding arrangement is also important.

For example, there is persuasive anecdotal evidence around Australia that short-term funding programs have led to poor outcomes in some cases. This evidence includes gross pollutant traps that were hastily built with grant funds, but never maintained due to a lack of ongoing funding. In this situation, gross

pollutant traps may exacerbate the pollution problem, by converting nutrients in an organic form to a bioavailable form in the anoxic environment of an unmaintained trap.

A good example of a funding system is the use of economic incentives that can operate under a property-based stormwater fee/utility. For example, such a funding mechanism can be structured so that properties with a large amount of directly connected impervious area (e.g. a traditional carpark) pay a relatively high fee, while properties with a small amount of directly connected impervious area (e.g. a carpark with bioretention systems) pay a relatively low fee. Such an arrangement provides a strong, ongoing economic incentive for water sensitive urban design for both developing areas and existing areas. It is also consistent with the ‘polluter pays’ and ‘user pays’ principles. This approach may be particularly attractive in developed areas where stormwater quality and quantity needs to be managed but there is little room downstream for stormwater detention and treatment structures.

## Challenges

A potential challenge to establishing stable, dedicated funding arrangements is resistance from existing ratepayers. However, such resistance is often minimal where the need for stormwater funding is clearly communicated to the local community, mechanisms are established to ensure stormwater-related fees/levies are used for stormwater-related projects only, and the community is involved in the design of the funding mechanism (e.g. through citizen juries or focus groups).

Another potential challenge is the amount of work required to establish the funding mechanism, particularly where a property-based stormwater fee is structured in relation to each property’s directly connected impervious area.

Another potential challenge is where jurisdiction for stormwater management is controversial or complex. In such circumstances, an organisation like a local government authority may be reluctant to invest resources in establishing a new stormwater funding mechanism. Also, the legal validity of the mechanism may be uncertain. Responsibilities (e.g. of State government agencies and local government authorities) must be clearly established before new funding mechanisms can be introduced.

## Cost

It is estimated that it would cost a local government or regional stormwater authority approximately \$50,000 to establish a property-based stormwater management fee that is structured in relation to each property’s directly connected impervious area. The bulk of this cost is associated with calculating a suitable fee for each property. These costs could however be quickly recovered once the fee is established.

Following a survey of 97 stormwater utilities across 20 States in North America, Black and Veatch (1996) reported that the average monthly residential charge was approximately US\$2.50 (in 1996 dollars).

## Additional Information

The US Centre for Watershed Protection (2000) stressed the importance of involving the public before and after the implementation of a stormwater-related funding mechanism. They concluded that the experience of communities that have successfully implemented stormwater utilities underscores the importance of public education and involvement. It should initially be assumed that the general public is unaware of the impact of stormwater runoff, or the role it plays in maintaining watershed quality. However, it assumes that once educated, the public will be discriminating in the services and programs they expect to be delivered from a new stormwater utility (p. 408).

## Examples / Case Studies

Black and Veatch (1996) conducted a survey of 97 stormwater management agencies across 20 States in North America that had implemented a property-based stormwater management fee to address stormwater quality and quantity (i.e. a 'stormwater utility'). Some of the trends they observed are provided below as an indicator of typical experiences.

- 61% of respondents felt public information/education was essential to the success of the funding mechanism and only 1% considered it unnecessary.
- 55% of respondents used the percentage of impervious cover as the basis for the fee.
- 74% of respondents billed on a monthly basis.
- 57% of respondents provided some form of credit if on-site detention/retention practices exist.
- 81% of respondents reported that the stormwater utility helps to fund capital as well as operating and maintenance costs.
- 82% of respondents reported that the stormwater utility revenue meets 'most needs' or at least 'most urgent needs'.
- 11% of respondents reported that the stormwater utility revenues were adequate for 'all stormwater needs'.

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## 2.4 Funding, policy, regulatory and enforcement practices

### 2.4.2 Point source regulation of stormwater discharges and enforcement activities

#### Description

##### Point source regulation

Regulation of specific commercial and industrial premises (e.g. automotive industries, nurseries, landfills, waste recycling facilities, etc.) is a widely used technique to minimise stormwater and groundwater pollution. Such premises are typically licensed by a government agency, with their activities controlled through legally enforceable licence conditions that are regularly checked by enforcement officers who audit the premises. These officers also provide guidance, training and, if necessary, perform an enforcement role.

Control of *point sources* of stormwater pollution is generally easier than controlling diffuse sources (e.g. runoff from roads and rural land uses), and more rewarding on a cost-benefit basis. A well-managed point source regulation program should be a priority of agencies that are responsible for managing stormwater and groundwater quality.

##### Enforcement activities

Enforcement is another cost-effective regulatory tool for the management of stormwater and groundwater quality. This BMP uses enforcement of State legislation or local laws to modify behaviour that has the potential to pollute stormwater or groundwater. Legislation is often passed and enforced to address specific forms of pollution (e.g. cigarette butts) or control high-risk activities (e.g. specific industrial facilities). Consequences of enforcement activities to a polluter can include the payment of a fine, the payment of clean-up costs, being unable to legally operate a business, and, in extreme cases, imprisonment. Enforcement is primarily an economic disincentive that is designed to influence people's behaviour.

#### Applicability

##### Point source regulation

Point source regulation is a BMP that is highly applicable to all urban areas in Western Australia where:

- The basic regulatory framework is provided under the *Environmental Protection Act 1986*. However, licensing/registration under the *Environmental Protection Act* is for large industry/prescribed premises only. Currently there are no provisions under local law to register or license small to medium-sized enterprises.
- There is a clear need for improved environmental management of small to medium-sized commercial and industrial premises (SRT, 1999). For example, the Swan-Canning Industry Survey Report (WRC, 2000) undertook a survey and risk assessment of light industrial premises in the Swan-Canning region in 1997 and 1998. It involved more than 550 premises. These were effectively unregulated premises, as approximately 95% of the 2,000 – 2,500 industrial premises in Perth are not regulated by a licensing/registration instrument that aims to implement environmental controls. Accordingly, they are not routinely inspected by government regulators, nor are they subject to specific licence conditions with respect to environmental management. The overall conclusion of the Swan-Canning Industry Survey Report was 'because of the large number of premises and generally poor environmental

management practices, light industry also presents a significant pollution risk. This arises from the cumulative impact of small discharges and the potential for accidents to cause serious pollution’.

The Swan-Canning Industry Survey Report (WRC, 2000) gives an indication of which small to medium-sized industrial premises pose a risk to the health of the Swan-Canning system. The survey identified the following proportion of premises as being of ‘medium risk’ to the Swan-Canning: 29% of audited pool suppliers, 30% of automotive industries, 36% of vehicle depots, 19% of engineering/manufacturing type industries and 17% of recyclers. The equivalent figures for ‘high risk’ were: 14% of audited vehicle depots, 3% of automotive industries, and 1% of chemical/pesticide premises.

Some local governments in Western Australia (e.g. the City of Canning, City of Bayswater, Town of Kwinana, Town of Vincent and others) have expressed an interest in using delegated powers under the *Environmental Protection Act 1986* to regulate small to medium-sized industry in their region (i.e. undertake training, audits and enforcement activities) in response to rising expectations from their ratepayers that these premises should improve their environmental performance. Regulations under this Act (gazetted on 12 March 2004) provide local authorities with the regulatory tools they need to fully undertake a point source regulation program that targets small to medium-sized industry. In addition, discussions are occurring between local and State government authorities to determine the best way to fund such programs.

The Swan-Canning Cleanup Program Action Plan (SRT, 1999) also recommends that local governments in the Swan-Canning region need to take more responsibility for promoting pollution prevention in light industrial premises by encouraging the use of best practice environmental management via training and auditing. In addition, the plan recommends that local governments should be able to recover the cost of regulating light industry according to the principle of ‘polluter pays’ (SRT, 1999).

The Swan-Canning Cleanup Program Action Plan (SRT, 1999) also highlighted the following *industrial site management practices* that determine the level of pollution risk a premises poses to the surface and groundwater resources of the Swan-Canning region:

- emergency management practices in response to events such as accidental spills;
- illicit practices or poor housekeeping, resulting in pollutant discharges to surface or groundwaters;
- storage practices, i.e. where there is no bunding of chemical storage areas;
- waste management, i.e. the extent to which solid and liquid wastes contaminate stormwater and groundwater; and
- stormwater management.

*Commercial premises* highlighted by the Swan-Canning Cleanup Program Action Plan (SRT, 1999) as requiring improved management included retail establishments, car yards, nurseries, medical and business offices, churches, government offices and museums. Some of these may require regulation through a licensing instrument in the Swan-Canning region (e.g. nurseries, due to the potential to generate excessive loads of nutrients), while others may only need regular education.

## Enforcement activities

Enforcement of relevant legislation is also an option that is widely applicable to Western Australia. However, enforcement programs typically *follow* major educational initiatives. For example, an ‘on-the-spot fine’ enforcement program that targets littering in the central business district of Perth would normally follow an intensive education exercise, and an evaluation process that demonstrates levels of people’s awareness are high but significant behavioural change has not occurred.

Areas of stormwater and groundwater quality management where enforcement has the most potential include:

- littering;
- illegal dumping of wastes in locations where water bodies may be affected;
- stormwater management on building sites;
- car washing on the street;
- feeding of birds in water bodies where eutrophication is a problem;
- liquid and solid waste discharges from vessels; and
- discharges to stormwater or groundwater from commercial and industrial premises.

For enforcement strategies to work in this context, the regulatory instruments must be simple to use (e.g. on-the-spot fines, where court proceedings only occur if fines are challenged by the recipients) and the magnitude of the fines must be suitable deterrents. For example, if it costs \$300 per residential building site to implement sound erosion and sediment controls, the on-the-spot fine for failing to take reasonable and practical measures to minimise the risk of sediment being discharged to stormwater would need to be significantly in excess of \$300 to provide a strong incentive to comply.

The Unauthorised Discharge Regulations 2004 have recently been enacted under the *Environmental Protection Act 1986* in Western Australia (see <[www.slp.wa.gov.au/statutes/av.nsf/doi](http://www.slp.wa.gov.au/statutes/av.nsf/doi)> or telephone (08) 9321 7688). These regulations include an on-the-spot infringement notice system for minor pollution offences. These powers can be delegated to local government officers. The new on-the-spot fines currently carry a penalty of \$250 to \$500, which increases to \$5,000 if the matter proceeds to court. The fines apply to commercial and industrial premises and cover the discharge of substances to stormwater or groundwater. These substances include hydrocarbons, solvents, degreaser detergent, dust, engine coolant, food waste, laundry waste, pesticides, paint, dyes, acids, alkali, sediment, sewage and substances containing heavy metals (Raine, 2004).

## Recommended Practices

### Point source regulation

In some jurisdictions, several tiers of licensing are used (e.g. ‘licences’ for high risk premises and ‘permits’ for low risk premises). The tiers are distinguished by the cost of annual licence/permit fees, the frequency of inspections/audits, and the tailoring of licence/permit conditions. In addition, financial incentives are often provided for premises that exceed the minimum stormwater management requirements as set out in the licence/permit (e.g. a ‘green licensing system’ that allows businesses with excellent environmental performance to pay a reduced annual licence fee and gain positive publicity).

Determining which premises should be regulated via a licence/permit should involve a risk assessment that considers current environmental management practices of various premises types, potential risks to stormwater and groundwater quality, and potential risks to the health of water bodies.

Ideally, costs of running a best practice point source regulation program should be recovered on a ‘polluter pays basis’. That is, the program should be cost neutral to the regulator, with all revenue being raised through licence/permit application fees, annual licence/permit fees and prosecutions for breaches of environmental regulations.

## Enforcement activities

Common examples of laws to prevent or minimise specific forms of stormwater pollution include those that:

- Encourage builders to minimise the discharge of sediment, litter and wash-waters from building sites.
- Discourage illegal dumping of wastes (e.g. waste oil, domestic solid waste).
- Encourage pet owners in public areas to correctly dispose of their pets' waste.
- Discourage the illegal connection of sewage and other wastewaters to the stormwater drainage network.
- Discourage littering in public places.
- Discourage the discharge of commercial or industrial wastes to stormwater (or groundwater).

Some less common examples reported by Taylor and Wong (2002c) include laws that aim to:

- Encourage xeriscaping. For example, the City of Albuquerque in New Mexico, US, has a Water Conservation Ordinance that requires xeriscaping on new developments and works in partnership with a rebate system to encourage the conversion of existing turfed areas to resource sensitive alternatives (Lehner *et al.*, 1999).
- Discourage the feeding of birds in and around water bodies. For example, the Hopatcong Borough in New Jersey, US prohibits the feeding of geese in and around their lake systems as a measure to improve water quality (Lehner *et al.*, 1999).



Figure 1. Department of Environment, Pollution Response Unit testing of an industrial site. (Photograph: Department of Environment.)

Enforcement of environmental management standards on premises that are regulated by a licensing instrument typically occurs via State legislation (e.g. the *Environmental Protection Act 1986*), although the power to enforce this legislation may be delegated to trained and authorised local government officers.

## Benefits and Effectiveness

### Point source regulation

The primary benefits of running a point source regulatory program are:

- The ability to prevent or minimise pollution at the source.
- The ability to run the program on a polluter pays basis (i.e. at no cost to the wider community).
- The ability to provide economic incentives for those premises whose performance exceeds minimum regulatory standards.

- The ability to easily identify and remove major sources of pollution (e.g. wastewater from industrial plants being illegally discharged to stormwater or groundwater).
- The opportunity to build a constructive partnership between the regulator and the operators through regular education, auditing, the development of site-specific licence conditions, and performance reporting.
- The requirements set out in licence/permit conditions are not voluntary (i.e. a breach of conditions may be followed by enforcement).
- New environmental management technology, new knowledge about risks to the receiving environment and new management/political priorities can be incorporated in the program (e.g. newly identified risks can be addressed via modified audit checklists, amended licence/permit conditions, updated industry guidelines, new training materials, etc.).

While the licensing of industrial and commercial premises is a common form of environmental management in urban areas, Taylor and Wong (2000c) report that few agencies have evaluated and reported the *effectiveness* of the approach for stormwater quality improvement (e.g. reductions in pollutant loads due to regulation).

Some case studies however give an indication of the potential of the BMP. The Clean Bay Business Program in Palo Alto, California, is a good example of a program where impressive outcomes were achieved in terms of behavioural change (see the Examples / Case studies section below for details).

In a literature review involving non-structural measures for stormwater quality improvement, Taylor and Wong (2002c) concluded that a best practice, small industry licensing program that includes regular inspections, education, incentives and disincentives should be able to deliver levels of compliance with stormwater-related requirements of approximately 90% - 95%. They also concluded that such licensing programs could be some of the most effective non-structural BMPs for improving stormwater quality and the health of water bodies.

## Enforcement activities

The primary benefits associated with using enforcement measures to influence behaviour include the following:

- It sends a strong message that government is serious about minimising stormwater and groundwater pollution.
- It can be a powerful educational instrument.
- It uses an economic driver to promote behavioural change.
- It implements the 'polluter pays' principle.
- It is flexible, in that enforcement strategies can be quickly adjusted to respond to new issues and priorities.

The potential effectiveness of enforcement campaigns is perhaps best demonstrated by studies involving erosion and sediment control programs. There is strong evidence to suggest a well-designed, strict and sustained enforcement program that complements an educational campaign is essential in order to substantially increase the performance of erosion and sediment control on construction sites (Taylor and Wong, 2002c). For example:

- Lehner *et al.* (1999) concluded from a review of 100 stormwater-related case studies in the US that ‘communities reiterate the need to develop the financial resources and authority necessary to *enforce* standards and maintenance of stormwater controls before a problem or violation occurs’ (p. 5-7) and ‘programs with high accountability [e.g. enforcement elements] often reduce pollutant loadings by 50% or greater’ (p. 1-2).
- Lehner *et al.* (1999) also concluded in relation to erosion and sediment control programs that ‘whatever the education program however, they have not proven successful without the accompanying teeth of enforcement’ (p. 5-13).
- The necessity for strong enforcement has also been stressed by experienced Australian erosion and sediment control project officers and managers (e.g. Gaudry and Geier, 2000) and overseas (e.g. Fritz, 2002). Fritz (2002), a stormwater manager from Chattanooga, US, commented on the importance of enforcement in successful erosion and sediment control programs, saying ‘it is very important to point out that education and awareness [alone] does not lead to compliance. There must be an incentive for compliance to work. This can be either positive (monetary savings, awards) or negative (regulatory intervention)’.
- Findings from case studies reported in Taylor and Wong (2002c) indicate that citywide erosion and sediment control programs with strong and *sustained* educational and enforcement elements may represent the best performing non-structural BMP for the control of stormwater pollution from industry. Lehner *et al.* (1999) also concluded ‘from the [100 US] case studies, it appears that, even more than with respect to other industries, education and enforcement can achieve measurable stormwater pollution reduction’ (p. 5-13).

Achieving and maintaining high levels of compliance with erosion and sediment control requirements on a citywide basis is difficult. Based on Australian and overseas data, Taylor and Wong (2002c) estimate that best practice erosion and sediment control programs should be able to achieve a 20% - 30% increase in compliance levels in the first few years (based on a typical baseline compliance level of 20% - 30%), and achieve a 60% - 70% increase from baseline levels over a decade<sup>20</sup>. In addition, compliant sites can be expected to reduce the average load of total suspended solids (TSS) in stormwater during the construction phase by approximately 60% on average.

Consequently, the overall TSS pollutant removal efficiency of citywide erosion and sediment control programs that include strong town planning, enforcement and educational elements is approximately 12% - 14% in the short term (e.g. one to three years) and 36% - 42% over a decade. These percentages represent an approximate reduction in the average load of TSS in stormwater leaving construction/building sites over the life span of the construction phase (see Taylor and Wong, 2002c for more details).

Erosion and sediment control case study information summarised in Taylor and Wong (2002c) highlights the need for *sustained* levels of enforcement (as compliance levels can quickly drop after a short-term enforcement campaign has finished) and programs that seek improvement over the *long term* (e.g. a decade). An important consequence of this finding is that program managers in Australia should ensure that erosion and sediment control programs are self-funding or have a secure funding base.

## Challenges

The primary challenge associated with using *point source regulation* is the difficulty that may be encountered when first *establishing* the regulatory framework (i.e. the necessary delegations under the

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<sup>20</sup> Phrased another way, average compliance levels for erosion and sediment control on building/construction sites can be expected to rise from approximately 20% - 30% (at the start) to 50% (after a few years), then up to 90% (after a decade) as a result of such programs.

*Environmental Protection Act 1986* and practical regulatory tools such as the on-the-spot fining provisions of the Unauthorised Discharge Regulations 2004) and funding mechanism. Local government agencies may be cautious about accepting delegations to regulate small to medium-sized industry, unless it can be done on a cost-neutral basis. Some local authorities may not wish to undertake such a program, as they might consider it to be a State government responsibility.

The primary challenge associated with *enforcement activities* is the risk of a negative reaction from some stakeholders when an enforcement program begins, particularly if there are some ‘teething troubles’ during the beginning of the campaign (e.g. inconsistent interpretation of the law by enforcement officers, enforcement agencies not leading by example). During this early period, strong managerial and political commitment is often needed to ensure the program proceeds and becomes successful.

Another challenge with the use of enforcement is the magnitude of penalties (e.g. on-the-spot fines issued under the Unauthorised Discharge Regulations 2004). The size of the penalty must be proportional to the offence and the cost of compliance, yet not be perceived as a ‘revenue raising exercise’. A careful balance must be achieved - a balance that will subtly change over time. In some cases, the enforcement agency may have limited power to alter the magnitude of the fines (e.g. where powers are delegated to local government by the State).

## Cost

### Point source regulation

In a literature review involving non-structural measures for stormwater quality improvement, Taylor and Wong (2002c) concluded that point source regulatory programs involving small to medium-sized businesses may cost \$287 - \$1,204 per premises per year to run, with a typical Australian local government-managed program costing in the order of \$480 per premises per year.

However, these programs can be structured to be cost-neutral to the regulatory agency. That is, the revenue from licences, prosecutions and cost-recovery following incidents should cover the regulator’s expenses. In some cases, additional expenditure is incurred by regulatory agencies, particularly when the magnitude of licence fees is set by another tier of government. For example, as a local government regulator, the Brisbane City Council in Queensland administers devolved provisions of State environmental legislation and regulates approximately 2,600 – 3,000 potentially polluting small to medium-sized premises (Taylor, 2002). In 2002, Council collected approximately \$1.2 million in environmental licence fees but spent approximately \$1.44 million (20% more) on these regulatory activities to deliver a standard of service that meets the expectations of the community (Taylor, 2002).

Indicative costing information is also available from the Auckland Regional Council in New Zealand, which has run an Industrial Pollution Prevention Program since 1998. The program includes regulation, education and auditing components and cost approximately NZ\$350,000 to run in 2000-01. This level of funding enabled more than 400 premises to be audited (Sturrock, 2002).

### Enforcement activities

In terms of enforcement, the primary costs to the enforcement agency include:

- staff time by enforcement officers (e.g. enforcement officers need to be trained, maintain a presence in the field, resolve disputes, process warnings/infringement notices, collect evidence for major prosecutions, etc.);
- legal costs (e.g. to manage hearings or prosecutions that are resolved in court); and

- associated educational initiatives (e.g. the provision of information to ensure that the target audience know how to comply with regulations and avoid enforcement action).

Costing figures are also available for regional or citywide erosion and sediment control programs with a strong enforcement element (see Taylor and Wong, 2002c). The cost of running such programs in Australia ranges from \$0.19 - \$0.51 per capita per year, and averages \$0.32 per capita per year (where 'per capita' refers to the residential population of the area affected by the program).

## Additional Information

Discussions are continuing between local government and State government in Western Australia on the best way to regulate small to medium-sized commercial/industrial premises. Changes to regulations have been enacted and funding mechanisms are being explored. When planning to implement a point source regulation program at the local government level, it is recommended that consultation occur with the Department of Environment to gain the latest information on these initiatives.

Once a best practice point source regulation program is in operation, regulatory agencies may wish to consider an advanced water quality management technique, namely to implement a pollutant trading scheme for a given receiving water. These systems operate by:

- Setting a sustainable load of pollutants for the receiving waters based on scientific studies (e.g. average annual loads for TN and TP).
- Setting discharge standards on regulated industry to reflect the receiving water's sustainable pollutant loads.
- Allowing regulated industries that can reduce their pollutant discharge loads below minimum standards to gain an economic advantage by selling their 'excess discharge credits'. For example, these credits may be bought by a new industry that wants to start discharging some pollutants into the receiving waters, or an industry that finds it more economical to buy these credits than upgrade its own on-site stormwater treatment technology to reduce its discharge loads by similar amounts to meet licence conditions.

Such pollutant trading schemes operate for all sources of water pollution, whether they are stormwater or wastewater.

Enforcement of regulations is usually considered an option of last resort, although experience around the world has demonstrated that it is often needed and is highly effective at managing stormwater-related behaviour in some contexts. If an enforcement program is to be used, the regulatory agency should demonstrate that less litigious alternatives (e.g. education) have been attempted but found to be insufficient. Agencies need to have a sound monitoring and evaluation program to monitor the effectiveness of education programs. For guidelines on how to plan and undertake an evaluation process, see Taylor and Wong (2002d).

## Examples / Case Studies

### Point Source Regulation - Clean Bay Business Program, Palo Alto, California

A good overseas case study involves the Clean Bay Business Program in Palo Alto, California, (reported in Aponte Clarke and Stoner, 2000, and Lehner *et al.*, 1999). Vehicle service facilities (e.g. petrol stations) were regulated through licensing, education, inspections and the provision of incentives for good performance (e.g. attaining the status of a Clean Bay Business, which allowed businesses to access free advertising).

When premises were first inspected under the program in 1992, only 4% of 318 facilities complied with regulations relating to discharges to stormwater and sewer. By the end of 1992, this percentage had risen to 41% and by 1998 it had risen to 94%. In addition, violations of regulations that specifically protect *stormwater* drains fell by 90% between 1992 and 1995. The program also found and eliminated 78 direct discharges to stormwater (e.g. wash-water discharges).

The cost of running the Clean Bay Business Program for each business in 1998 was US\$300 for the first year, followed by an annual fee of US\$150. The cost of running the program for the regulator in Palo Alto was not available.

## Enforcement Program - Brisbane City Council, Queensland

Brisbane City Council is Australia's largest local authority. It has a population of approximately 864,000 and a focus on erosion and sediment control. A multi-dimensional Erosion and Sediment Control Action Plan has been implemented and progressively refined since the late 1990s. The 2001 version of the City's Action Plan included 55 discrete actions/projects to improve erosion and sediment control and minimise the loads of sediment entering the City's creeks, river and bay (Taylor and Wong, 2002c).

The typical annual cost to implement the Erosion and Sediment Control Action Plan in 2001 was approximately \$265,000, including costs associated with employing an Erosion and Sediment Control Officer to undertake assessment of developments, administration of the Action Plan, development of educational products, delivery of training, annual auditing and delivery of intensive media campaigns. The additional cost of enforcement has been a substantial component of the overall cost in recent years (e.g. employment of four full-time enforcement officers). However, by 2001, all of Brisbane's erosion and sediment control activities had become effectively self-funding, as a result of revenue generated through enforcement activities.

Since 1996, erosion and sediment control audits have been regularly undertaken in Brisbane to measure the degree of compliance with legislation by different sectors of the development industry. In early 1999, the widespread use of on-the-spot fines was added to the City's erosion and sediment control strategy, after several years of relying primarily on education. These fines were relatively minor and were primarily intended to be an appropriate enforcement tool for small residential building sites.

For residential building sites in Brisbane, 22.5% of sites audited prior to introducing on-the-spot fines in early 1999 complied with relevant environmental legislation (a weighted average over two audits, involving a total of 54 randomly selected sites). After the introduction and use of on-the-spot fines, the equivalent percentage had increased to 38.8% (a weighted average over four audits, involving a total of 122 randomly selected sites). Over the same period, compliance rates on larger development sites in the City (where small, on-the-spot fines did not act as a significant motivator) fell by 3% - 7% (Brisbane City Council, 2002).

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## 2.4 Funding, policy, regulatory and enforcement practices

### 2.4.3 Illicit discharge elimination programs

#### Description

Illicit connections are defined as ‘illegal or improper connections to storm [water] drainage systems and receiving waters’ (CWP, 1998). Illicit discharge elimination programs seek to identify and remove illegal or inappropriate waste streams entering the stormwater network. The most obvious of these waste streams include trade wastes from commercial and industrial premises and wastewater from domestic premises.

Illicit connections to stormwater can be surprisingly common. For example, a 1986 US study found 38% of businesses surveyed in Washtenaw County (Michigan) had illicit connections, mostly in automobile-related and manufacturing businesses (Schmidt and Spencer, 1986).

These connections can also represent a *major* source of pollution. For example, the Clean Charles 2005 Initiative in Boston (Massachusetts) found one connection that contributed approximately 327,000 litres of sewage to stormwater per day (Lehner *et al.*, 1999).

#### Applicability

This BMP is applicable to all urban areas, but has increased value in commercial and industrial areas, older areas where several generations of plumbing may have occurred, and unsewered areas. Case studies indicate that this BMP can result in *major* reductions in pollutants being discharged to the stormwater network, and therefore it should be a priority in any urban stormwater quality management program.

For *new* developments, preventative practices such as the thorough inspection and verification of drainage and sewerage arrangements during the construction phase can avoid the need for more extensive detection techniques and subsequent disconnection (US EPA, 2001). For *existing* developments, illicit connections are detected using the techniques briefly described below.

#### Recommended Practices

The US EPA (2001) recommends that illicit discharge elimination programs should have four principal components:

- procedures for locating priority areas that are likely to have illicit discharges;
- procedures for tracing the source of an illicit discharge;
- procedures for removing the source of the discharge; and
- procedures for program evaluation.

Illicit discharge education initiatives are also needed, which may include stormwater drain stencilling, a program to encourage public reporting of illicit connections or discharges to stormwater/water bodies and the distribution of educational materials to businesses, tradespersons (e.g. plumbers) and residents.

Other features of illicit discharge elimination programs are the mapping of the region's stormwater drainage network, targeted education campaigns, plans to detect and remove non-stormwater discharges<sup>21</sup>, and regulatory mechanisms that:

- prohibit non-stormwater discharges from entering the stormwater network;
- allow inspectors to access private property to investigate potential illicit discharges; and
- allow regulatory action to be taken to eliminate the discharge and prosecute offenders (where appropriate).

See Section 2.4.2 for more discussion on point source regulation and enforcement activities. In particular, the Unauthorised Discharge Regulations 2004 have recently been enacted under the *Environmental Protection Act 1986* in Western Australia (see <[www.slp.wa.gov.au/statutes/av.nsf/doi](http://www.slp.wa.gov.au/statutes/av.nsf/doi)> or telephone (08) 9321 7688). These regulations include an on-the-spot infringement notice system for *minor* pollution offences. These powers can be delegated to local government officers. The new on-the-spot fines currently carry a penalty of \$250 to \$500, which increases to \$5,000 if the matter proceeds to court. The fines apply to commercial and industrial premises and cover the discharge of substances to stormwater or groundwater. These substances include hydrocarbons, solvents, degreaser detergent, dust, engine coolant, food waste, laundry waste, pesticides, paint, dyes, acids, alkali, sediment, sewage and substances containing heavy metals (Raine, 2004).

Typically, illicit discharge elimination programs focus on identifying and removing direct connections of wastewater to the stormwater network (e.g. from domestic, commercial or industrial premises). The programs may include the following techniques to identify such illicit discharges:

- field testing of dry weather discharges in the stormwater drainage network;
- visual inspections by closed circuit cameras;
- undertaking a review of architectural plans and plumbing details to identify potential sites where improper connections may have occurred;
- conducting field tests of selected pollutants in stormwater;
- smoke testing; and
- dye testing.

Following identification of an illicit discharge, an inspection of the discharging premises occurs, followed by elimination of the discharge and, potentially, prosecution of those responsible for the discharge.

Note: An Industrial Waste Permit is required to connect and discharge wastewater to sewer.

Further information is available from the Water Corporation by telephoning the Customer Service Centre on 13 13 95 or via <[www.watercorporation.com.au/indwaste](http://www.watercorporation.com.au/indwaste)>.



*Figure 1. Testing of an industrial site stormwater drain for illicit discharges. (Photograph: Department of Environment.)*

<sup>21</sup> In this context, 'non-stormwater discharges' to the stormwater drainage network (or water bodies) that may need to be controlled include illegal dumping, swimming pool discharges, wastewater from car washing, street wash water, wastewater from the scouring and/or sterilisation of water mains, contaminated groundwater, and stormwater/groundwater that is pumped out of deep excavations on construction sites.

In some jurisdictions, community volunteers are engaged to help identify dry weather discharges to the stormwater system and minimise the cost of the program. For example, the Department of Environmental Protection in Montgomery County (Maryland, USA) has an illicit discharge detection and elimination initiative called ‘Pipe Detectives’. Under this initiative, community volunteers undertake dry weather inspections and report suspicious findings to a community hotline (MCDEP, 1997).

## Benefits and Effectiveness

Taylor and Wong (2002c) report that illicit discharge elimination programs can be a highly effective non-structural BMP for the improvement of stormwater quality and waterway health. They found evidence from several case studies that receiving water quality can be improved (particularly for faecal coliform levels and dissolved oxygen concentrations), large volumes of liquid wastes can be prevented from entering stormwater and significant loads of stormwater pollutants can be reduced over several years. For example, one study reported that an illicit discharge elimination program was responsible for a 75% decrease in faecal coliform levels in a receiving water, over three years. Another program prevented 999 litres/km<sup>2</sup>/day of raw sewage entering receiving waters, while another eliminated 4,321 litres/km<sup>2</sup>/day of liquid waste discharges (Taylor and Wong, 2002c).

Such evidence prompted Lehner *et al.* (1999) to conclude that, in the US, ‘local governments have found that identifying and eliminating illicit connections and discharges is a remarkably simple and cost-effective way to eliminate some of the worst pollution from stormwater and to improve water quality’ (p. 5-15).

## Challenges

Illicit discharge elimination programs are publicly funded, and despite attempts to involve volunteers in the detection and reporting process, they are often labour-intensive and require a substantial commitment of funds to carry out the detection tasks. In addition, jurisdictional disputes may arise in some areas about whether such programs should be funded and/or delivered by the agency that owns the sewerage network or by the affected stormwater drainage network.

Another challenge is the issue of gaining access to private property for inspection purposes. A regulatory instrument that ensures right of entry is critical in locating potential illicit discharges (US EPA, 2001).

In areas with highly permeable soils, such as much of the Swan Coastal Plain, illicit discharges to *groundwater* can be harder to detect than those discharges entering an impermeable drainage network. Detection techniques in this context may include inspection of ‘high risk’ premises (e.g. unlicensed premises that typically generate liquid trade wastes), dry weather water quality monitoring in drains and waterways (such programs may indicate the approximate location of a plume of contaminated groundwater), and groundwater quality monitoring. Similarly, in areas where the stormwater drainage network is discontinuous (i.e. where infiltration of stormwater is encouraged), illicit discharges may quickly drain to groundwater and be hard to detect using simple methods such as dry weather inspections.

## Cost

Based on four successful US programs, Taylor and Wong (2002c) report that the cost of running an illicit discharge elimination program is approximately AUD\$0.23 - AUD\$14.23/km<sup>2</sup> per annum<sup>22</sup> (averaging

<sup>22</sup> Based on a 2003 currency conversion rate of US\$1 = AUD\$1.92.

AUD\$3.77/km<sup>2</sup> p.a.), when the total program costs are spread over the entire city area. Another cost estimate based on US programs is AUD\$935 - AUD\$1,241/km<sup>2</sup>, where the entire area is tested for illicit discharges to stormwater. Equivalent costs for Australian programs are not currently available.

## Additional Information

The *National Menu of Best Management Practices for Storm Water Phase II* (US EPA, 2001) contains excellent on-line guidelines that contain a number of useful references and fact sheets on key aspects of illicit discharge elimination programs, such as:

- identifying illicit connections;
- industrial/business connections;
- recreational sewage;
- sewer overflows;
- wastewater connections to the stormwater drainage system;
- failing septic systems;
- illegal dumping; and
- non-stormwater water discharges.

## Examples / Case Studies

### Tulsa, Oklahoma (USA)

Taylor and Wong (2002c) report that the City of Tulsa, Oklahoma, started an illicit discharge elimination program in 1994, in cooperation with State agencies. The program included inspection of premises (using remote camera and smoke inspection techniques), dry weather field screening, industrial surveys, enforcement activities, repairs to sewerage infrastructure, as well as community education and involvement. The number of inspections and enforcement actions in the 1997-98 reporting year was 164 and 20, respectively. The program covered a region with a population of approximately 367,000 and an area of 471 km<sup>2</sup> (Lehner *et al.*, 1999), and cost approximately US\$3.5M p.a. (Van Loo, 2002).

Changes to the quality of the City of Tulsa's stormwater before and after the program were measured and analysed using event mean concentrations averaged over four year intervals. The results include a 13%, 17% and 18% reduction in event mean concentrations for total suspended solids, total phosphorus and total kjeldahl nitrogen, respectively (US EPA, 2001; Lehner *et al.*, 1999). Taylor and Wong (2002c) report that the bulk of this improvement may be attributable to the City's illicit discharge elimination program (including its educational elements).

### New York City, New York State (USA)

The New York City Department of Environmental Protection began a Shoreline Survey Program in 1989 to detect and eliminate illegal dry weather discharges to the City's stormwater and estuaries. The region over which the program operated was approximately 2,939 km<sup>2</sup>, with a population of approximately 8.5 million (Lehner *et al.*, 1999). The approximate cost of the program was US\$475,000 p.a. (Lehner *et al.*, 1999).

It is estimated that from 1989 to 1998, the Shoreline Survey Program eliminated approximately 12.7 million litres per day of illicit discharges. The Department also reported that overall water quality

conditions in the City's receiving waters from 1991 to 1995 improved on pre-1990 conditions. Levels of faecal coliforms and dissolved oxygen concentrations, in particular, continually improved throughout the 1990s (Lehner *et al.*, 1999).

## Local Examples

An illicit discharge elimination program is proposed in Maddington during late 2004 (contact the Department of Environment for an update on this program).

The Swan River Trust has commenced a program to encourage diverting wastewater from air conditioners away from stormwater drains.

The Department of Environment, Fire and Emergency Services Authority and the Department of Industry and Resources are inspecting 'Special Risk Plan' premises that pose a high risk to the environment and public safety if a fire should occur. The inspections determine if any illicit discharges are occurring and if the premises are complying with regulations or licence conditions.

The WA Light Industry Working Group has been established to help manage illegal discharges from light industry. This program has education and legislative (Unauthorised Discharge Regulations 2004) components.

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## 2.5 Catchment planning practices

### 2.5.1 Risk assessments and environmental management systems

#### Description

Managing stormwater at the catchment or citywide scale is a challenging task, as there are typically many sources of pollution and limited resources to manage them. Each of these sources poses a different level of risk to the health of receiving waters. One way of identifying stormwater management risks, assessing them, prioritising them, and allocating resources to manage them is to use 'risk assessments' and associated 'environmental management systems'.

The Australian Standard for environmental risk management (Standards Australia, 1999, p. 14) defines risk as 'the chances of something happening that will have an impact on objectives. It is measured in terms of consequences and their likelihood'.

*Risk assessment* is defined as the process of risk analysis and risk evaluation, as illustrated in Figure 1:

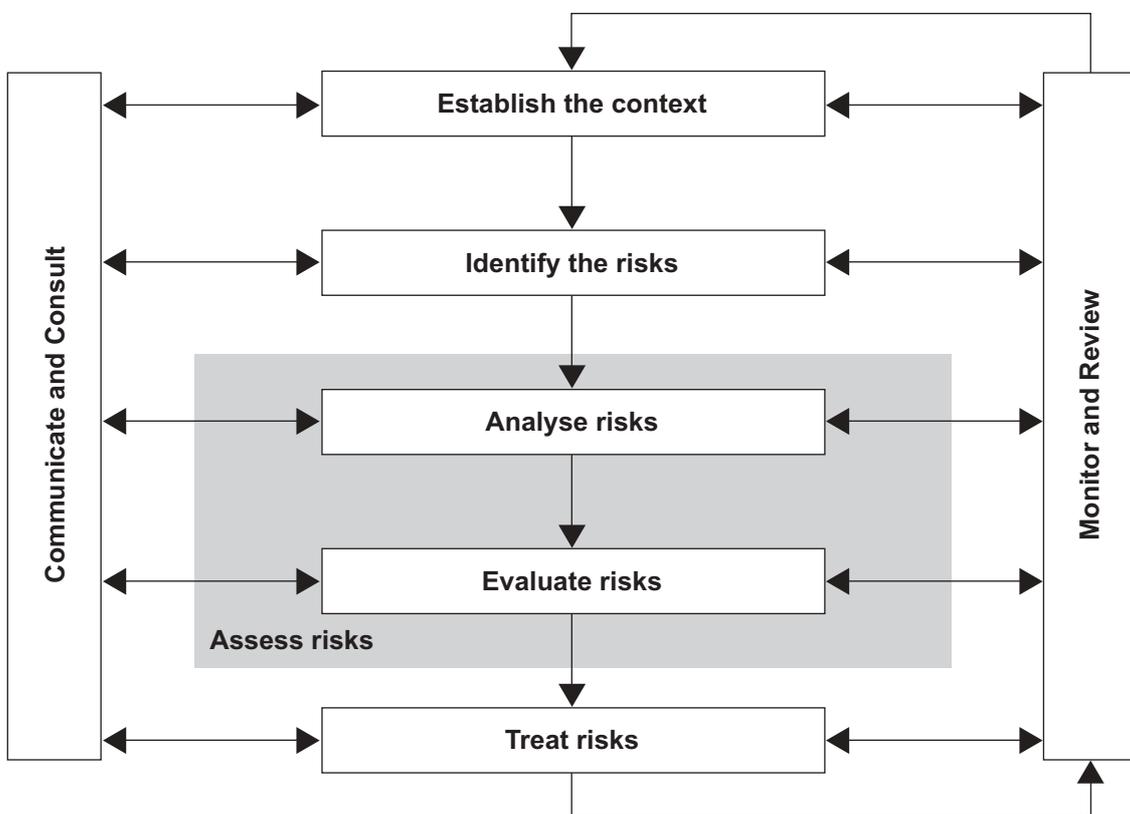


Figure 1. The process of risk assessment (Standards Australia, 1999)

An *environmental management system* (EMS) is defined as 'the part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy' (Standards Australia, 1996, p. 2). Risk assessments are an important component of effective environmental management systems.

For stormwater management in Australia, these tools are commonly used in the following contexts:

- When a local authority is developing a stormwater management plan for a catchment or region, they may use a risk assessment process to help prioritise management actions.

- When a local authority, State government department or business is reviewing their own operations and premises to ensure all reasonable and practicable steps are being taken to prevent or minimise stormwater pollution, they may undertake a risk assessment (often within the framework provided by an environmental management system).
- A risk assessment process may be used during the identification of priority areas within a City or Shire that require:
  - strengthened town planning controls to ensure new development adopts a level of water sensitive urban design that matches the sensitivity of the environmental values of downstream water bodies; or
  - the application of structural stormwater management measures in developed areas (e.g. gross pollutant traps, Living Streams and constructed wetlands).
- An erosion hazard/risk assessment may be used on major construction sites to identify the need for erosion and sediment controls (see Section 2.1.1).

This guideline will focus on the first two of these applications.

## Applicability

The use of risk assessments and environmental management systems as tools for managing stormwater is highly applicable to local government authorities, government departments, industry and business.

A risk assessment process is suggested as being essential to develop a focused and practical stormwater management plan for a local government area or catchment, given the multitude of sources of stormwater pollution and limited funds for management.

Environmental management systems are recommended as a highly valuable organisational tool to systematically identify, assess and manage stormwater, particularly for organisations that have many activities or premises that may pollute stormwater.

Both of these tools are applicable to any geographic region.

## Recommended Practices

### Risk assessment during the development of stormwater management plans

The Eastern Regional Metropolitan Council (EMRC, 2002) has developed *Stormwater Quality Management Plan Guidelines* which have been modified from Victorian guidelines and are currently being trialled in Perth. These guidelines incorporate a risk assessment process as part of the overall stormwater management planning process, to identify those activities that should be a priority to manage, due to the potential risk they pose to the environmental values of receiving waters. This process is summarised in Figure 2.

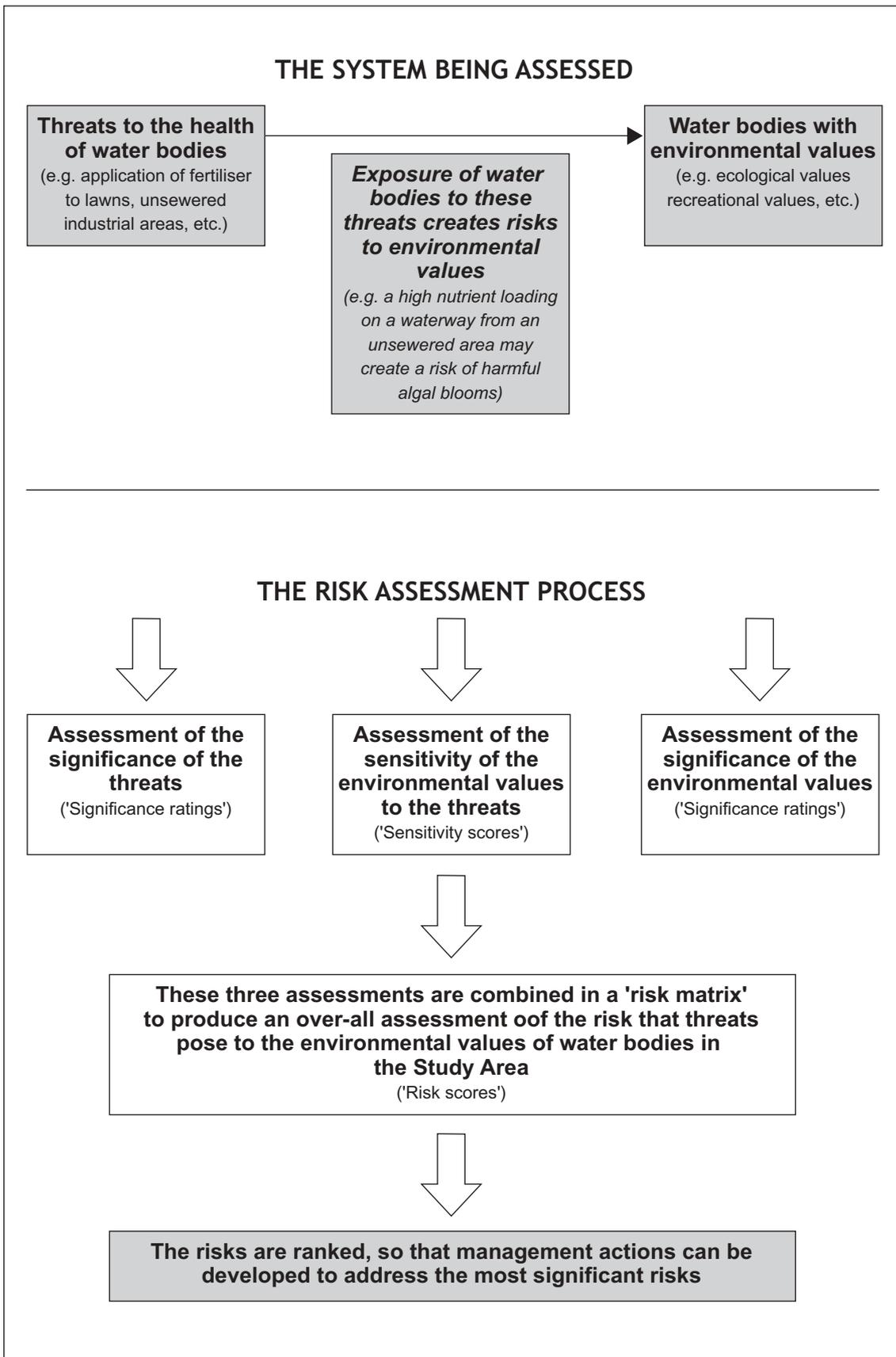


Figure 2. A risk assessment process used to develop a stormwater quality management plan (Parsons Brinckerhoff and Ecological Engineering, 2003)

Chapter 5 outlines the risk assessment process for the preparation of Stormwater Management Plans.

See the last paragraph under 'Risk assessments and EMSs to review an organisation's activities and premises' for information on checklists/methods for undertaking risk assessments.

### Risk assessments and EMSs to review an organisation's activities and premises

Environmental management systems provide the framework within which an organisation can systematically develop its environmental policy, identify and assess its environmental risks (including risks to stormwater quality and water body health), develop measures to manage these risks (e.g. new procedures, equipment and training), monitor the success of these measures, report on its environmental performance, and revise its environmental programs where necessary.

The Australian Standard for environmental management systems (AS/NZS ISO 14001:1996) provides guidance on how to establish an EMS, drawing upon well-established principles that have been widely used for quality systems (see Australian Standard AS/NZS ISO 9001).

Some organisations develop integrated management systems that address quality, health and safety, risk and environmental management. Some organisations also obtain independent certification of these systems, usually to demonstrate to senior management and stakeholders that the system is sound, and the organisation's responsibilities are being diligently exercised.

The development of an EMS has five principal steps, which are repeated to promote continuous improvement over time. These steps are:

1. Develop environmental policy (e.g. an environmental policy that includes stormwater management).
2. Develop programs and frameworks to assess environmental risks (e.g. undertake risk assessments of all work processes and premises).
3. Implement measures to manage environmental risks (e.g. implement environmental programs/plans, procedures, guidelines, manuals, training, reporting systems, install environmental management equipment or change practices).
4. Monitor, audit and assess environmental outcomes (e.g. undertake regular audits of activities and water body health monitoring).
5. Report (internally and externally) and revise programs where necessary (e.g. undertake incident and complaint reporting and regular environmental performance reporting).

The risk assessments step in this process (no. 2 above) is a critical one. A sound methodology needs to be developed (e.g. using the environmental risk management process outlined in Standards Australia, 1999) and the risk assessor needs to be suitably experienced and qualified. Checklists are often used to prompt the risk assessor to examine particular aspects of stormwater management. Basic checklists are provided in VSC (1999) and NSW EPA (1998). The Victorian *Urban Stormwater Best Practice Environmental Management Guidelines* (VSC, 1999) provides checklists for assessing basic stormwater management practices on construction sites and in relation to businesses, and for operations typically undertaken by local government. Another approach is to identify guidelines for the activity being assessed (e.g. erosion and sediment control guidelines), and simply convert these guidelines into a checklist to help identify threats/hazards during the risk assessment process.

## Benefits and Effectiveness

The primary benefit of undertaking risk assessments is to prioritise the allocation of limited resources to maximise the outcomes to the community and environment. The process of undertaking risk assessment may also identify serious breaches of environmental legislation, activities that are having significant impacts on the health of water bodies, and legal risks to the organisation (and individuals), and may help educate staff about best practice stormwater management.

Benefits of implementing an environmental management system include:

- It provides a systematic framework for rigorously identifying, assessing and managing risks, minimising the chance that the organisation's activities will adversely affect water body health.
- It potentially provides a 'due diligence defence' to environmental prosecutions (i.e. providing protection to staff and the organisation).
- It provides a 'paper trail', that minimises the loss of corporate knowledge when key staff leave the organisation.
- It can identify savings to the organisation (e.g. waste recycling opportunities, water minimisation and reuse initiatives).
- It provides senior management and stakeholders (e.g. community groups, shareholders) with a mechanism to quickly identify whether environmental management is being adequately undertaken within the organisation (particularly if the system has independent certification).

In terms of the effectiveness of these tools, the methodology is widely used, well accepted and has been documented as Australian Standards (e.g. AS/NZS 4360:1999 and AS/NZS ISO 14001:1996). However, no system is perfect. A well-designed and maintained environmental management system should minimise the risk of stormwater-related environmental impacts.

## Challenges

The following challenges may need to be addressed to improve implementation:

- Their effectiveness primarily depends upon the skills of those people implementing various elements (e.g. risk assessments, audits, developing policy). This is particularly the case during the risk assessment stage, when hazards/threats are easily missed and when there is often a subjective element to the assessment that relies heavily on expertise.
- Some risk assessment processes and environmental management systems can be cumbersome to run (e.g. risk assessments that incorporate a quantitative assessment or environmental management systems with frequent auditing and reporting requirements). These tools should be based on the financial and human resources of an organisation. A trial project or period is highly recommended to ensure this occurs. In the case of environmental management systems, it is also recommended that a paper-based system be successfully implemented for at least 12 months before moving to an electronic system (e.g. where all of the EMS's documentation is on-line).

## Cost

The cost of running these processes and systems will vary greatly depending upon their design and context.

As a general guideline, a medium-sized local government authority (say with 50,000 people) would require one full-time environmental engineer/scientist (say at a salary of \$50,000 p.a. and on-costs) to

coordinate the development and maintenance of an environmental management system. This person would also need:

- input from operational staff during risk assessments, procedure development, audits and reporting; and
- an expenses budget (say \$50,000 in the first year and then \$20,000 p.a. thereafter) to acquire specific expertise (e.g. specialist auditors, environmental monitoring specialists, trainers and analysis of samples).

## Additional Information

Potential synergies emerge when an organisation combines environmental management systems with equivalent systems for managing health and safety, quality, and other forms of risk (e.g. legal, political). The philosophy and steps in these systems are similar. Some organisations reduce costs by combining several staff roles. For example, a medium-sized business may hire one professional who is trained in environmental management and health and safety, to operate an integrated environmental, health and safety management system.

There are a number of Australian and international standards that relate to environmental management systems, risk assessment and auditing. The two *primary* Australian Standards that are relevant to this guideline are listed in the reference section below. Additional references can be obtained from these standards.

## Examples / Case Studies

### Stormwater self management system - City of Greater Shepparton, Victoria

In 2003, the City of Greater Shepparton developed a simple form of environmental management system that focused on stormwater quality (Clearwater, 2003). The stormwater self-management system (SMS) was developed to achieve successful and sustainable implementation of stormwater best practice with respect to local government activities (e.g. street sweeping and construction). It is an interactive tool involving input from all departments within the organisation to monitor compliance with best practice standards. The system has also been developed as a software package.

The SMS process is as follows:

- Stormwater management tasks are assigned to Council personnel (i.e. these are management actions to address previously identified risks to stormwater quality).
- Audits are carried out using a checklist.
- Findings from the audits are entered into a database (i.e. necessary actions).
- Necessary actions are electronically sent to the responsible department.
- Actions that are delegated or completed are electronically entered back into the database.
- Regular checks are undertaken of compliance.

The SMS's checklist was obtained from the Victorian *Urban Stormwater Best Practice Environmental Management Guidelines* (VSC, 1999).

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## 2.5 Catchment planning practices

### 2.5.2 Managing the total water cycle

#### Description

Increasingly, agencies responsible for stormwater management are realising that the issue cannot be managed in isolation from other elements of the water cycle. The new approach to managing water resources in an integrated fashion is known as ‘total water cycle management’, or ‘integrated water resource management’, or ‘water sensitive urban design’ (where stormwater quality, stormwater quantity, water supply and wastewater/effluent are all considered during the design process).

Institution of Engineers Australia (2003) summarised the need for an integrated approach, stating ‘it is no longer tenable to consider the various types of urban water flows in isolation. Management should take into account the complete urban water cycle in order to include all water flows, such as water supply, stormwater and wastewater. These flows have quantitative and qualitative impacts on land, water and biodiversity, and the public's aesthetic and recreational enjoyment of waterways.’

A good example of why an integrated approach is required concerns the use of rainwater tanks. Policies that promote the widespread uptake of tanks has the potential to reduce the need for mains water supply, but may also reduce the social and ecological impact of frequent minor flood events, reduce environmental flows in urban areas, reduce stormwater pollutant loads, and create risks to human health that must be managed. Responsible policy decisions involving the widespread use of rainwater tanks would need to consider all of these issues.

Water sensitive urban design that considers the total water cycle aims to minimise the impact of urbanisation on the natural water cycle. Its key objectives are to:

- Manage the water regime:
  - maintain appropriate aquifer levels, recharge, and stream and wetland flow characteristics in accordance with assigned beneficial uses;
  - prevent flood damage in developed areas; and
  - prevent excessive erosion of wetland and waterway slopes and banks.
- Maintain and where possible enhance water quality:
  - minimise waterborne sediment loading;
  - protect existing riparian or fringing vegetation;
  - minimise the export of pollutants to surface water or groundwater; and
  - minimise the export and impact of pollution from sewage.
- Encourage water conservation:
  - minimise the import and use of scheme water;
  - promote the use of rainwater, stormwater and groundwater, where such use does not adversely affect existing environmental values associated with this groundwater (e.g. groundwater dependent ecosystems, or public drinking water supplies);
  - promote the reuse of wastewater/effluent;

- reduce irrigation requirements; and
- promote opportunities for localised supply.
- Enhance water-related environmental values.
- Enhance water-related recreational and cultural values.
- Add value while minimising development costs. (Modified from Whelans *et al.*, 1994, and Institution of Engineers Australia, 2003.)

Institution of Engineers Australia (2003) highlighted one major impediment to the trend in Australia towards total water cycle management, stating ‘the fragmentation of responsibilities for water supply, water quality, drainage and environmental protection, and the need to interface with the development process suggests the need for greater coordination of land use and water decision making, particularly at the strategic level, if water sensitive urban design is to be effective. This is particularly relevant when considering decentralisation of water and wastewater services, seeking recycling opportunities and implementing water conservation strategies’.

## Applicability

Resolving the organisational impediments to promote an integrated approach to urban water cycle management is relevant to all regions. It is particularly relevant to those regions:

- facing pressure to improve the management of more than one part of the water cycle, and seeking to harness the synergies that are available from an integrated approach; and
- where responsibilities for parts of the water cycle are fragmented, and the interests of the relevant organisational units are not clearly aligned.

## Recommended Practices

To help overcome these organisational impediments to promoting an integrated approach to urban water management, the following actions are suggested as essential:

- ✓ Ensure there is a clear and consistent vision (or policy) for total water cycle management that is shared by all agencies in the region with a role in water management.
- ✓ Ensure measurable targets are developed that relate to the management of stormwater quality, stormwater quantity, water supply and wastewater/effluent (including reuse).
- ✓ Ensure there is strong managerial and political commitment to the vision and targets.
- ✓ Ensure that all organisational units that manage parts of the urban water cycle are committed to the same vision and their interests are aligned. For example, if an organisational unit’s performance is judged on narrow objectives (e.g. ‘how much water is sold’, ‘how much wastewater is reused’), it may constrain an integrated approach to projects where collaboration occurs between all units whose water-related interests may be affected. Such collaboration is required to maximise the probability of finding an optimal outcome for the community in terms of *total* water cycle management.
- ✓ Ensure responsibilities for managing all parts of the urban water cycle are clear and agreed (e.g. the responsibilities of local government, State government departments and water service providers).

- ✓ Ensure public reporting mechanisms foster accountability within all agencies responsible for urban water management. The development of measurable targets can assist this process.
- ✓ Ensure that the total water cycle management philosophy permeates all water-related decisions and projects, such as:
  - The design and construction of new government assets (e.g. roads, buildings);
  - Development assessment decisions;
  - Decisions relating to regional stormwater treatment devices, sewage treatment plants, reuse schemes, rainwater tank subsidies, grant programs, etc.;
  - Town planning instruments;
  - State and local government policies;
  - Development control plans/strategies; and
  - Catchment-based water management plans.

## Benefits and Effectiveness

The Institution of Engineers (2003) sees the new, integrated approach to urban water management as having significant benefits in comparison to the traditional, ‘conveyance-orientated approach’ primarily because it has the potential to reduce development costs, reduce water pollution, reduce the consumption of scheme water, and reduce water balance problems by minimising changes to pre-development hydrological regimes.

Many desktop studies and practical demonstrations are now available showing the advantages of taking an integrated approach to urban water systems compared to the traditional approach (Clark, 2003).

Mitchell (2003) believes the most important benefit of taking an integrated approach to the management of urban water systems is that it potentially increases the range of opportunities available to design and deliver more sustainable systems. Speers and Mitchell (2000) support this view, by stating ‘in as much as the robustness of ecological systems is increased through diversity, so too will the sustainability of urban water systems be improved if an increased range of options are made available enabling solutions to be tailored to local circumstances’ (p. 17).

From case study information, the following quantitative benefits can result from an integrated approach to urban water cycle management:

- Reduction of scheme water consumption by approximately 25 to 30% per cent is possible in a typical household, through the adoption of water efficient appliances and practices. This figure could rise to 65% in the long term through the use of alternative sources of water, as well as demand reduction strategies (Institution of Engineers Australia, 2003).
- Average annual pollutant loads in stormwater can be substantially reduced (e.g. 80% reduction in typical urban TSS loads and 45% reduction in TP and TN loads are objectives that can be met in most circumstances within Australia). For more information, see Institution of Engineers Australia (2003) or Taylor and Wong (2002c).
- In the long term, 100% reuse of treated wastewater effluent is possible within large individual developments or within the region (Institution of Engineers Australia, 2003).

- In terms of hydrological performance, water sensitive urban design can often ensure the peak stormwater discharge is maintained at pre-development levels, while pre-development runoff volumes are also maintained (Institution of Engineers Australia, 2003).

## Challenges

The move towards an integrated approach to urban water management has been limited in some regions because of factors such as:

- organisational fragmentation, cultures, inertia and unaligned interests (as highlighted above);
- concerns over post-development operation and maintenance costs (e.g. for structures such as aquifer storage and recovery systems);
- increased complexity in decision-making;
- the lack of an effective regulatory and operating environment at the State or local government level;
- limited quantitative data on the long-term performance of best management practices;
- the current skills within some local governments and water service providers do not yet support the changes required for the assessment, approval, construction and maintenance of development schemes based on water sensitive urban design principles;
- lack of guidance on the life cycle costs of best management practices (including a lack of guidelines on how to undertake such analyses, especially where externalities are included); and
- uncertainties regarding the market acceptance of residential properties with water sensitive urban design features. (Modified from Lloyd *et al.*, 2002.)

## Cost

Information from case studies on the cost of development using an integrated approach to water management is available in Lloyd *et al.* (2002) and Taylor and Wong (2002c).

The cost of successfully overcoming organisational impediments to integrated urban water cycle management cannot be estimated, due the large number of unknown variables.

## Additional Information

In summarising key environmental issues for the Australian water industry, Langford (2000) stated that the objectives of a more sustainable urban water system should be defined by the *total urban water cycle*, specifically:

- Reduced diversions of freshwater from the environment to service growing urban populations.
- Reduced environmental impacts of pollutants from point and non-point sources such as nutrients and sediment.
- Reduced potential for pathogens to adversely impact human health.
- Lower energy consumption.
- Reduced net emissions of greenhouse gases.

- Increased resilience to manage variability in demands and unexpected events.
- Increased cost-effectiveness.

Although new to Australia, the philosophy of integrated water resource management is not new. Beck (2002) quoting Kneese (1967) notes that its history extends back a century when it was used in the Ruhr and Wupper catchments of Germany.

Despite the strength of the arguments for integrated water resource management, it should not be considered to be the ‘correct’ problem-solving model that will automatically produce sustainable and cost-effective urban water systems. In reality, the approach to managing water resources in urban areas will evolve over time as new ideas, information, drivers for change and technologies emerge. This approach is sometimes called ‘adaptive environmental management’.

## Examples / Case Studies

Several leading water sensitive urban design case studies for specific developments in Australia are described in Institution of Engineers Australia (2003) and Lloyd (2001).

In terms of *organisational* case studies, the greater Melbourne region provides an example of how jurisdictional fragmentation was managed to achieve positive results. In Melbourne, responsibility for stormwater management is split between Melbourne Water (which manages the trunk drainage network), numerous local government authorities (which manage the minor drainage network), and the Victorian Environmental Protection Authority (which is the lead agent for environmental protection). To help clarify roles and responsibilities with respect to stormwater and to ensure that all organisational units were coordinated, a ‘Partnership Agreement’ was jointly developed and signed on 26 November 2002 (Clearwater, 2002). This was seen as a major step forward towards improved management of stormwater in the greater Melbourne region.

Another organisational example is Brisbane City Council. Brisbane City Council manages virtually the entire urban water cycle in Brisbane. In 2002, the policy (or ‘purchaser’) units of Council that were responsible for stormwater quality, stormwater quantity, catchment management, water supply and wastewater were combined to form one branch (the Water Resources Branch). Other initiatives include:

- the development of a citywide Water Management Strategy as a vehicle to define an agreed vision for 2020, and the major projects that will be delivered to achieve this vision; and
- the use of multi-disciplinary project teams to ensure all aspects of the water cycle are considered during major projects.

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Stormwater  
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8  
Education and  
awareness for  
stormwater  
management



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# Stormwater Management Manual for Western Australia

## 8 Education and awareness for stormwater management

Prepared by Elizabeth Morgan, Department of Environment  
Consultation and guidance from the Stormwater Working Team



Department of  
**Environment**

February 2004

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## Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the *State Water Strategy* (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Catchment Management Branch of the Department of Environment.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

The aim of this chapter is to present ways in which an education and awareness program can be developed for various sectors of the community to raise awareness and provide a catalyst for a change in behaviour to reduce the amount of pollution that enters the stormwater system. Education and Awareness is one of the non-structural methods that can be used in an integrated approach to best practice stormwater management.

The chapter utilises and expands on the concepts contained in the Australian Guidelines for Urban Stormwater Management (ARMCANZ/ANZECC, 2000). The Australian Guidelines place primary importance on education and awareness. This is consistent with the principle that any attempt to incorporate sustainability into the community must also explicitly address education and awareness.

Stormwater pollution from residential, industrial, commercial and agricultural areas is the result of many actions at various locations within the catchment. People are often unaware that their activities can impact on stormwater. Once they are aware and have learnt simple solutions to reduce or avoid causing stormwater pollution, changes to their behaviour are more likely. However, it has been found that in addition to education, it is important to have a supporting infrastructure and social structure close to people so that it is easy for them to comply with educational messages (e.g. providing adequate recycling stations).

The development of an environmental education program for stormwater can be split into a nine-step process. These nine steps recognise that for the program to be effective, a thorough understanding of the environmental issues, stakeholders, behaviour targeted and the best way to achieve an improved environment is needed.

Stormwater education programs have been shown to have many benefits over 'engineering' solutions, including favourable cost-benefit comparisons.



# 1 Introduction

Traditionally engineered stormwater systems capture water runoff from roads, roofs and land and direct it through stormwater pipes to rivers, streams, wetlands, compensating basins and oceans. In these situations, pollution from many sources within the catchment can be carried by stormwater into the streams and wetlands. As stormwater is rarely filtered or treated, refuse, chemicals and oils can enter our rivers, streams and the ocean, or into compensating basins for infiltration. This pollution can harm our wildlife and degrade local waterbodies or groundwater quality.

Contemporary stormwater management is aimed at reducing the impacts of development on the natural water cycle (Victorian Stormwater Committee, 1999, ARMCANZ/ANZECC, 2000, Institution of Engineers Australia, 2003). Stormwater management now emphasises stormwater quality, health of aquatic ecosystems and public amenity, in addition to managing stormwater quantity. By necessity, stormwater management needs to be broadly based, requiring multi-disciplinary inputs.

People are often unaware that their activities can impact on stormwater quality and result in environmental degradation. Once aware and informed of simple solutions that reduce or avoid causing stormwater pollution, a change in people's behaviour is more likely, keeping in mind other motivators behind behavioural change. However, although environmental education has shown to be successful in a number of cases, stormwater management usually requires an integration of approaches.

Figure 1 illustrates the numerous stormwater management approaches and that education and awareness is only one of these approaches. Other approaches are detailed in various chapters of this Manual.

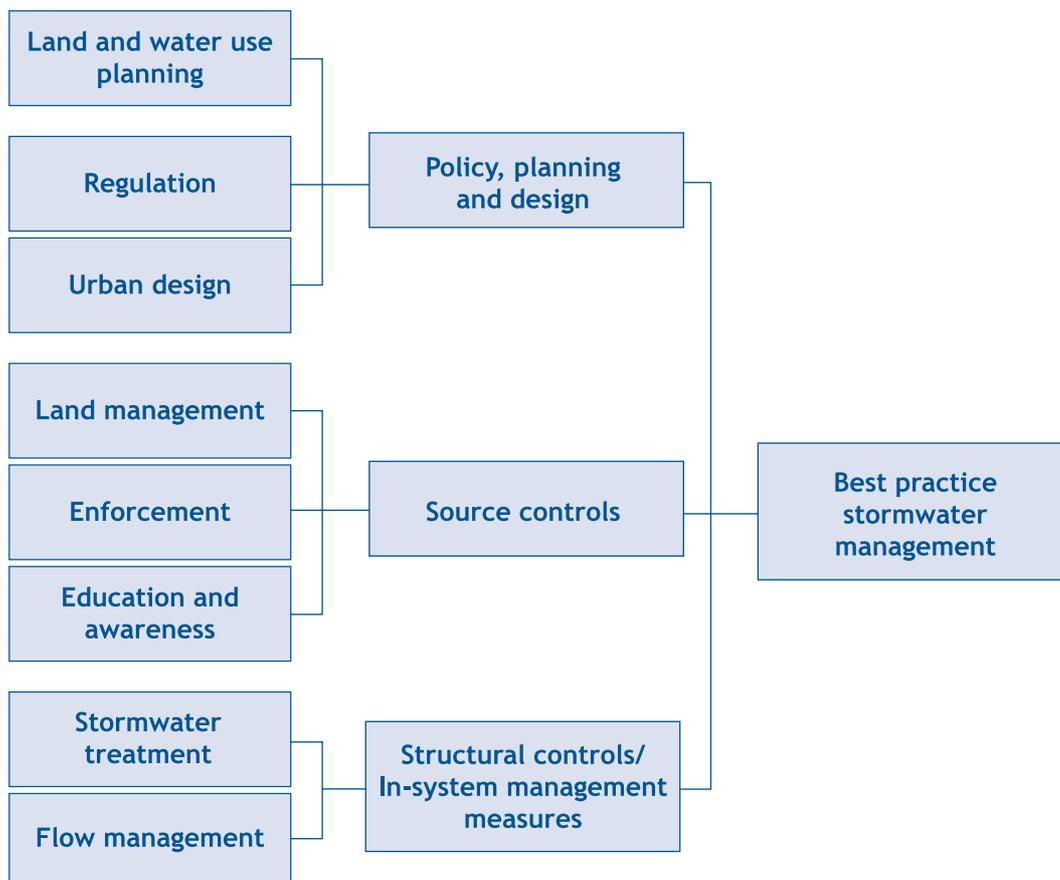


Figure 1. Best Management Practice of stormwater requires integration of a range of measures (ARMCANZ/ANZECC, 2000).

This chapter describes a methodology for developing education and awareness programs for stormwater pollution. A number of tools, techniques, methods and examples of successful programs are presented to help in the process of developing an education and awareness program.

**The aim of this chapter is to present ways in which an education and awareness program can be developed for various sectors of the community to raise awareness and provide a catalyst for a change in behaviour to reduce the amount of pollution that enters the stormwater system. Education and Awareness is one of the non-structural methods that can be used in an integrated approach to best practice stormwater management.**

## 1.1 What is stormwater pollution?

The main types of stormwater pollution include:

- litter, such as cigarette butts, cans, paper or plastic bags
- chemical pollution, such as detergents, oil or fertilisers, and
- 'natural' pollution, such as leaves, garden clippings or animal droppings.

Everyone has a part to play in reducing the amount of pollution contaminating our valuable water resources.

## 2 The broad policy context

There are a number of National and State strategies that provide the framework and principles for the development of best management practice for stormwater management in WA and the development and implementation of education and awareness programs as an integral part of stormwater management in this State. Below is a short description of some of the key policies that provide a framework for stormwater education in Western Australia.

### **Sustainability strategies**

The 'National Strategy for Ecologically Sustainable Development' (NSES)(Commonwealth Government, 1992) sets out national objectives and principles of Ecologically Sustainable Development (ESD) for development that improves the total quality of life in a way that maintains the ecological processes on which life depends; including water quality management planning. The development of the National Strategy was one of the responses to the global agreement to move towards sustainability. Western Australia is a signatory to this Strategy.

The WA State Government has produced the draft State Sustainability Strategy (Government of Western Australia, 2002), in line with the NSES. The draft State Sustainability Strategy and the State Water Strategy, produced in 2003 by the State Government as a response to the need for sustainable water use in WA, make recommendations to promote Water Sensitive Urban Design and total water cycle management, of which stormwater management is a primary component. The National Strategy for Ecologically Sustainable Development, draft State Sustainability Strategy and State Water Strategy also recommend that education and awareness needs to play an integral part in delivering the objectives of sustainability.

## **Implementing sustainability through an education framework**

The Commonwealth released 'Environmental Education for a Sustainable Future – National Action Plan' in 2000. The National Action Plan is intended to provide a framework for environmental education activities in Australia. It is also intended to be a starting point for an enhanced national effort in support of Australia's ecologically sustainable development.

The Department of Environment has prepared a draft Environmental Education Strategy for Western Australia. The draft is currently undergoing a further round of key stakeholder consultation before presenting to Cabinet later in 2003. The objectives of the WA Environmental Education Strategy and Action Plan are:

- i. Co-ordination and integration
- ii. Government leadership
- iii. Formal education
- iv. Building partnerships with the community, and
- v. Building partnerships with industry and business.

The National and State Strategies provide the framework by which an understanding of ESD can be developed by the community. As stated in the draft State Sustainability Strategy, 'we need to raise awareness of sustainability and provide education for sustainability if we are to shift to a more sustainable society' (Government of Western Australia, 2002).

## **The National Water Quality Management Strategy**

Another key Commonwealth strategy is the 'National Water Quality Management Strategy' (NWQMS), from which a number of guidelines have been developed. This strategy is consistent with the NSESD and its principles, and the finalisation of the NWQMS was one of the recommendations of the NSESD. Western Australia is a signatory to the NWQMS and its implementation, as are all States in Australia. The NWQMS will be implemented in Western Australia through the State Water Quality Management Strategy (SWQMS).

The 'Australian Guidelines for Urban Stormwater Management' (ARMCANZ/ANZECC, 2000), is one of the guidelines that have been developed under the 'National Water Quality Management Strategy', and provides a nationally consistent approach for managing urban stormwater in an ecologically sustainable way. The Guidelines outline current best practice in stormwater planning and management in Australia and has set out a management preference hierarchy in line with the principles of ESD.

**The application of ESD to management of urban stormwater therefore aims 'to develop and manage in an integrated way, the quality and quantity of surface and groundwater resources and to develop mechanisms for water resource management which maintain ecological systems while meeting economic, social and community needs' (ARMCANZ/ANZECC, 2000).**

## **The Western Australian Stormwater Management Hierarchy**

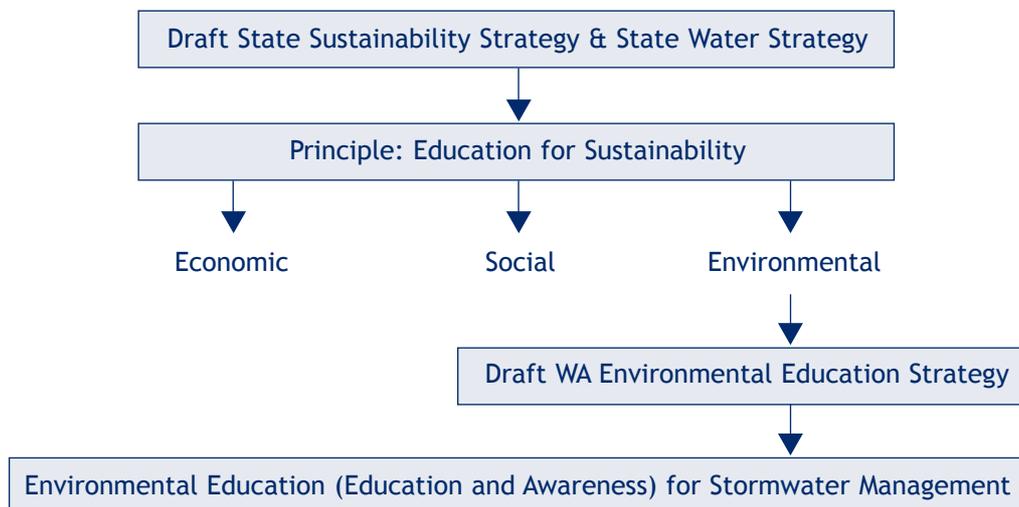
In line with the Australian Guidelines, a stormwater management hierarchy approach for managing urban stormwater is taken in Western Australia. The stormwater management hierarchy applied in WA is listed below.

1. Retain and restore natural drainage lines – retain and restore existing valuable elements of the natural drainage system, including waterway, wetland and groundwater features and processes.
2. Implement non-structural source controls – minimise pollutant inputs principally via planning, organisational and behavioural techniques, to minimise the amount of pollution entering the drainage system.
3. Minimise runoff – infiltrate or re-use rainfall as high in the catchment as possible. Install structural controls at or near the source to minimise pollutant inputs and the volume of stormwater.
4. Use of in-system management measures – includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps.

These steps require the preservation of the valuable features of the water environment, control of the pollution at the source, and only proposes management measures within stormwater systems for residual impacts that cannot be cost-effectively mitigated by source or near source controls. The principles and objectives for stormwater management in WA are presented in Chapter 2 of this manual.

The stormwater management hierarchy and the principles and objectives of stormwater management place utmost importance on education techniques for stormwater management. Community participation is now considered an integral objective in stormwater management and is an effective means of preventing pollution of stormwater ‘at source’. If successful, and there is a reduction of pollution entering the stormwater system, then the need for other stormwater management techniques are reduced.

**This chapter on education and awareness utilises and expands on the concepts contained with the Australian Guidelines for Urban Stormwater Management. The Australian Guidelines place primary importance on education and awareness. This is consistent with the principle that any attempt to incorporate sustainability into the community must also explicitly address education and awareness.**



*Figure 2. Western Australian Framework for Environmental Education for Stormwater*

### 3. Who will benefit from this chapter?

This chapter of the Manual has been developed for people interested or involved in planning an environmental education program for stormwater, including:

- Local government authorities
- State Government departments and agencies
- The wider community
- Environmental groups, and
- Industry associations (and groups).

Table 1 gives some examples of how environmental education for stormwater can be delivered by various sectors.

**Table 1. Delivery methods for stormwater environmental education projects.**

Sector	Example projects
Local government	Providing subsidised composting bins Talks, presentations and seminars Exhibitions and displays Targeted mail outs
State government	River cleanup programs Joint government/industry programs Courses through schools, universities, TAFE and other educational bodies
Environmental/community groups	Planting days Project development Drain Stencilling Permanent displays and signs erected adjacent to waterways School visits Professional Development for Teachers
Industry associations	Teachers notes (like NIA) Workdays Member accreditation

### 4. What will an education and awareness program achieve?

Stormwater pollution from residential, industrial, commercial and agricultural areas is the result of many actions at various locations within the catchment. People are often unaware that their activities can impact on stormwater. Once aware and informed of simple solutions that reduce or avoid causing stormwater pollution, a change in people's behaviour is more likely. However, it has been found that in addition to education, it is important to have a supporting infrastructure and social structure around individuals so that it is easy for them to comply with educational messages (e.g. providing adequate recycling stations) (Taylor & Wong, 2002).

It also should be noted that education is only one factor that influences an individual's behaviour. Other factors that influence behaviour include:

- the social values and standards passed on in the home, at school, through social groups and in the media
- age, gender, ethnicity, income and occupation
- recent events
- laws, regulations and policies – and how these are monitored, implemented and enforced
- the availability of technology, products and services; and economic factors such as financial incentives or disincentives, and
- convenience factors.

Education should be considered as one of a number of mechanisms to address issues that arise from people's actions. Other mechanisms include:

- enforcement: policy, legislation and regulation
- economics: monetary incentives and disincentives
- engineering, science and technology, and
- evaluation, monitoring and research.

**The aim of environmental education for stormwater is therefore to influence behavioural change to reduce the amount of pollution that enters the stormwater system. The programs are more likely to show results if they are planned as part of an holistic approach towards stormwater best practice management.**

#### 4.1 What is environmental education and what makes it effective?

'Environmental education' is defined in its broadest sense to encompass raising awareness, acquiring new perspectives, values, knowledge and skills, and formal and informal processes leading to changed behaviour in support of an ecologically sustainable environment (Commonwealth of Australia, 2000).

Community education is a process used to:

- create awareness of issues
- enhance knowledge, understanding and skills
- influence values and attitudes, and
- encourage more responsible behaviour.

Community education can include formal education such as schools and tertiary institutions, public involvement activities, vocational education and training and community marketing campaigns.

Effective community education projects:

- involve stakeholders and learners in decisions about the planning, management, content, style and delivery of the project
- create a supportive environment for influencing behaviour

- support and strengthen existing community networks and help create new ones
- motivate and encourage ownership
- provide opportunities for examining beliefs and values
- identify and promote positive actions rather than discourage undesirable ones
- are relevant, accessible and affordable, recognising the differing circumstances and constraints in a community
- use two-way communication methods, and
- respond to the diverse needs of the community.

*Source: NSW EPA and DLWC, 2001.*

Community involvement in stormwater management is important to enable the community to develop ownership of both issues and the solutions. Raising the profile of stormwater issues in the community is likely to encourage greater involvement in stormwater management. Programs such as the ‘Yellow Fish Road’ drain stencilling for schools and industries or involvement in water quality monitoring can help mobilise some community participation and raise awareness about stormwater issues (EMRC, 2002). Further details on the Yellow Fish Road drain stencilling program, as well as numerous other stormwater education programs can be found in the examples section further in this chapter.

Research undertaken in the US found that the most successful stormwater management programs, out of over 150 programs surveyed, accomplished three goals in response to stormwater pollution problems (Morison, undated); these goals being:

- educating the public about the nature of the problem
- providing information to the people about what they can do to solve the problem, and
- involving the local community in hands on activities to achieve pollution reduction or restoration targets.

**Environmental Education is a process that promotes knowledge and understanding of an issue, links processes, and encourages ownership that leads to positive behaviour changes.**

## 4.2 Key principles of environmental education

Five key principles of environmental education are presented in the ‘Environmental Education for a Sustainable Future: National Action Plan’ (Commonwealth of Australia, 2000). These are:

- i. Environmental Education must involve everyone – environmental education cannot be confined to any one group in our society, it involves government, industry, the media, educational institutions, community groups and individuals.
- ii. Environmental Education must be lifelong – knowledge and skills continually need to be refreshed.
- iii. Environmental Education must be holistic and about connections – people need to think broadly and understand systems, connections, patterns and causes.

- iv. Environmental Education must be practical – one of the most fundamental defining characteristics of effective environmental education is that it must lead to actions which result in better environmental outcomes, not simply the accumulation of inert knowledge or impractical skills.
- v. Environmental Education must be in harmony with social and economic goals and accorded equal priority – effective environmental education should not be taught in a vacuum.

### 4.3 Current level of understanding and improvement through programs

The Urban Water Research Association of Australia (UWRRA) conducted a two-stage study throughout Australian cities (Brisbane, Sydney, Melbourne and Perth) (1995 and 1998) in response to the stormwater issue. The study had the following objectives:

- to determine the extent of community awareness and knowledge of issues associated with urban stormwater management;
- to determine community perceptions of urban stormwater as a potential resource;
- to investigate community attitudes to and perceptions of urban stormwater management in terms of responsibility;
- to determine the amenity value of urban stormwater management based on the community's economic, social and environmental attitudes; and
- to determine the extent to which communities can and want to be involved in the management of urban stormwater, and the actual effectiveness of community involvement in improving stormwater management outcomes.

The study found that 91 percent of Perth residents said they knew what stormwater was, only 45 percent explained that it was any form of urban runoff. In all cities, very few respondents had no idea what stormwater was.

Perth people have quite a good knowledge of where stormwater goes and although they have a better knowledge of the full definition of what stormwater is than either Melbourne or Brisbane, public education and awareness programs in this area would be useful.

The study attempted to define what was an individual's willingness to pay (WTP) to reduce the pollutant effects of stormwater on waterways. The WTP technique is a hypothetical evaluation technique that asks respondents how much they would be willing to pay for this reduction. The technique is an attempt which places a dollar value on how much reducing the effects of stormwater on the water quality of the wetlands, waterways and ocean is worth to the individual respondent and estimates of the benefits (value) from a reduction in stormwater effects can be made.

Stage 1 of the study also looked at reported community behaviour or action. The results indicate that people were generally positive about doing things that would assist stormwater pollution abatement. On calculating a total potential action score, Perth and Sydney showed a greater potential for action than Brisbane or Melbourne. The study also showed that the major predictors of potential community action in stormwater management were attitudinal. Therefore, any intervention that increases the extent to which stormwater is viewed as an environmental problem could also increase reported community action and WTP (Nancarrow *et al*, 1998, p 92). A study undertaken in 1993 (Syme *et al*, cited in Nancarrow *et al*, 1995, p 166) on motivation for reported involvement in wetlands preservation in Perth found that knowledge did affect reported behaviour, but only as filtered through emotion and assessment of the seriousness of the environmental problem.

Stage 2 of the study was to determine if specifically targeted information and activity produced positive changes in the attitudinal measures over time, and hence have some effect on pro-environmental behaviour. The study concluded that no measurable behavioural change occurred in any of the cities as a result of the experiment. It was found that there was little evidence to demonstrate that respondents were doing things to assist with stormwater management even though respondents reported that they were doing so (Nancarrow *et al*, 1998, p 159). However, it was reported that what was occurring was consistent with the familiar model from the behavioural change literature, awareness leads to knowledge, which leads to attitudinal change and then to practice, and that longer timeframes of about 7-10 years are needed for behaviour to change (Nancarrow *et al*, 1998, p109).

Andre Taylor and Tony Wong (2002) have presented an extensive literature review on various education programs nationally and internationally in the Cooperative Research Centre for Catchment Hydrology Technical Report 02/13 'Non Structural Stormwater Quality Best Management Practices – A Literature Review of their Value and Life-Cycle costs'.

### **Local levels of understanding**

One Western Australian example of the level of understanding at catchment scale can be demonstrated by the Littoria Catchment Care Group, which has attempted to improve community awareness and understanding of stormwater issues that were formed as part of the above UWRRA study. This group has since disbanded, however, its work has continued through the Bannister Creek Catchment Group (formed in 1996). This group has continued with the 'Clean Drains...River Gains' stencilling that was adopted by the Littoria Catchment Care Group in the national study. A catchment group member has also continued the philosophy by integrating environmental education into Kinlock Primary school, which won the Earthschool awards.

The Bannister Creek Catchment Group (BCCG) has undertaken a project to transform a section of a drain, with support from the City of Canning, the Department of Environment, the Water Corporation, the Swan Catchment Urban Landcare Program, ALCOA, the Natural Heritage Trust and the local community. The project is part of the broader Swan-Canning Cleanup Program and Swan Region Natural Resource Management Strategy.

The retrofitting project at Bannister Creek is part of a broader program to improve the health of the catchment. More detail on the physical and biological parameters and results are given in Chapter 6. The project has been successful due to the high investment in partnership building with various stakeholders and a high level of community involvement and skill development.

Surveys and evaluation undertaken by BCCG show that the most important part of involving schools and the community in environmental education is that they have external support. It was also found that kit-based packs should only be a resource and needs to be integrated into an holistic environmental education program.

A second Western Australian example of the level of understanding at catchment scale is the ‘Phosphorus Awareness’ Project. This is being undertaken by the Canning Catchment Coordinating Group and assisted by a group of volunteers (Phosphorus Action Group). The project is based on the knowledge that we are using too much phosphorus in our daily lives. It has been found that about 64 tonnes of phosphorus is carried by Perth’s urban stormwater system each year.

Community surveys undertaken every two years has shown that 83 percent of respondents know that reduced phosphorus use in households and gardens could help the health of the river, while 93 percent of respondents would modify their household practices to help reduce the amount of phosphorus entering the river.

## 5 Developing an education and awareness program

Effective community education requires a thorough understanding of the environmental issues, stakeholder behaviour targeted, and is the best way to achieve an improved environment.

There are eight key steps to plan an effective community education program. Figure 3 shows the steps in the process:

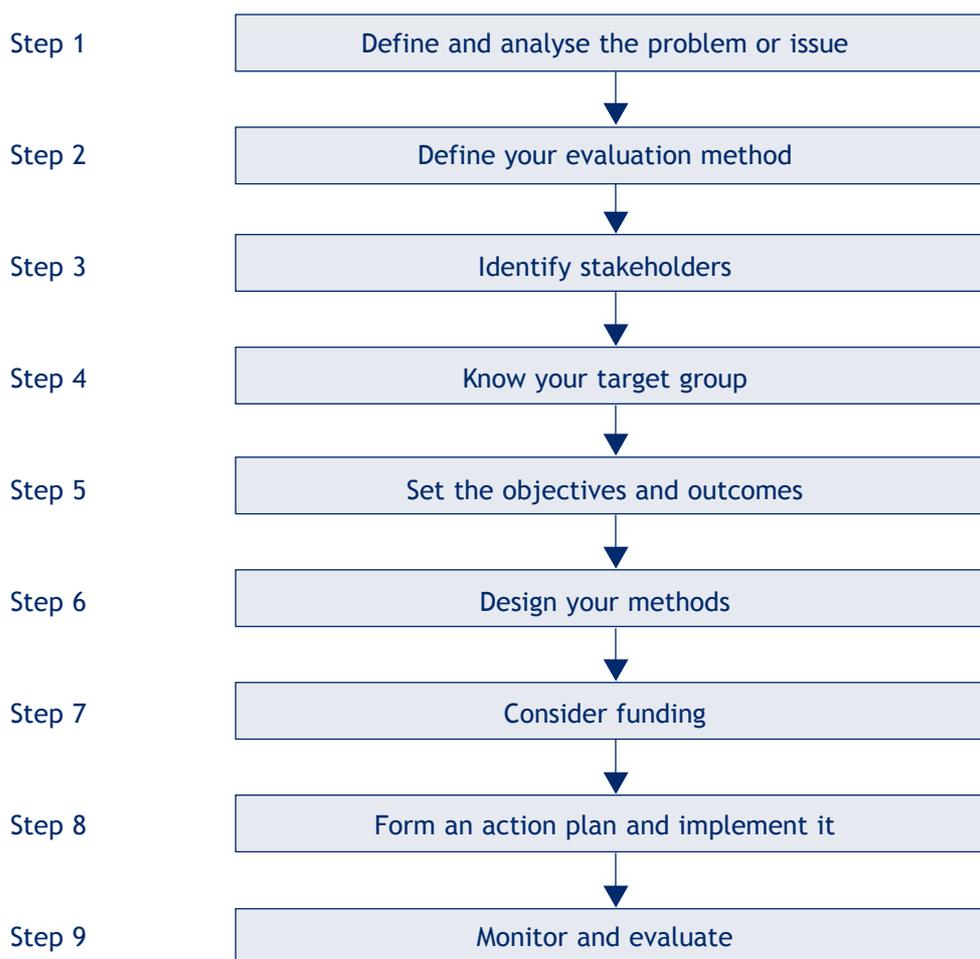


Figure 3. Steps in developing an education program

(adapted from VSC, 1999)

## Step 1: Define and analyse the problem or issue

The first step is to establish what is causing concern. It is essential to determine the sources of pollution and who impacts on these sources.

Find out how much is already known about the problem by professionals working in the area and the community members who are associated with the issue or problem location. To define an issue or problem, you need to investigate, discuss, analyse and review with inputs from stakeholders. If you look for solutions before you fully understand the issue, you could have trouble clarifying what you want and are able to achieve.

Some of the questions that you may want to ask are:

What is the problem? Does the community realise the problem? What are the causes of the problem? What is the level of understanding? Have there been any campaigns in the area before? What has been done before? Is education the best way to deal with the problem?

**If you know where you are, it is easier to define where you are going and produce an effective outcome.**

Table 2 shows a few of the problem pollutants, with some examples of impacts the pollutant may have and some possible causes. This list is by no means extensive, but provides a starting point from where an issue can be identified and analysed. The importance of doing some research and preparation, and analysing a situation is clearly shown to be of prime importance at the inception of developing an education program. Issue identification is a vital step in developing a program that is effective, and for continual improvement, monitoring and evaluation of the program.

**Table 2. Examples of pollutants and their possible cause and effects.**

Issue	Potential negative impact	Possible cause
Sediment or turbidity	<ul style="list-style-type: none"> <li>• Smothering of plants and animals on the bottom of the waterbody</li> <li>• Clogging of fish gills</li> <li>• Negative aesthetic effects</li> </ul>	<ul style="list-style-type: none"> <li>• Erosion of sediment from catchment (e.g. building sites) or stream banks</li> <li>• Hosing path material into the stormwater drains</li> </ul>
Nutrients (algae problems)	<ul style="list-style-type: none"> <li>• Stimulates the growth of algae, with the resultant decay leading to low dissolved oxygen levels affecting animal and plant life</li> </ul>	<ul style="list-style-type: none"> <li>• Excessive use and inappropriate use of fertilisers, resulting in wash off into waterways, streams and wetlands</li> <li>• Animal faeces</li> <li>• Washing cars and disposing of water into drains</li> </ul>
Gross pollutants	<ul style="list-style-type: none"> <li>• Reduces aesthetic appeal of waterways</li> <li>• Detrimental to aquatic life</li> </ul>	<ul style="list-style-type: none"> <li>• Littering e.g. plastic bottles, wrappings or cigarette butts</li> <li>• Waste dumping</li> </ul>
Petrol, oils and grease	<ul style="list-style-type: none"> <li>• Reduces aesthetic appeal of waterways</li> <li>• Toxic effect on aquatic life</li> </ul>	<ul style="list-style-type: none"> <li>• Car maintenance activities (individuals or businesses)</li> <li>• Illegal dumping of waste lubricating or food oils</li> <li>• Leaks from vehicles</li> </ul>
Pesticides and herbicides	<ul style="list-style-type: none"> <li>• Harms aquatic plants and animals</li> </ul>	<ul style="list-style-type: none"> <li>• Inappropriate use of pesticides and herbicides</li> <li>• Pesticides and herbicides washed off into waterways and wetlands</li> </ul>

Depending on what the land use is within your catchment, or what activities are known to be of most prevalence, the education program can be tailored to suit a target audience. The following steps go through the process of identifying your target audience, defining objectives and forming methods to deliver the objectives. But all this does start with some analysing into the STATE of the issue and the PRESSURE analysis, before reacting with a RESPONSE.

The message might be: pick up your dog droppings, wash your car on the lawn, use less fertiliser – don't use fertiliser, pesticides or herbicides if it is just about to rain, or don't tip paint or chemicals down the drain. Step five details the process of creating and delivering a message.

Education and awareness programs focus mainly on quality source control, however, an education program may want to target or include quantity source control. For example, a program may want to encourage porous pavers so that stormwater can be infiltrated at source, and not enter stormwater infrastructure. In this way, the scouring and erosion effects of delivering high quantity bursts of stormwater through engineered drainage systems into wetlands or waterways can be decreased.

## **Step 2: Define your monitoring and evaluation methods**

Monitoring and evaluation is detailed in Step 9. It is important to determine how the stormwater education program is going to be evaluated when you are designing the program. Of course, as each Step in the design of the stormwater education program is worked through, the methods of how you will monitor and evaluate will be refined.

In Step 1, some level of understanding of the problem or issue should have been identified. Steps 3 and 4 outline the process of defining the stakeholders and target audience. Maybe this would be a good time for collecting some baseline information. This could be by using phone or mail surveys with target questions or desktop research. This is discussed further in Step 4.

Other monitoring and evaluation methods you may wish to consider using include: change in practice, or water quality monitoring.

## **Step 3: Identify stakeholders**

It is imperative that the education program identifies those individuals or groups that have responsibilities or are involved in some way in managing or protecting stormwater. Due to their involvement and ownership of the issue, many stakeholders will have knowledge, networks and resources that can add significant value to your project, such as: Local Government authorities, Department of Environment, Chamber of Commerce, a Catchment Management group and media.

**It is important to identify the stakeholders, to involve them and to establish their views about the issue.**

Partnerships can be formed to work together to solve an issue. At least one stakeholder should be from the target group.

Who are the key people in solving the problem? How will stakeholders be involved?

## Step 4: Know your target group

Who do you need to reach? Who are you trying to influence with the project?

**It is important to identify, get to know and involve your target group early in the project. Knowing the target group means much more than simple identification. A complete profile should be developed to identify the most effective communication methods to use.**

A complete profile includes detailed demographic information such as age, locality, occupation, culture, interest, gender, socio-economic status and level of education. An understanding of the group's current knowledge, attitudes and practices concerning the issue will have to be gained. Finding out how the target audience receives information will help you develop, format and distribute your messages. What radio and television stations do they use; which magazines, newspapers or newsletters do they read? Do they belong to any organisations? Whose opinions do they value?

Any information that can be gathered on the target group will serve to benefit the education program. Researching the target group need not be complicated. It may involve setting up a focus group or discussion with a sample of people who are representative of the group. Other methods of gathering information may include surveys by mail and phone. These are both useful ways to get baseline information about a target audience, or by accessing information that may have already been gathered (from one of the stakeholders or a database for example).

## Step 5: Determine objectives and outcomes

**What do you want to achieve? What outcomes do you want? What are the key messages you want to create? How will achieving the objectives help solve the issue or problem?**

Once the issues and the target groups are identified, it is necessary to determine the result you want from the education and awareness program. This can be defined by setting the goal, educational objectives and desired outcomes. The goal is a broad statement of what you want to achieve, such as, to undertake an education program to increase awareness of the connectiveness of stormwater pollution issues and encourage behaviour change. The objectives are how you want to achieve your goal, such as, to increase knowledge about the environmental impacts of stormwater pollution and to develop an understanding of the benefits of improved environmental management to the audience (e.g. economic). Outcomes are defined in terms of the effects and outputs you hope will result from the program, such as, increased knowledge and change of behaviour with respects to stormwater pollution.

How will the goals, objectives and outcomes be monitored and evaluated?

## Step 6: Determine your methods

Determine which education tools and techniques are likely to work most effectively with the target group and whether the methods reflect the educational needs of the target audience.

**Investigate methods, tools and techniques that will achieve the goals, objectives and outcomes – given time and financial constraints.**

A mixture of techniques may increase the chances of success. Consideration will also need to be made whether there is an appropriate mix of informing techniques and those that facilitate action. Combining formats can reinforce the message considerably. For example, promoting environmentally-friendly

fertiliser use to homeowners through newspaper articles, community action days such as waterway and wetland walks, displays at shopping centres and promotional material such as stickers and pens creates interest in and supports such practices.

Education tools and techniques may include the following:

- printed material – in the form of newsletters or brochures, sent to each individual reader (household or business)
- other distribution material – fridge magnets, pens and car stickers
- media – newspapers, television, magazines and radio. Can be paid advertising or publicity through media releases or interviews
- interactive computer packages including CD ROMs and the internet
- launches and public releases by influential community citizens (e.g. ministers and advocates)
- signs – at bus stops or on billboards
- displays – at local shopping centres or at special functions, festivals and trade displays
- courses through schools, universities, TAFE and community colleges
- training or train the trainer courses
- awards or accreditation programs as part of an integrated program
- demonstrations such as water quality monitoring
- talks, presentations and seminars
- individual advice, communication or instruction, and
- participation/involvement (meeting and discussions, road gully stencilling, planting and cleanup days and tours or field days, such as drain walks).

The application of some of these tools and techniques can be seen in the example section of this chapter. The mixture of tools and techniques can be quite different depending on the target audience.

Examples of posters, pamphlets and signs can be found on the various websites listed at the end of this chapter and on pages 37-38.

### **Messages**

There are two basic concepts that can form the basis of the messages in a stormwater education program, namely highlighting:

- the impacts of community activities on stormwater quality and the natural environment; and
- suggesting appropriate actions.

*(from NSW EPA, 1998)*

A key element to the success of your program will depend on how well you highlight the connection between people’s activities and the resulting environmental damage. Highlighting the ‘cause-effect’ relationship in an education campaign can assist people to recognise that their actions can reduce their environmental impact.

To be effective, messages must be understood by the target audience and appeal to them on their own terms. The message should be specific and tied directly to something your target audience values, such as money or health. These are the customers and you want them to ‘buy your product’ (CSOG, undated).

Issues and impacts have been identified in step one: analyse the problem or issue. Examples of issues and their impacts with possible causes are presented in Table 2. Table 3 gives some examples on MESSAGES that you may form based on the analysis of the problem.

**Table 3. Example messages for Stormwater Education Projects (adapted from: NSW EPA, 1998).**

<b>Key message</b>	<b>Actions to do more often</b>	<b>Actions to avoid</b>
<i>Changing motor oil</i> It takes only one litre of oil to contaminate one million litres of	Maintain the car check that there are no oil or radiator water leaks and that fuel is burnt ‘cleanly’ by keeping your car tuned. water.	Don’t maintain cars (including oil changing) where oil and grease may enter drains or groundwater. Never pour oil into the street drains.
<i>Landscaping and construction (sediment)</i> Sediment can be eroded from disturbed areas and be deposited into waterways.	Protect stockpiles from wind and rain by storing under secured plastic sheeting or tarpaulins.	Avoid piling sand and soil on areas where it can wash into the stormwater system. Don’t wash cement mixers into the drains.
<i>Gross Pollutants (rubbish)</i> Litter can blow into stormwater systems which reduces aesthetic appeal and can kill aquatic life.	Make sure that litter such as cigarette butts, cartons, fast food containers, plastic bottles and bags are disposed of correctly.	Never drop packaging or litter onto the ground.
<i>Fertiliser and Pesticide use</i> Fertilisers can encourage algal growth in waterways.	Consider alternatives to fertiliser, such as compost. If you do fertilise, use slow release fertilisers to the manufacturers directions, more will waste you money. Minimise areas of lawn, choose a water efficient and drought tolerant lawn such as some varieties of Couch or Saltene, improve the soil before planting and apply a soil wetting agent to help prevent runoff. Grow a native garden. Consider natural alternatives to pest control chemicals.	Don’t use fertilisers or pesticides when rain is forecast for the same day. Don’t over fertilise, it will just waste your money and potentially threaten the environment.

## Tips for effective communication

Community education needs to be delivered clearly from the outset. The messages need to:

- Be clear and concise – what is the issue, how does the target group contribute to the stormwater pollution, what are ways to reduce these impacts. The message should provide clear cause, effect and remedy linkages. The audience should become motivated and be given a sense of ownership of the issue and the solution.
- Use plain English – everyday language should be used, and the use of jargon or technical terms should be avoided as much as possible. The message should be pitched at the appropriate comprehension level of the audience.
- Use simple messages – avoid overloading the audience. Chances are that if too much information is given at one time, much of it will be overlooked, the audience will become disinterested and the message will not be delivered effectively.
- Link messages – ensure that each message clearly relates to the last sequence. The message should have a logical sequence.
- Translate to foreign languages if needed – this may be needed if your target audience is not English speaking. Ensure that cultural differences are considered when messages are translated.
- Be correct and up-to-date –the message should have a sound and current technical basis, and
- Be two-way – by allowing interaction, input and feedback from target groups.

These steps apply not only to written information, but also to verbal information and outreach programs.

## Step 7: Consider funding

**A primary practical consideration in developing an education and awareness program is establishing how much it will cost and who will pay.** It will be necessary to identify possible funding sources and the benefits for potential funding organisations. Potential sources of funding may include grants from Local government, State Government grants and Private sponsorships.

Are there any in-kind opportunities? How will the project be modified if insufficient funding is available?

In seeking funding, potential benefits must be effectively illustrated to increase their chances of success.

## Step 8: Form an action plan and implement it

**An action plan will need to be prepared to identify steps to achieve the program objectives. An action plan identifies who has to do what and by when, what resources will be needed and also keeps the program on track.**

The action plan should cover the ‘who, what, when, where and how’ theory. Timeframe, milestones, resourcing (money and people), and responsibilities are all necessary components.

## Step 9: Monitor and evaluate

This requires the collection of information to show the effectiveness of the education and awareness program.

Monitoring and evaluation of the program can:

- help make decisions and recommendations about future directions
- identify the strengths and weaknesses of your project
- enable judgements to be made about the worth of the project
- determine stakeholder and target group satisfaction
- determine the rate and level of attainment of the objectives
- be used to correct, adjust or formulate ongoing steps in the program
- measure performance, and
- meets demands for accountability.

Did the project succeed in reaching the target community? Were the messages understood? What was successful and what wasn't?

Building an evaluation component into the program from the beginning will ensure some feedback is generated. Of course, the most important stage when evaluation and monitoring should be considered is when objectives are set.

Three types of evaluation can be identified (COSG, undated). These are – Planning evaluation, Process evaluation and Impact evaluation. Planning evaluations assess the likelihood that outreach programs will achieve their objectives. This includes asking the questions such as 'Are the objectives consistent with the goals', or 'has the target audience been sufficiently defined'. Process evaluations focus on implementation of activities as they relate to budget requirements, schedules and staff resources. This includes asking questions such as, 'do I have the resources to accomplish the identified objectives', or 'have I factored in enough lead time to get the materials published and distributed'. Impact evaluations assess the outcome or impacts produced by the outreach program and are directly tied to the original objectives. Thus the question to ask would be, 'to what extent did we achieve our objectives'.

**The activity that results from this step could be the production of a report that summarises strengths, weaknesses and outcomes, with recommendations for future work.**

### 5.1 Concluding remarks in developing a stormwater education program

There are three factors influencing education effectiveness, and these are

- how prevalent is the behaviour that the program seeks to modify
- how effective is the program in delivering the message to the population whose behaviour needs to be influenced, and
- what is the most effective educational technique to actually change the identified behaviour.

*Source: The Centre for Watershed Protection*

There is evidence to suggest that in addition to education, it is important to have a supporting infrastructure and social structure around individuals so that it is easy for them to comply with educational messages (Taylor and Wong, 2002, p68). This may mean methods as simple as providing people with easy access to litter bins and recycling locations, together with appropriate education.

## 6 Resourcing an education and awareness program

### Cost of education programs

Taylor and Wong (2002, p70) found that ‘the costs of educational and participatory initiatives for stormwater management vary greatly but have been documented, where available, for comparative purposes. Cost information of particular note included:

- Australian and overseas case studies demonstrate that regional and Statewide stormwater awareness campaigns usually run for less than one year and typically cost AUD\$0.42 - \$0.82 per capita (averaging AUD\$0.62 per capita)
- Intensive training programs such as the Master Gardener Programs cost approximately AUD\$15 326-\$19 157 per year to run, or \$0.23 per person per year (when the costs are spread over the entire population of the programs’ area of influence), or AUD\$7.76-\$15.52 per hectare of lawn managed through the programs
- most education-based, US urban nutrient management programs cost less than AUD\$47 893 (US \$25 000) per year.’

### Cost vs benefits

The majority of attempts to measure the performance of education and participation programs utilise simplistic styles of evaluation (e.g. measuring participation rates, changes in knowledge or changes in self reported behaviour). Few attempts have been made to link educational programs with actual changes in stormwater quality and/or pollutant loads (US EPA 1997, cited in Taylor and Wong, 2002). For example, published studies containing quantitative information on the effectiveness of educational BMPs in terms of water quality improvement could not be identified in a literature review by Strecker and Quigley (1998) as part of the US National Stormwater BMP database project (cited in Taylor and Wong, 2002).

Structural source controls are usually tested in laboratory situations. The information gathered is used to predict performance in terms of nutrient and pollutant retention ability, and together with associated capital and maintenance cost estimates, can be used to assess the likely unit cost rate of pollutant removal (Water and Rivers Commission, 2002).

It is more difficult to predict the effectiveness of non-structural source controls in water quality management because they cannot be readily tested by the conventional methods (Water and Rivers Commission, 2002). There has traditionally been a reluctance to include non-structural source controls in stormwater management programs in other States. In particular, it has been highlighted that in NSW, where the EPA has stressed a source control philosophy should be applied initially, with in-transit controls only applied if necessary, a lack of cost comparison between structural and non-structural source controls has been highlighted (NSW EPA, 1998). However, it can be concluded that control of pollutants at source using non-structural measures has the potential to be a very efficient water quality management option through minimisation or prevention of input (Water and Rivers Commission, 2002).

### **A model that provides cost comparisons – Nutrient input Decision Support System (NiDSS)**

The Southern River/Forrestdale/Brookdale/Wungong Structure Plan Urban Water Management Strategy (UWMS) is a study recently completed to address issues of water and nutrient management for existing and future land uses in the Structure Plan Area (Water and Rivers Commission, 2002). As part of this study, a Nutrient Input Decision Support System (NiDSS) has been developed for the Swan Coastal Plain with particular relevance to the Southern River-Forrestdale-Brookdale-Wungong Structure Plan. The NiDSS is a tool to assist in land use management planning, to allow quantitative estimation of the potential reduction in nutrient inputs and provide cost estimates for various combinations of WSUD water quality management measures.

**‘NiDSS focuses on the adoption of an integrated catchment approach to water quality management, including measures to minimise nutrient inputs at source, and provides a logical framework for the evaluation of the effectiveness of various best management practices for nutrient input management’ (Water and Rivers Commission, 2002).**

The UWMS found that with respect to nutrients in the study area, current export to receiving waters is estimated to be less than 5 percent of input, with the majority coming from surface water rather than groundwater flow.

NiDSS calculates the total expected nutrient input for a particular residential density based on aggregating individual nutrient inputs from different land uses (lots, POS, road reserves, conservation areas) before implementing stormwater management measures. Information obtained from mail out questionnaire surveys of residential areas, aerial photography interpretation of land use within residential areas and other published information has been used to develop the data for the NiDSS. The impact of individual source and in transit (structural) controls on nutrient input can then be determined by either turning on/off individual controls or varying the effectiveness of these measures. The results present information on:

- estimates of total phosphorus (TP) and total nitrogen (TN) application to an area
- estimates of reductions due to source control measures (education, street sweeping, native plantings)
- estimates of reductions due to in-transit controls (e.g. Gross Pollutant Traps and Water Pollution Control Ponds), and
- estimates of the cost of removal (in Present Value Terms), including both capital and operating costs for a selected WSUD program.

The UWMS found that source control measures, such as education and native gardens, were found to be considerably more effective in reducing nutrient input than in-transit structural measures used to trap and remove inputs. Typically, 1-3 percent of total nutrient application to a catchment were found to be trapped by in-transit (structural) measures. Source controls were therefore considered the preferred method by which significant reduction in nutrient application can be achieved.

The study found that the order of cost for reducing phosphorus inputs are free for native plantings (assuming that they are planted at development stage), <\$5/kg/yr for education programs, \$150/kg/yr for street sweeping, \$800/kg/yr for GPTs, and \$4000/kg/yr for ponds and wetlands (Water and Rivers Commission, 2002, p23). Appendix 5 of the UWMS provides detail of the cost estimate calculations. The UWMS also tables the various constraints and pollutant removal efficiencies for various structural control methods.

The expected effectiveness of a public education campaign has been based on a phone survey conducted in NSW, as published in ‘Who Cares About the Environment 2000?’. In this survey, the environment was mentioned by 10 percent of those surveyed as one of the two most important issues for attention by State government at that time. It was also discovered that 17 percent of those surveyed nominated the environment as one of the two most important issues for attention by State government in 10 years from that time.

Water issues were the environmental issue of most concern, being nominated as the most important environmental issue by 27 percent of people surveyed. Additionally, the greatest number of those surveyed (17 percent) considered that education was the single most important thing that the government could do to protect or improve the environment.

Based on the results of the survey, NiDSS has assumed approximately 20 percent of people within a development could be reasonably expected to respond positively to a public education campaign on reduction of nutrient inputs.

The model then calculates education campaign nutrient reductions in lot garden and lawn fertiliser input, pet input (lot and POS) and car wash inputs. Cost estimates are based on distribution cost per household at annual frequencies.

Education programs are much less likely to have high engineering maintenance costs when compared to structural controls, such as Gross Pollutant Traps. Other benefits of education include:

- can target diffuse sources and specific pollutants – the diffuse source nature of stormwater pollution means that structural control techniques are less effective and more costly
- programs can be changed, so are flexible – structures are fixed into the landscape
- targets the individual, and
- mobilising the community into a different mindset to achieve a more sustainable environment.

## 7 Examples of program development and planning

The following examples follow eight steps (ie. does not explicitly address ‘Step 2: design your evaluation methods’ presented in this manual). The design of the evaluation methods, however, would have been planned at an early stage in all of these cases.

### Example 1: Green Stamp Business Program

An accreditation program for the automotive industry developed and initiated by the Motor Trades Association WA in conjunction with the Department of Environment that is now being adopted nationally.

For more information, please contact Bernie Riegler at the Western Australian Motor Trades Association (MTA-WA) on (08) 9345 3466.

#### Step 1: Issue

Due to the nature of the chemicals used and traditional processes undertaken automotive repairers are often seen as polluters of their local environment.

Traditionally, a lack of succinct, industry-specific information and training has seen this trend continue within the industry, with many businesses struggling to comply with their legislative requirements. This is coupled with an inability of Government agencies to enforce their legislation, which has led to a substantial commercial imbalance between those that do burden the costs of proper environmental management and those that do not.

Consumers, though concerned about the environment, often don't consider the other environmental impacts of their vehicles and hence fail to recognise the additional commitment that many automotive repairers will make to manage their environmental responsibilities.

### **Step 2: Identify stakeholders**

- Motor Trade Association of Western Australia (MTA-WA).
- Department of Environment.

### **Step 3: Target group**

- All facets of the automotive industry, including mechanics, spray painters and panel beaters, engine reconditioners, wreckers, car yards, detailers, mobile mechanics, radiator repairers, etc.
- Vehicle owners.

### **Step 4: Objectives**

- To assist small to medium businesses in the automotive service industry to incorporate processes that avoid, reduce, reuse, recycle or dispose of their wastes in a cost effective, efficient and environmentally sensitive manner.
- Raise consumer awareness of the 'other' environmental impacts of their vehicles and encourage them to utilise the services of Green Stamp Accredited businesses to service and repair their cars.
- Raise the profile of those industry leaders that are including the environment in their operating objectives.
- Work with relevant Government agencies to promote and encourage better environmental management within the industry.

### **Step 5: Methods**

- Conduct obligation-free environmental audits to identify an individual business' current environmental impacts and provide practical solutions and if necessary, follow-up support.
- Compilation of industry-specific Environmental Guidelines that identify the environmental problem, the practical solutions and parties that can assist in their implementation.
- Via the Environmental Product and Service Directory, the Green Stamp has identified for automotive businesses the product and service providers in Perth that can help them to minimise or abate their environmental impacts.
- Delivery of environmental training seminars to managers and employees, educating them on the environmental impacts and practical solutions for responsible environmental management.
- Compilation and distribution of the Cleaner Times, an environmental newsletter for WA's automotive industry and related organisations and departments.

- Free drain stencilling to remind employees, contractors and visitors to premises that nothing except rain water should enter stormwater systems.
- Simplified environmental management plans to help businesses to monitor their practices and set a plan for future consideration.
- Dissemination of a range of Green Stamp information at [www.greenstamp.com.au](http://www.greenstamp.com.au). This includes a list of Green Stamp Accredited businesses, the Environmental Guidelines, the Environmental Self-audits for mechanical repairers and body repairers and the Environmental Product and Service Directory.
- Promotion of automotive businesses that have received the Green Stamp Accreditation. Launched at the end of 2002, the Accreditation is rewarding those businesses that are incorporating environmentally friendly practices by promoting them as industry leaders. It also provides an incentive for those businesses that are not incorporating environmentally sensitive processes to do so.

### **Step 6: Funding**

- To date, the Green Stamp has been driven by the MTA-WA, with funding assistance from the State Government's Waste Management and Recycling Fund.
- In May 2003, the Commonwealth government through Environment Australia's Eco-efficiency agreements began to support the program at the National level. This funding support was directed towards assisting the other affiliated Associations of the Motor Trade Association of Australia to implement the Green Stamp program's initiatives in their own States.

### **Step 7: Action plan**

- Continued implementation of the Green Stamp program in Western Australia, including the dissemination of the program's resources and initiatives throughout the automotive industry.
- Promotion of Green Stamp Accredited workshops to consumers.

### **Step 8: Monitor and evaluate**

- Follow up visits on 40 workshops that received an Environmental Audit found that 90 percent improved at least three of their practices within three months and 86 percent of those improved their overall Environmental Rating to the next level. (The "Environmental Rating" is a four-tier scoring system developed by the Green Stamp to show businesses their current level of achievement and help them identify priority issues they should address to improve.)
- In 2001, to improve the efficiency of the auditing process and the number of businesses surveyed, the audit was modified. Since then, over 200 Environmental Self-Audits for mechanical repairers and body repairers have been distributed throughout the industry.
- Since November 2001, the Green Stamp has presented 13 Environmental Seminars. The Seminars have attracted 126 participants from 99 companies and organisations. Though initially set up for automotive businesses, the Environmental Seminars have also attracted TAFE lecturers, Chamber of Commerce and Industry representatives, Local and State Government officers and students.
- There are 11 Green Stamp Accredited businesses in Perth at present, 10 of which are at the top level of Accreditation (Level 3) and the other at level 2.

## Example 2: (sourced from NSW EPA & DLWC, 2001) Hawkesbury-Nepean Phosphorus Action Program

A community education and awareness project initiated by the Hawkesbury-Nepean Catchment Management Trust to improve water quality in the catchment.

For more information, phone Peter Salier on (02) 9995 5364.

### Step 1: Analyse the issue or problem

The problem was the current health of the Hawkesbury-Nepean River, including the growth of algal blooms and water weeds (caused by excessive amounts of phosphorus and increasing population growth).

### Step 2: Identify Stakeholders

The stakeholders were:

- local government/catchment councils
- Hawkesbury-Nepean Catchment Management Trust
- Department of Land and Water Conservation
- Environment Protection Authority
- Sydney Water Corporation.

### Step 3: Know your target group

The target group comprised:

- catchment residents and the general community
- local government
- industry
- agriculture
- schools
- recreational and tourist groups.

### Step 4: Determine objectives and outcomes

The goal was a healthy, diverse and productive Hawkesbury-Nepean river system for all.

The objectives were:

- To increase public awareness about the harmful effect of phosphorus on river health
- To provide information about the sources of phosphorus
- To encourage individual and corporate actions to help minimise phosphorus and pollutants, and
- To provide monitoring data to verify changes in the generation of phosphorus to reduce the incidence of algal blooms.

The outcomes were:

- Increased community awareness about the harmful effect of phosphorus on the river
- Less phosphorus generated in the catchment and entering watercourses
- Change in attitude and behaviour within the community, leading to sustainable gains, and
- Reduced chemical dosing required to treat phosphorus at sewage treatment plants.

## Step 5: Design your methods

Methods comprised:

- Appointing a full time project manager
- Establishing a steering committee with representatives from the community, local government, government agencies and the Trust to set strategic direction for the program
- Establishing a working party with joint representatives from government and the Trust to implement Steering committee recommendations, and
- communication/marketing:
  - brochures, posters, T-shirts, drink coasters, bookmarks, carry bags, displays, catchment mailout, calendar
  - media activities: radio and press advertising, competitions, trade journal articles
  - meetings with key stakeholders and organisations to enlist support and develop joint programs
  - regular media releases to key stakeholders
  - school activities, teaching resources, competitions, and
  - public awareness; operational monitoring.

## Step 6: Consider funding

The program was funded by the Special Environmental Levy, the Hawkesbury-Nepean Catchment Management Trust, Department of Land and Water Conservation and some catchment councils. The agencies and the Trust also gave 'in kind' support.

## Step 7: Make an action plan and stick to it

The plan involved:

- a pre-benchmark survey (Nov 94)
- strategic media and marketing plan approved (Mar 95)
- a program launch (May 95)
- a local radio campaign (May 95)
- negotiating with Cumberland Newspaper Group for a regular column in each catchment paper and to support the program (Jun-Jul 95)
- negotiating with John Williamson to lend his support to the program (Jun 95)
- negotiating with Radio 2WS FM for community service time and support (Jul 95)
- a Streamwatch Open Day (Jul 95)
- intensive radio/print campaign (Aug-Dec 95)
- launch of the local government Phosphorus Action Policy (Aug 95)
- bus and carpark advertising (Aug-Dec 95)
- mail-out to all residents in catchment (Oct 95)
- school art, pledge and advertising projects (Sep-Dec 95)
- a schools Presentation of Awards Day (Dec 95)
- a field day for dairy farmers to promote dairy waste systems (Nov 95)
- an on-site wastewater disposal training course (Dec 95)
- an evaluation survey (Dec 95)

- negotiating with Panthers for monthly column and to support the program (Feb 96)
- negotiating with Sydney Water to monitor influent phosphorus at 3 STPs (Dec 95-May 96)
- launch of the school education package Enough is Enough with Sydney Water (Jun 96)
- preparing and circulating a report.

### **Step 8: Monitor and evaluate**

Activities involved:

- a benchmark survey (telephone poll of 120 residents in 6 subcatchments) (Nov 94)
- monitoring of progress (Steering Committee, monthly)
- monitoring of influent to 3 STPs (ongoing)
- media monitoring
- water quality monitoring of Hawkesbury-Nepean River and tributaries (EPA, Sydney Water, StreamWatch)
- monitoring changes in practices of local government and agriculture
- an evaluation survey (telephone poll of 120 residents in 6 subcatchments) (Dec 95).

### **Example 3: (sourced from Douglas, 1998) Litter Awareness - Butt of our Beach, Waverley Council, NSW**

For more information, phone Emily Scott on (02) 9369 8094.

**Step 1: Issue:** Cigarette butts are a major litter problem.

**Step 2: Stakeholders:** Local businesses, Council, Tourists.

**Step 3: Target groups:** smokers in public places.

**Step 4a: Objectives:**

- To raise awareness level of impacts of cigarette butts and other small pieces of litter on the environment
- To offer solutions to promote behaviour change
- To promote a positive image of Bondi Bay marine environment to show why it is worth protecting and how litter is affecting it
- To trial a variety of visual images to determine target group appeal.

**Step 4b: Outcomes:**

- To influence the behaviour of litterers and particularly smokers to dispose of their butts properly.

**Step 5: Methods used:**

- Development and distribution of 4 posters (3 with beach/marine focus and one on Centennial Park)
- Distribution of butt bottles – a pocket sized disposal option for use at the beach
- Installation of 25 ash cylinders at bus shelters, also posters were displayed at these shelters.

## Step 6: Funding

### Step 7: Action plan and implementation:

- Launch at Bondi Beach – with good media coverage
- Posters distributed and displayed at strategic outlets in the community
- Posters also sent to all coastal communities
- Butt bottles distributed at Bondi beach
- Ash cylinders installed at bus shelters and posters displayed.

### Step 8: Monitoring and evaluation:

- No formal evaluation but anecdotally and by observation
- There has been a positive community response to the posters
- The ash cylinders and butt bottles are being used.

There is a recognised need for formal education but it was outside the scope and timeline of the project.

## 8 Linking programs

There are some programs and resources that already exist, which can provide resources when developing a stormwater education program.

Your education and awareness program may wish to include linking in with one of these already existing programs.

### **Swan River Trust and Swan Canning Cleanup Program**

The Swan-Canning Cleanup Program is a major environmental management program that is working to reduce the frequency and extent of algal blooms in the Swan and Canning rivers, and prevent toxic blooms. It also aims to help maintain water quality now and in the future, help change land uses, planning and development to reduce nutrient inputs, and inform and involve the public in the process. The Cleanup Program is a \$3.5 million per annum program and is a State Government initiative managed by the Swan River Trust.

Through the Cleanup Program, the Swan River Trust has funded a large number of projects related to river and catchment monitoring and mapping, algae and nutrient research, computer modelling of estuarine dynamics, stormwater design, water quality management and Catchment Management Plans for key areas.

The Drain Game and Corporate Care Workdays are two new targeted-communication strategies being implemented to raise awareness and increase involvement.

The Drain Game was successfully launched at the 2001 Perth Royal Agricultural Show and proved highly popular with the community. The colourful community education activity helps people to understand how their actions affect the health of the rivers and was used at more than 24 community events in 2003.

Corporate Care Workdays is a new program that connects the corporate sector with the community in the catchment and gives private business the opportunity to make a significant contribution to environmental restoration projects and learn about river management issues. During 2001-2002 corporate care workdays were organised with four major city-based corporations.

For more information on using the Drain Game and planning a Corporate Care Workday, please contact the Swan River Trust on (08) 9278 0400. For more information on the Swan-Canning Cleanup Program and the Swan River Trust in general, visit the website [www.wrc.wa.gov.au/srt](http://www.wrc.wa.gov.au/srt) or contact the Trust on (08) 9278 0400.

The Cleanup Program provides support to catchment groups and has also provided support for the development of the Local Government Natural Resource Management (NRM) Policy Development project conducted through the Eastern Metropolitan Regional Council.

The Local Government NRM Policy Development project gives environmental support to local governments in the Swan-Canning Catchment through policies, guidelines and checklists on different land activities available for direct adoption by local governments. The project also provides training in environmental areas to local government staff.

For more information on the Policy, please contact the Eastern Metropolitan Regional Council on (08) 9479 4808, or visit the website [www.emrc.org.au](http://www.emrc.org.au).

The Swan Catchment Centre provides some resources for community participation in the Swan-Canning Cleanup Program through catchment management. One of its services includes the implementation of the Swan River Community Action Program, based on the Swan River Action Kit.

The Swan Catchment Centre has worked with local catchment groups to produce the Catchment Education Strategy for schools in the Perth Region. The Catchment Education Strategy aims to set a strategic framework for Integrated Catchment Management groups working in the Perth Region and as such serves as a common direction for the groups as a whole. One of the goals is to promote environmental education within the schools' Curriculum Framework, with one of the strategies being to support schools to select, plan and develop whole school environmental education programs linked to the Curriculum Framework. Before developing an education program, it may be helpful to contact your local catchment group or the Swan Catchment Centre.

For more information on the Swan River Community Action Program and the Swan River Action Kit, please contact the Swan Catchment Centre on (08) 9374 3333. For more information on the Catchment Education Strategy and Swan Catchment Centre in general, visit the website [www.wrc.wa.gov.au/swanavon](http://www.wrc.wa.gov.au/swanavon).

Swan Canning Industry Project: The Swan-Canning Industry Survey found small to medium industry was a major contributor of pollutants to the rivers. It recommended training and legislative measures to avoid these pollution risks.

In 2001-2002 training support in Cleaner Production was provided to 18 local government officers, eighty priority catchment group coordinators and seven industry operators.

The Cleaner Production Industry Training package was developed together with the Centre for Excellence in Cleaner Production. It addresses industry needs and encourages the development of cleaner production environmental management action plans.

For more information on the Swan Canning Industry Project, please contact the Industry Project Coordinator at the Department of Environment on (08) 6250 8000.

### **Ribbons of Blue**

Ribbons of Blue is an environmental education network aimed at increasing community awareness and understanding about local water quality, and taking action for a better environment. Ribbons of Blue programs involve school students and community groups in monitoring water quality. Data collected from the sampling provides valuable information for identifying environmental problems and preparing management plans. Based on the outcomes of their monitoring, participating groups may develop action strategies to help manage any problems identified. Ribbons of Blue encourages a team oriented approach and fosters partnerships with local management authorities.

Ribbons of Blue Regional Coordinators, located throughout the State, support school and community involvement in the program. They provide technical expertise during fieldwork, training and help plan on-going monitoring and education programs.

Ribbons of Blue is part of the Natural Heritage Trust funded Waterwatch Australia network and is coordinated by the Department of Environment as the lead agency for Waterwatch in Western Australia. Ribbons of Blue is also supported by the Swan River Trust, Education Department of WA, Agriculture WA, GeoCatch, WA Plantation Resources, Friends of the River Toodyay, Manjimup Land Conservation District Committee and the Bennett Brook Catchment Group.

For more information on Ribbons of Blue and current contact details, visit the website [www.wrc.wa.gov.au/ribbons](http://www.wrc.wa.gov.au/ribbons) or contact the Department of Environment on (08) 9278 0300.

The Geographe/Cape to Cape/Lower Blackwood Ribbons of Blue began a stormwater education project in 2001 with the production of posters, flyers, magnet, stickers and t-shirts- funded by a Coast and Clean Seas project. All the items produced were titled 'Don't let your Bay go down the Drain' or 'Take Care in the Catchment'. Several schools participated in painting local drains with messages such as 'don't let your bay go down the drain, 'clean water only' and 'drains to the bay'.

Please contact Ribbons of Blue/Waterwatch, GeoCatch, Busselton on (08) 9754 4331 for further information on the stormwater education project, including designing lesson plans and drain painting.

### **Yellow Fish Road**

Yellow Fish Road is a network of volunteer groups who use stormwater drain stencilling to raise community awareness about stormwater pollution.

After purchasing a Yellow Fish Road Kit, community groups stencil anti-pollution slogans next to stormwater drains to remind other members of the community to help keep the waterways clean. Each community group is responsible for implementing its own Program. Participation helps remind the community that aquatic life can only live and thrive in unpolluted water.

Yellow Fish Road also produces information and education resources to inform communities about stormwater pollution.

For more information, please contact the Yellow Fish Road National Coordinator on (02) 9357 7377 or visit the website [www.yellowfishroad.com.au](http://www.yellowfishroad.com.au).

### **Yellow Fish in Rockingham**

The Yellow Fish program is a joint funded project by Coast and Clean Seas and the City of Rockingham. The program is based on similar programs in Australia and overseas. The stencil kit was altered for this project.

The stencilling of yellow fish on stormwater drain inlets by school children is linked to educational programs about reducing nutrients and other pollutants entering Cockburn Sound. The City of Rockingham stressed the importance of this linkage for sustainable behavioural change. The City of Rockingham also prepared a drainage management plan for the Palm Beach area.

For more information, please contact the City of Rockingham on (08) 9528 0333.

The Yellow Fish Program has also been implemented in a number of other catchments.

### **Yellow whale in Albany**

Stencilling of stormwater drains with a yellow whale in Albany was part of a community awareness raising exercise by the City of Albany and Department of Environment. A local school designed a flyer as well as the logo for the stencil design, and undertook the stencilling. This formed a component of an overall Coast and Clean Seas project designed to demonstrate best practice in stormwater management through demonstration sites, leaflets, a foreshore clean up day and drain stencilling.

For more information, please contact the Department of Environment's Albany Office on (08) 9842 5760.

### **Phosphorus Awareness Project**

The aim of the Phosphorus Awareness Project is to reduce phosphorus (P) and nutrient loads in the Swan-Canning catchment through changes in community and industry behaviour and practices resulting in healthy, sustainable river systems. This community awareness campaign seeks to promote appropriate fertiliser practices for the soils in the catchment, educate householders to use P free detergents in unsewered areas and consider P in pet droppings and bread fed to water birds. The project is managed by the Canning Catchment Coordinating Group and assisted by a group of volunteers, the Phosphorus Action Group. The project is funded by the Swan-Canning Cleanup Program and the Natural Heritage Trust's Envirofunds.

The project targets the community, schools, Local Government and high phosphorus using industries, through talks, displays, articles and demonstrations. The Algae Buster School Visitation Program educates school children on the effects of nutrients in river and wetland systems through hands on activities and is complemented by teacher resources. Community members are educated through presentations and displays at libraries, fairs, festivals and shows. Local Government and industry are educated through presentations, seminars, trade displays and articles. A Local Government Nutrient Survey is also conducted annually to educate and assess behavioural change.

The Phosphorus Awareness Project has a range of brochures, stickers and a magnet that are used to inform and educate the community about nutrient sources. The Fertilise Wise Guide is also a community education tool consisting of a soil map poster with five associated brochures, one for each main soil type in the Perth Metropolitan Area, providing information to gardeners on appropriate fertiliser types and application rates for their soil type.

For more information, please contact the Coordinator of the Phosphorus Action Group on (08) 9258 3493.

### **Great Gardens**

Provides urban gardeners with additional knowledge and practical skills so that they become an integral part of the drive towards urban sustainability. Gardeners learn how to create a wonderful garden, attract native fauna, and be water and fertilise wise. The benefits for gardeners can include an attractive and functional garden that delivers their particular needs, while enhancing the value of their property and reducing their impact on the environment. The overall outcome of the program is the reduction of nutrients and pollutants reaching the Swan and Canning rivers through the application of improved gardening practises.

The Swan River Trust delivers the Great Gardens program through the Swan-Canning Cleanup Program, a major environmental management program that supports sustainability through State government, local government, industry, business, community groups and learning institutions to embrace 'best practice' and to become an integral part of the paradigm shift towards embracing urban sustainability. The program is delivered with support from the Water Corporation and the Nursery & Garden Industry Association, as well as Local Government within the Perth Metropolitan Area.

For more information, please contact the Community Relations Manager, Swan River Trust on (08) 9278 0400 and <http://www.greatgardens.info>.

### **Earthcarers in Western Australia**

The Department of Environment, Western Metropolitan Regional Councils, the City of Nedlands and Edith Cowan University are currently trialing and evaluating the 'Earth Carers' behavioural change and involvement program. The Trial has been supported by the Waste Reduction and Recycling Fund, and is based on the NSW EarthWorks program.

Earth Carers is designed to instil a set of positive waste minimisation behaviours within households and the wider community. The program's principal focus offers considerable scope to reduce production of domestic waste and that is disposed of in landfill.

Earth Carers is designed for adoption by local government authorities and is comprised of two main components. The first component – the Earth Carers Course, provides skills to Earth Carer Volunteers in waste reduction, reuse, recycling and, importantly for the second component, techniques of community 'outreach.' Trained Earth Carer Volunteers supported by the local government authority then conduct the second component – community outreach, encouraging community members to minimise their household waste through use of compost bins, worm farms and purchasing decisions.

The trials are being evaluated with the assistance of Edith Cowan University and will provide valuable information for the development and implementation of Earth Carers throughout WA. The Western Metropolitan Regional Council has undertaken the first phase of evaluation of the Earth Carers program (WMRC, 2003). This has shown that the percentage of active participation rate is high at 63 percent and that the Earth Carers are very willing to be involved in outreach activities. Almost all of the participants who have completed the course have indicated that their knowledge of waste issues and belief in the value of waste minimisation has increased. Ninety-five percent of graduates who completed the survey claimed to have participated in one or two forms of public outreach (an organised event in a public place to encourage others to improve their waste behaviour – for example, all have been involved with composting demonstrations).

The next phase of the program is to establish Earth Carer Coordinator positions within local government authorities via applications to the Waste Reduction and Recycling Fund. These coordinator positions would establish, train and support Earth Carers Volunteers within local government authorities.

Although not targeting stormwater education, the program can be expanded to incorporate these issues. For example, a council may wish to emphasise the message that using compost and worm castings in the garden improves the soil and decreases the need for fertiliser. This in turn is good for our waterways because it reduces fertiliser in runoff (improving stormwater quality), can act to increase infiltration (meaning less runoff on the property) and reduces nutrient loss to groundwater. Most importantly, the program also illustrates that environmental education and outreach do have successful environmental outcomes.

For further information, please contact the Department of Environment on (08) 9278 0300, or the Western Metropolitan Regional Council on (08) 9384 1633.

### **Bannister Creek Catchment Group**

The Bannister Creek Catchment Group (BCCG) is involved in several activities including: community events, community and school involvement/education, stakeholder meetings, project planning, revegetation works, weed removal and river restoration. As discussed in section 4.3, the BCCG has undertaken a project to transform a section of a drain, with support from the City of Canning, the Department of Environment, the Water Corporation, the Swan Catchment Urban Landcare Program, ALCOA, the Natural Heritage Trust and the local community. The retrofitting project at Bannister Creek is part of a broader program to improve the health of the catchment.

For more information on the Bannister Creek Catchment Group or the retrofitting project, please call the Catchment Coordinator on (08) 9458 5664.

### **Local Catchment Groups**

Local Catchment Groups can prove a source of much information when planning a stormwater education program.

For more information on local catchment groups, friends groups or conservation groups, please refer to the Swan Catchment Centre website [www.wrc.wa.gov.au/swanavon](http://www.wrc.wa.gov.au/swanavon).

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## 10 Further information and resources

### Internet Resources

#### **[www.epa.nsw.gov.au/stormwater/usp/index.htm](http://www.epa.nsw.gov.au/stormwater/usp/index.htm)**

The New South Wales Environmental Protection Authority (NSW EPA) and the Stormwater Trust. The NSW EPA conducted a number of stormwater education campaigns between 1994 and 2000 to raise awareness of stormwater issues and in particular, certain behaviours that can pollute stormwater. The evaluations of these campaigns, together with the results of several other EPA surveys, have provided significant data on community knowledge, attitudes and behaviours in regard to stormwater pollution and the shift that has taken place. The EPA report 'Findings of EPA Social Research on Stormwater, 1994-2002' (Kimberley, 2002) presents these findings.

The website has a wealth of information on best practice for stormwater quality protection. Case studies of stormwater education in various councils are featured on the Council resource page link. Appendix 1 contains one example of a brochure on Stormwater Pollution that NSW EPA has produced. Many other examples can be viewed at the website.

#### **[www.epa.vic.gov.au/programs/stormwater/goals.asp](http://www.epa.vic.gov.au/programs/stormwater/goals.asp)**

EPA Victoria's urban stormwater program (VSAP) is part of the Victorian government's 'Greener Cities' policy, and was launched by the Victorian Government in June 2000. The Victorian Government allocated \$22.5 million over three years to improve the environmental management of urban stormwater in Victoria.

The Urban Stormwater Best Practice Environmental Management Guidelines, published by CSIRO in 1999, were developed by EPA Victoria, Melbourne Water, Municipal Association of Victoria, local government, industry and Department of Natural Resources and Environment. These guidelines are referenced in this document.

**[www.stormwater.melbournewater.com.au](http://www.stormwater.melbournewater.com.au)**

Melbourne Water conduct a variety of programs for community and school education on stormwater issues. Examples of the education kits for school children are: ‘Drains to the Bay’ kit for years 3-6 and ‘Drain to our Waterways’ for years 5-9.

**[www.mav.asn.au/stormwater](http://www.mav.asn.au/stormwater)**

Capacity Building Program for Best Practice Urban Stormwater Management is coordinated by the Municipal Association of Victoria & Stormwater Industry Association of Victoria.

Funded by EPA Victoria through the Victorian Stormwater Action Program (VSAP), the CBP will develop and deliver statewide training/education packages to improve best practice environmental management of urban stormwater and sustainable urban development.

**[www.environment.sa.gov.au](http://www.environment.sa.gov.au)**

The SA EPA has three very useful codes of practice: “Stormwater pollution prevention code of practice for the community”, “Stormwater pollution prevention code of practice for the building and construction industry” and “Stormwater pollution prevention code of practice for local, State and Federal government”.

**[www.stormwater.asn.au](http://www.stormwater.asn.au)**

The Stormwater Industry Association (SIA) is for people and organisations involved with or concerned about stormwater in Australia. The mission of the Association is to provide an integrated Stormwater Industry of a quality that satisfies customer needs in an effective, efficient and affordable manner. Each SIA state committee has representatives from educational organisations, product manufacturers, local government and consultancies.

**[www.yellowfishroad.com.au/aboutthesiaef/ouraims.html](http://www.yellowfishroad.com.au/aboutthesiaef/ouraims.html)**

The Stormwater Industry Association Education Foundation (SIAEF) is an environmental trust created by the New South Wales chapter of the Stormwater Industry Association in 2002. The SIAEF's objective is to develop and support stormwater education to help protect and improve the environment.

It oversees Yellow Fish Road, which has been gaining momentum since its introduction to Australia in 1998. The Foundation is dedicated to developing programs to service the educational needs of councils, residents, schools, community groups and the private sector that are working to prevent stormwater pollution.

**[www.waterwatch.org.au](http://www.waterwatch.org.au)**

In recognition of the growing concern for water quality, the Commonwealth Government initiated Waterwatch in 1993.

Waterwatch Australia is a national community water monitoring program that encourages all Australians to become involved and active in the protection and management of their waterways and catchments.

**[www.wrc.wa.gov.au](http://www.wrc.wa.gov.au), [www.environ.wa.gov.au](http://www.environ.wa.gov.au)**

Water and Rivers Commission website and Department of Environmental Protection website – containing policies, guidelines and guidance statements for the community and industry sectors.

**[www.wrc.wa.gov.au/srt/index.html](http://www.wrc.wa.gov.au/srt/index.html)**

Swan River Trust website – One of the core tasks of the Swan River Trust is to raise awareness about issues affecting the river and increase community involvement in caring for the river and its catchment. Information is provided on their community awareness programs.

**[www.epa.gov/npdes/stormwater](http://www.epa.gov/npdes/stormwater), [www.epa.gov/owow/nps](http://www.epa.gov/owow/nps)**

US EPA has outreach kits, including an overview brochure on stormwater pollution, a homeowner's guide to preventing stormwater pollution and a poster for construction site operators on implementing sediment and erosion control practices, examples of which can be seen on these websites.

**[www.mastergardener.wsu.edu](http://www.mastergardener.wsu.edu)**

The Washington State University Master Gardener website. WSU were the originators of the Master Gardener program. The website contains links to other programs run elsewhere.

The Master Gardener program originated in Washington State to enable Washington State University Co-operative Extension to better serve the public, specifically home gardeners. Whilst Master Gardeners teach gardening and horticultural classes, much of the emphasis is on social and environmental issues in their communities, such as the threat to water quality if used improperly, or threat to water quality from unsustainable practices. The Master Gardeners program also strongly advocates composting, which reduces waste to landfill, and revegetation of eroded river banks.

**[www.ngia.com.au](http://www.ngia.com.au)**

The Nursery and Garden Industry Australia has designed projects for teachers to use in schools. These projects include themes such as soil science, which provides a flow chart of the methods involved in checking and improving soil quality, design briefs to help students plan and plant native and heritage gardens, vegetables, fruit and pot plants, and environmentally friendly pest control.

The Nursery Industry Association also runs an accreditation program for nurseries and garden centres, which includes some environmental considerations. Contacts and further information can be found on the website.

**[www.catchment.crc.org.au](http://www.catchment.crc.org.au)**

The Cooperative Research Centre for Catchment Hydrology's mission is to deliver to resource managers the capability to assess the hydrologic impact of land use and water management decisions at a whole of catchment scale. The CRC is undertaking a number of research programs and the website is a good resource for stormwater information.

CRC have developed a model, Model for Urban Stormwater Improvement Conceptualisation (MUSIC), which enables users to evaluate conceptual designs of stormwater management systems to ensure that water quality objectives for their catchments are met. However, education programs are not one of the BMPs evaluated.

**[www.canterbury.nsw.gov.au](http://www.canterbury.nsw.gov.au)**

Cooks River Environmental Assessment and Education Project – Bringing the Cooks River to Life.

**[www.manly.nsw.gov.au/thegreatestate](http://www.manly.nsw.gov.au/thegreatestate)**

Manly Council has joined forces with the NSW Government Stormwater Trust and the University of Western Sydney (UWS) to develop a unique program linking environmental education, water quality monitoring, infrastructure provision and legislation to address concerns about ecosystem health in the catchment of Balgowlah Industrial Estate.

The Manly website also has details of the Council's independent telephone survey it commissioned. To assist with the development of an Environmental Education Strategy, the surveys objectives were to explore the local community's knowledge, attitudes, skills and behaviours in respect to environmental protection. It is the first known instance where a NSW Council has undertaken a telephone resident survey wholly devoted to environmental matters.

**[www.hastings.nsw.gov.au/fsMain.htm](http://www.hastings.nsw.gov.au/fsMain.htm)**

Hastings Council Stormwater Education and Evaluation Program. This project aims to provide integrated, cost effective and long-term solutions to stormwater pollution by implementing an area wide education program as a key 'source control' tool. This program will be complemented and reinforced by structural measures, improved stormwater system maintenance and enhanced Council activities.

**[www.buttlitteringtrust.org](http://www.buttlitteringtrust.org)**

Research has found that cigarette butt littering is a complex behaviour compounded by a lack of infrastructure (bins, portable ashtrays), consistent enforcement of the law and a general lack of community knowledge about the environmental impact of butt littering. Cigarette butts are carried to our waterways through the stormwater system and pose an environmental threat.

The Butt Littering Trust is being developed to address cigarette butt littering in Australia.

The Trust's development has been facilitated to date by Nolan-ITU, an independent sustainability consultancy, in consultation with key environmental stakeholders. Funding support has been provided by British American Tobacco Australia Limited (BATA): \$1 million maximum will be committed by BATA to the Independent Trust for an initial trial period of two years. It is proposed that the Trust will distribute grants to the general categories of: Education, Research, Innovation, Benchmarking and measurement, Infrastructure provision and Infrastructure servicing.

Example poster signs and brochures



Figure 4. Poster  
Don't let your river go down the drain – protect it (Swan River Trust and Water and Rivers Commission).



Figure 5. Poster  
H<sub>2</sub>Only (Swan River Trust and Water and Rivers Commission).



Figure 6. Poster  
Make the connection – emergency (Swan River Trust).



Figure 7. Poster  
Make the connection – pollution (Swan River Trust).



Figure 8. Poster  
Make the connection – are you doing the right thing? (Swan River Trust).



Figure 9. Sign for drain  
Do not wash anything down this drain (Swan River Trust and Water and Rivers Commission).



Figure 10. Sign for workshop  
No Washing down in this area (Swan River Trust and Water and Rivers Commission).



Figure 11. Brochure  
Stormwater Pollution (NSW Environmental Protection Authority).

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Stormwater  
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Manual for  
Western Australia

9  
Structural  
Controls



Department of Water  
Government of Western Australia



*Cover photograph: Vegetated Swale, Southern River. (Source: Department of Water.)*

# Stormwater Management Manual for Western Australia

## 9 Structural Controls

Department of Water and Swan River Trust  
Consultation and guidance from the Stormwater Working Team



Department of Water  
Government of Western Australia



May 2007

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# Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the *State Water Strategy* (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Drainage and Waterways Branch of the Department of Water.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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# Summary

The aims of this chapter are to:

- Describe structural controls, as well as provide an overview of their benefits, use, effectiveness and evaluation.
- Provide basic information on the selection of structural controls and the use of relevant technical guidelines.
- Provide technical guidelines on some of the most relevant structural controls that can be applied at regional, estate and allotment scales in Western Australia.

Structural controls are engineered devices implemented to manage runoff quality and quantity, to control, treat or prevent stormwater pollution and/or reduce the volume of stormwater requiring management. Structural controls may be located at-source, in-transit or at end-of-catchment. They are ideally installed at or near the source of stormwater runoff, to protect receiving environments, including groundwater, waterways and wetlands. The implementation of structural stormwater best management practices into an urban landform has multiple benefits, including reducing storm flows, reducing pollutant export, maintaining and improving the urban landscape, protecting receiving environments and reducing irrigation and potable water supply requirements.

Structural controls can be designed for a new development on a greenfield or brownfield site, as well as retrofitting within existing developed areas. They should be used in combination with non-structural controls (i.e. the ‘treatment train approach’) to achieve a balanced mix of stormwater management measures.

This chapter aids in the selection, location and design of the most appropriate structural controls based on current understanding of the performance of structural controls and assessing the controls in the context of Western Australia’s local hydrology.

This chapter aims to ensure stormwater best management practices are implemented in a consistent manner and are achieving the objectives previously determined for a catchment through appropriate urban water management planning processes.

Table 1 on page 3 highlights the relevance for application by the target audiences of each of the structural controls that are addressed in this chapter. The structural control selection process is illustrated in the flow chart in Figure 1 on page 5 and discussed in the remainder of Section 1.7. A summary of each structural control addressed in this chapter is provided in Section 1.10.

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# 1 Introduction

## 1.1 Aims of the structural controls chapter

The aims of this chapter are to:

- Describe structural controls, as well as provide an overview of their benefits, use, effectiveness and evaluation.
- Provide basic information on the selection of structural controls and the use of relevant technical guidelines.
- Provide technical guidelines on some of the most relevant structural controls that can be applied at regional, estate and allotment scales in Western Australia.

It should be noted that the chapter does not seek to address all possible structural controls for stormwater management, but focuses on those currently recommended for use and generally supported in Western Australia by government agencies, and those which represent emerging technology considered suitable for application in Western Australia.

## 1.2 Scope of the chapter

This chapter focuses on the most relevant structural stormwater controls that can be used in Western Australia to manage the quantity and quality of stormwater runoff, prevent or treat stormwater pollution, and provide opportunities for water conservation through the use of stormwater as a resource.

This chapter aids in the selection, location and design of the most appropriate structural controls based on current understanding of the performance of structural controls and assessing the controls in the context of WA's local hydrology.

This chapter aims to ensure stormwater best management practices (BMPs) are implemented in a consistent manner and are achieving the objectives previously determined for a catchment through appropriate urban water management planning processes.

Structural controls can be designed for a new development on a greenfield or brownfield site, as well as retrofitting within existing developed areas. Chapter 6 contains more information on retrofitting.

Non-structural controls are addressed in Chapter 7.

## 1.3 Stormwater management approach

This manual encourages a treatment train approach to stormwater management, where combinations of measures (structural and non-structural) are implemented in parallel or sequence to achieve best management of stormwater.

The implementation of structural stormwater BMPs into an urban landform has multiple benefits, including reducing storm flows, reducing pollutant export, maintaining and improving the urban landscape, protecting receiving environments and reducing irrigation and potable water supply requirements.

Chapter 2 of the manual recommends the following stormwater management approach in Western Australia:

1. **Retain and restore natural drainage lines:** retain and restore existing valuable elements of the natural drainage system, including waterway, wetland and groundwater features and processes.
2. **Implement non-structural source controls:** minimise pollutant inputs principally via planning, organisational and behavioural techniques, to minimise the amount of pollution entering the drainage system.
3. **Minimise runoff:** infiltrate or reuse rainfall as high in the catchment as possible. Install structural controls at or near the source to minimise pollutant inputs and the volume of stormwater.
4. **Use in-system management measures:** includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps.

BMPs presented in this chapter address measures 1, 3, and 4 of this approach.

## 1.4 Terminology and key definitions

**Structural stormwater best management practices** are engineered devices implemented to manage runoff quality and quantity, to control, treat or prevent stormwater pollution and/or reduce the volume of stormwater requiring management. Structural controls may be located at-source, in-transit or at end-of-catchment. They are ideally installed at or near the source of stormwater runoff, to protect receiving environments, including groundwater, waterways and wetlands.

**Source controls** are structural or non-structural best management practices designed to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source (New South Wales Environmental Protection Authority 1998) and protect receiving environments, including groundwater, waterways and wetlands.

**Non-structural stormwater best management practices** are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management (United States Environmental Protection Agency 1999). They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), education and/or economic instruments (Taylor & Wong 2002).

**Receiving environments** are areas that receive stormwater runoff, including wetlands, waterways, coastal waters/dunes, groundwater and bushland areas.

**Water bodies** are waterways, wetlands, coastal marine areas and shallow groundwater aquifers.

**Effective imperviousness** is the combined effect of the proportion of constructed impervious surfaces in the catchment, and the connectivity of these impervious surfaces to receiving water bodies.

A detailed glossary at the end of the manual provides definitions of technical terminology used in this chapter.

## 1.5 The target audience

This chapter is primarily aimed at engineers and other urban water management professionals and local and State government approval officers.

Due to the range of multi-disciplinary professionals usually involved in urban development and catchment management, it is also an information source for planners, urban designers, landscape architects, environmental scientists, landcare and community groups, developers and individual landowners.

Table 1 provides a summary of the structural best management practices that are addressed in this chapter and highlights the relevance for application by the target audiences.

**Table 1. Structural control BMP summary and target audiences**

Structural Best Management Practices Addressed in this Manual	Target Audience				Section Reference
	Government Stormwater Management Agencies	Developers and Consultants	Commercial or Industrial Landowners/Managers	Individuals, Landowners and Community Groups	
<b>Stormwater Storage and Use</b>					
Rainwater Storage Systems	✓	✓	✓	✓	2.1
Managed Aquifer Recharge	✓	~	×	×	2.2
<b>Infiltration Systems</b>					
Infiltration Basins and Trenches	✓	✓	✓	✓	3.1
Soakwells	✓	✓	✓	✓	3.2
Pervious Pavement	✓	✓	✓	✓	3.3
<b>Conveyance Systems</b>					
Swales and Buffer Strips	✓	✓	✓	✓	4.1
Bioretention Systems	✓	✓	✓	~	4.2
Living Streams	✓	✓	~	✓	4.3
<b>Detention Systems</b>					
Dry/Ephemeral Detention Areas	✓	✓	~	~	5.1
Constructed Wetlands	✓	✓	~	~	5.2
<b>Pollutant Control</b>					
Litter and Sediment Management	✓	✓	✓	✓	6.1
Hydrocarbon Management	✓	✓	✓	×	6.2

Key: ✓ = Highly relevant      ~ = Some relevance      × = Not relevant

## 1.6 How to use the BMP guidelines in this chapter

Structural controls should be selected according to the BMP selection process outlined in Section 1.7.

The BMPs in Sections 2 to 6 of this chapter contain summarised background information, recommended practices, factors to consider, cost details, performance indicators, local application examples and references for a number of structural controls.

It is not necessary to read all of the information in Sections 2 to 6 in order to use this chapter. The detailed content should be selectively accessed as needed, to gather information on how to select and apply specific structural controls.

The dollar values quoted in this chapter relating to BMP costs have not been adjusted for inflation or potential cost reductions due to technological advances which may have occurred since reference document publishing. Costs presented in this document should therefore be considered indicative only and users of the manual are encouraged to seek further specific industry advice on BMP costs as appropriate.

## 1.7 How to select structural BMPs

The selection of structural BMPs requires consideration of multiple factors, such as catchment management objectives, site characteristics, target pollutants, social values, and capital and operating costs to achieve a balance between quantity and quality management objectives and to create a sustainable outcome.

All BMPs, whether they are structural, non-structural, at-source, in-transit or end-of-catchment, have potential benefits and limitations. The key is finding the best combination of these measures to suit local circumstances.

Performance of structural BMPs largely depends on the pre-development (pre-implementation) site characteristics and scale in which the measures are to be implemented. Structural controls are designed to achieve pollutant removal (quality), volume management (quantity) and/or water conservation functions.

The approach adopted in the selection process recommends that these factors be examined before the assessment of BMP characteristics and functionalities.

A key decision for BMP selection is the life cycle cost (capital and maintenance costs). This will require a balance between outcomes sought and available funding.

The BMP selection process is illustrated in the flow chart in Figure 1 and discussed in the remainder of this section.

### 1.7.1 Setting objectives, outcomes and design criteria

Structural BMPs will be selected through two main planning processes: statutory planning in greenfield developments and stormwater management planning in developed catchments. In new developments, stormwater management objectives are outcomes determined by the statutory process typically undertaken at a structure planning level, where a drainage and water management strategy (DWMS) is developed focusing on major arterial drainage for flood protection and storage requirements. The DWMS also provides an overview of the requirements for nutrient management, wetland and waterway protection and groundwater protection requirements. See Chapter 3 for more information about drainage and water management strategies.

In developed catchments, stormwater management plans are prepared to identify desired stormwater management outcomes for lot/neighbourhood, catchment or local government scales. Structural BMPs

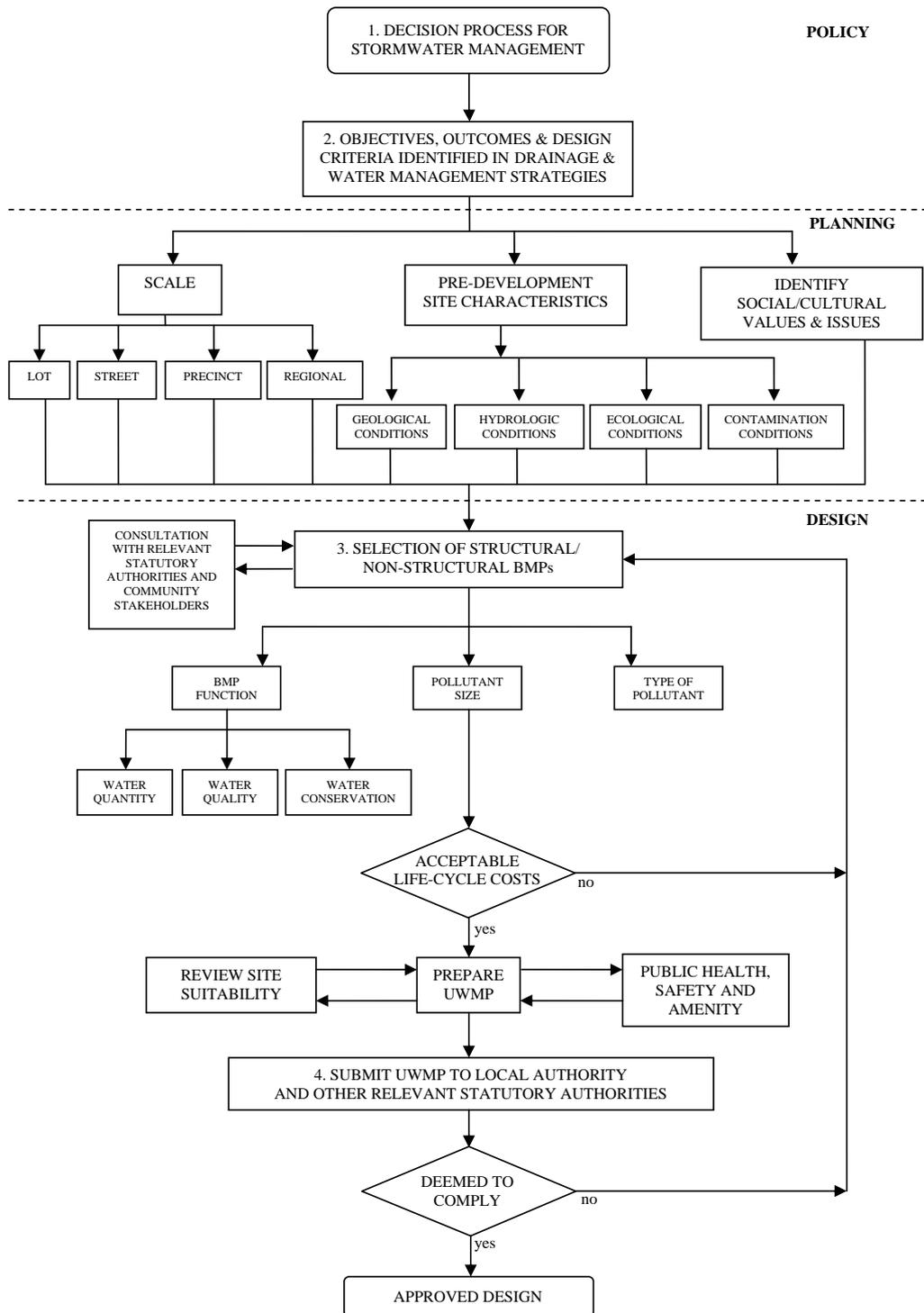


Figure 1. BMP selection flow chart.

may be chosen as a retrofitting strategy to improve management of stormwater at-source, in-transit and end-of-catchment. Implementing numerous small-scale retrofit projects throughout the catchment can have significant beneficial impacts on the health of receiving water bodies and on the community amenity of the area. Chapter 5 addresses stormwater management plans that are prepared for a local government area or catchment area. See Chapter 6 for more information on retrofitting.

Objectives should be clearly defined at the beginning of a BMP selection process. It is a common mistake to poorly define the objectives of the BMPs, to allow these objectives to evolve as the project is implemented, or to define objectives that are impractical to measure. To demonstrate success or failure of the BMPs, the

objectives should be specific, measurable, achievable, relevant and linked to a timeframe. See Chapter 10 for further information on performance monitoring and evaluation.

The BMP selection process discussed in Section 1.7 is reliant on the establishment of water quantity and quality objectives in the DWMS process for greenfield developments. In established areas, water quantity and quality objectives are defined through natural resource management strategies, catchment management plans and stormwater management plans.

The main water sensitive design approaches discussed in the remainder of this section must be factored into the selection of structural controls.

Natural drainage systems should be protected, and constructed stormwater systems should mimic natural drainage processes. Water sensitive urban design includes maintenance of the pre-development hydrologic regime; that is, maintenance of the pre-development stormwater quantity characteristics. This includes retaining/detaining small – moderate rainfall events throughout the catchment, as close to the runoff source (i.e. the impervious surface) as possible.

Water sensitive urban design increases disconnection between impervious surfaces and receiving water bodies. As a general rule, stormwater should not be discharged directly into receiving water bodies and only moderate – large rainfall events should reach receiving water bodies via overland flow paths across vegetated surfaces.

Stormwater management systems should be incorporated throughout a catchment and integrated in the urban landscape, such as within road reserves and public open space. This will minimise the social and economic issues associated with allocating (and often fencing off) large areas of land for traditional devices such as steep sided trapezoidal open drains and large sumps. As shown in Figure 1, social/cultural values and issues should be identified during the planning stage of the BMP selection process and relevant statutory authorities and community stakeholders should be consulted during the BMP design stage of the selection process.

These approaches result in improved biodiversity and health of receiving water bodies and improved amenity and quality of urban areas.

### 1.7.2 Scale of BMPs

Scale refers to the intended location and ownership of structural BMPs. Four broad scales have been identified for the purpose of this manual. They include:

- lot level
- street level
- precinct level
- regional level

BMP selection is best achieved using an integrated approach that focuses on meeting the overall objectives as set in the DWMS, catchment management plan or stormwater management plan. This typically requires the implementation of a treatment train approach across more than one scale. For example, a soakwell infiltration BMP may be proposed at a lot scale to complement the vegetated swale BMP at a street scale and the infiltration basin BMP at a precinct scale. This arrangement will satisfy the water quantity and quality objectives that might be unachievable if relying on a single BMP. Additionally, the impact from the failure of one device (e.g. flooding or water quality issues) will be reduced by the operation of the other devices in the treatment train.

The suitability of structural control BMPs applied to different scales can be assessed using the selection matrix in Table 2.

Table 2. Structural control BMP selection matrix

BMP	BMP Function		Scale				Pollutant Type							Pollutant Size						
	Water Quantity	Water Quality	Water Conservation	Lot	Street	Precinct	Regional	Litter and Sediments	Particulate Nutrients	Dissolved Nutrients	Heavy Metals	Oxygen Demanding Materials	Micro-organisms	Hydrocarbons	Gross Solids	Coarse to Medium Solids	Fine Particulates	Very Fine Colloidal Particulates	Dissolved Particulates	
<b>Stormwater Storage and Use</b>																				
Rainwater Storage Systems	R		✓ <sup>P</sup>	✓																
Managed Aquifer Recharge	R		✓ <sup>P</sup>	✓	✓		✓													
<b>Infiltration Systems</b>																				
Soakwells	R <sup>P</sup>	✓	~	✓	✓			✓												
Pervious Pavement	R <sup>P</sup>	✓	~	✓	✓			✓												
Infiltration Trenches	R <sup>P</sup>	✓	~																	
Infiltration Basins	R <sup>P</sup>	✓	~					✓												
<b>Conveyance Systems</b>																				
Swales and Buffer Strips	C <sup>P</sup> R D	✓	~	✓	✓	✓	✓	✓	✓	~			✓	✓	✓	✓	✓	✓	✓	✓
Bioretention Systems	C R D	✓ <sup>P</sup>	~	✓	✓			✓	✓	~			✓		✓	✓	✓	✓	✓	✓
Living Streams	C <sup>P</sup> R D	✓	~		✓	✓	✓	✓	✓	~			✓		~	~	~	~	~	~
<b>Detention Systems</b>																				
Dry/Ephemeral Detention Areas	D <sup>P</sup>	✓				✓	~	✓	✓	✓	✓	✓	✓	~	✓	✓	✓	✓	✓	~
Constructed Wetlands	D	✓ <sup>P</sup>			✓	~	~	✓	✓	✓	~	~	✓	✓	✓	✓	✓	✓	✓	✓
<b>Pollutant Control</b>																				
Litter and Sediment Management		✓ <sup>P</sup>		✓	✓			✓	✓		~				✓	✓				✓
Hydrocarbon Management		✓ <sup>P</sup>		✓	✓								✓		✓	✓	✓	✓	✓	✓

Key: ✓ BMP is applicable, ~ BMP is applicable to some extent, R = Retention, D= Detention and C= Conveyance. (P = Primary BMP Function)

### 1.7.3 Pre-development site characteristics

Detailed knowledge of the pre-development site characteristics is critical in the selection of BMPs, and the following characteristics can often dictate what structural control BMPs may or may not be effectively used at a particular site.

#### **Geological conditions**

The geotechnical and hydrogeological site assessment principally aims to determine the site constraints and the suitability of potential BMPs.

Soil permeability is a significant factor in selecting suitable devices. On-site hydraulic conductivity tests should be conducted due to the differences in permeability through the vertical and horizontal soil profiles.

#### **Hydrologic conditions**

The hydrologic conditions of a catchment include the relationships between rainfall, runoff, infiltration and evaporation. Water sensitive urban design can maintain a catchment's hydrology by mimicking the natural hydrologic characteristics (volume, frequency, recharge and discharge). These characteristics are in balance with the unique soils, vegetation and topographic features of the catchment and should where possible be maintained to maximise the protection of receiving environments.

Natural surface to groundwater separation is another important issue to consider when selecting BMPs. Infiltration BMPs typically require some separation to deliver desired hydraulic performance and to allow treatment to be carried out as stormwater percolates through the soil. However, site modification using permeable fill may provide sufficient separation for the implementation of infiltration BMPs under certain circumstances. Also, due to the seasonal variability in groundwater levels in sandy soils, the separation distance may only be limited for part of the year and may not necessarily preclude the selection of a particular BMP. The water table is likely to be at the annual maximum groundwater level for only a short duration throughout the year. Performance may not need to be optimal year round. For example, in the south-west of the State, a stormwater management system may perform as a retention/detention system for the majority of storm events, particularly in summer, autumn and early winter (when groundwater levels are at their lowest and pollutants carried by stormwater are usually at their highest), but act primarily as a conveyance system for the short duration that the groundwater is at its maximum level in late winter and spring each year, when pollutants carried by stormwater are usually at their lowest.

An indication of groundwater levels can be obtained from the Department of Water's Water Information Network (WIN) database or the Department of Water's Perth Groundwater Atlas. However, site specific groundwater monitoring programs should be undertaken to determine the actual groundwater regime at a proposed development site.

#### **Ecological conditions**

Protection and enhancement of the natural site attributes should be maximised when selecting and locating BMPs. There are generally more opportunities for this in greenfield developments; however, protection of remnant environments is important in both greenfield and brownfield developments.

Landform and ecological surveys of local significant vegetation, waterways and wetlands should be conducted during pre-design work. A good understanding of the existing hydrology, water quality and ecological structure and interactions is required for setting objectives. Assessments should also consider the impacts of BMPs on the ecological system, such as permanently altering groundwater levels in natural wetlands.

Opportunities for retaining natural overland flow pathways should be identified as part of the assessment. The rehabilitation of degraded waterways can provide significant economic advantages in stormwater management, particularly due to their conveyance and water quality improvement functions and the improvement of aesthetic values within the development.

### **Contamination conditions**

#### *Historical land use*

Historical land uses can cause soil and groundwater contamination. With urbanisation, it is important to manage stormwater quantity at-source so that there is less risk of these contaminants being potentially mobilised. BMP selection offers an opportunity to target specific contaminants or hot spots for treatment. In extreme cases, site remediation may be required for the complete removal of these contaminant sources.

#### *Acid sulphate soils*

Acid sulphate soils (ASS) form when soils naturally containing sulphide minerals are oxidised, forming sulphuric acid. Oxidation can occur when soils are exposed to the air following excavation or draining, or lowering water tables. Large-scale drainage for flood mitigation, urban expansion and agriculture has exposed many areas of acid sulphate soils in WA.

The acidic leachate and the metals consequently released from the exposed or drained soils cause significant environmental problems such as poor water quality and fish kills, as well as economic costs to communities through degradation of roads and corrosion of pipes and footings.

There are also public health risks associated with ASS via exposure to dissolved acids in water. These risks include potential for consumption, or skin and eye irritation from contact with acidic water.

ASS risk areas for parts of Western Australia can be viewed at the Department of Environment and Conservation website (<<http://www.environment.wa.gov.au>>).

Guidelines for managing ASS are contained in Department of Environment (2003).

#### *Secondary salinity*

Catchments with secondary salinity require urban stormwater management systems to be designed and managed to meet the outcomes of the local salinity management strategy. Issues such as exposing saline subsoils through cut and fill, increasing the regional groundwater level, changes to soil groundwater flow and disturbance to sensitive areas such as riparian corridors are some of the issues that will need to be considered when selecting structural BMPs.

### **Safeguarding Indigenous heritage**

In addition to the physical site characteristics, it is recommended that stormwater managers and designers investigate other land issues that may impact on the implementation of BMPs.

Under the *Aboriginal Heritage Act 1972*, landowners have an obligation to determine if any Indigenous heritage sites may be affected by any proposed development or constructed infrastructure. If there is a possibility of affecting Indigenous heritage sites, the proponent must abide by the provisions of the *Aboriginal Heritage Act 1972*, as administered by the Department of Indigenous Affairs.

More detailed information on Indigenous values can be found in Chapters 5 and 6. Contact the Indigenous Support Unit at the Department of Water to find local Indigenous contacts.

## Protecting social values

It is important to ensure that social values (including cultural values) are taken into account. Social values embrace qualities for which a place has become a focus of spiritual, political, national or other cultural sentiment to a minority or majority group. Cultural significance includes aesthetic, historic, scientific or social values for past, present or future generations.

For example, a site (e.g. a park), natural feature (e.g. a water body, tree or rock formation) or structure (e.g. a weir) might have significant social/cultural values and will therefore require consideration in the selection and/or siting of a particular structural BMP.

As shown in Figure 1, consultation with the community to determine social/cultural values and issues is an essential component of BMP selection and design.

### 1.7.4 BMP function

Urban runoff has the potential to have a significant impact on the ecology of water bodies due to altered water regimes (volume, energy, frequency and timing of runoff) and poor water quality. Urban stormwater management BMPs can employ achieve key functions:

- Stormwater quantity management
- Stormwater quality management
- Water conservation

A structural control will have single or multiple functions that will help contribute to the overall objectives or outcomes established in the catchment management plan, stormwater management plan or urban water management plan for the area. Typically, a combination of structural and non-structural controls will be implemented in series or concurrently, forming a treatment train to help achieve an overall outcome (Chapter 4).

#### Stormwater quantity management

Stormwater quantity management recognises that urbanisation will typically lead to an increase in imperviousness and a corresponding increase in volume and rate of runoff.

The sustainable approach to urban water management emphasises replicating post-development hydrology as close to pre-development conditions as possible (*National Water Quality Management Strategy*, ARMCANZ & ANZECC 2000). Figure 2 illustrates this recommended approach in relation to managing runoff from various design storm events.

Techniques that can be incorporated to maintain the pre-development hydrology through effectively minimising the 'effective imperviousness' of a development area include:

- reducing the amount of constructed impervious areas; and
- disconnecting constructed impervious areas from receiving water bodies.

Reducing the amount of constructed imperviousness in a development area can be achieved through the application of alternative surfaces with lower runoff coefficients, such as permeable pavement, and through the retention of pervious areas, such as native vegetation, garden beds and parkland. This will reduce peak discharge, particularly for smaller storm events such as the 1 year average recurrence interval (ARI) event.

Direct connection of impervious areas to receiving water bodies results in altered hydrologic regimes with associated erosion, loss of habitat, and the efficient delivery of pollutants (Walsh et al. 2004). Disconnecting impervious areas from receiving water bodies helps to maintain the pre-development hydrologic regime.

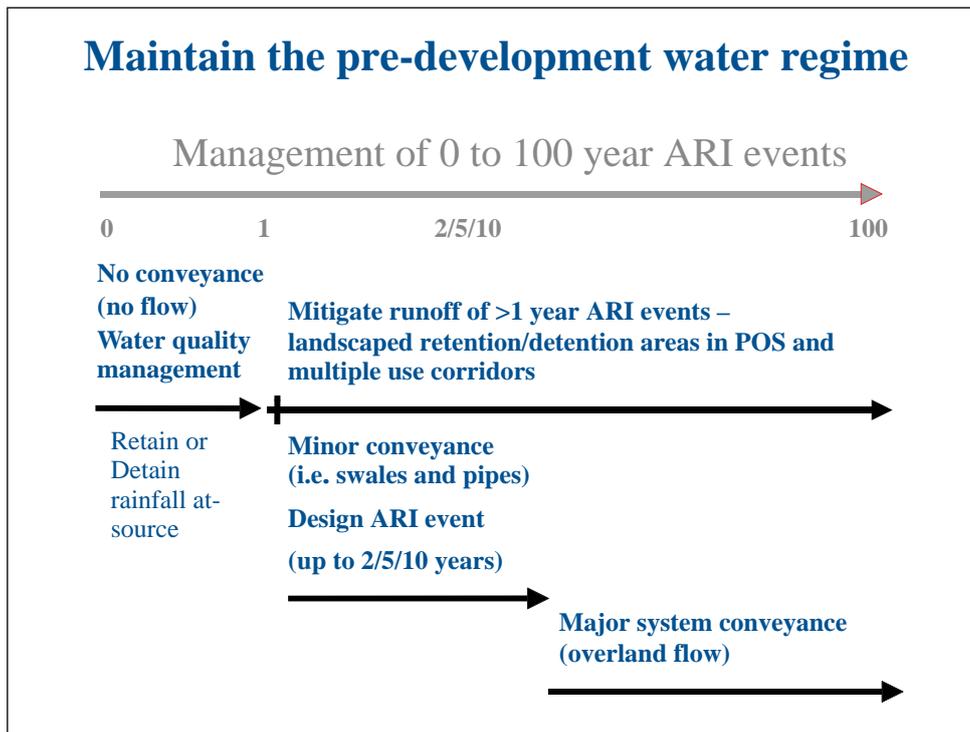


Figure 2. Approach to maintaining pre-development hydrology.

Runoff disconnection is typically designed to retain storm events up to the 1 year ARI event. This can be achieved through employing BMP retention and detention techniques.

Retention systems are designed to prevent off-site discharges of rainfall runoff, up to the design ARI event. Stormwater may be infiltrated to groundwater or used as a water source. Retention and reuse devices include rainwater tanks, aquifer storage and recovery, soakwells and infiltration basins.

Detention systems reduce the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design ARI event) and then releasing it slowly. Constructed wetlands and ephemeral detention basins can be used to detain stormwater.

Some structural controls have a conveyance function, such as swales, bioretention systems and living streams. Many of these conveyance systems also provide seasonal detention and retention functions.

### Stormwater quality management

Urban surfaces collect contaminants, which are typically washed off during storm events. Typical contributors to pollutants in runoff include vehicular traffic, industries, garden maintenance and fertilisers, animal manure, eroded sediments and vegetative litter.

The major non-point source pollutants in urban development include litter and sediments, nutrients, heavy metals, oxygen demanding materials (e.g. leaves), toxic materials (e.g. pesticides), microorganisms, surfactants (e.g. detergents) and hydrocarbons (e.g. asphalt and petrol). Structural stormwater quality management typically involves utilising a combination of physical, chemical and biological processes to achieve the desired objectives. The locations of the various BMPs in the treatment train are important considerations in ensuring the sustained effectiveness of the management approach. Generally, the siting of BMPs should take account of the pollutant treated by each of the treatment measures. For example, gross pollutants and sediment can reduce the performance of infiltration systems, constructed wetlands, pervious paving and swales. Pre-screening devices such as buffer strips, gross pollutant traps and sediment trapping areas can be installed before discharging stormwater runoff to downstream treatment systems. BMPs

to remove types of pollutants are shown in Table 2. Sections 1.7.5 and 1.7.6 discuss pollutant removal further.

Designers are encouraged to infiltrate at-source as many rainwater events as possible, where site conditions allow, to increase disconnection and therefore reduce the collection and transportation of pollutants to receiving water bodies. Site investigations should be undertaken to select appropriate infiltration BMPs (as shown in Figure 1). Development should not result in deterioration of water quality in receiving water bodies, including mobilisation of existing contaminants. For example, it would usually be unsuitable to install an infiltration system up-gradient of a plume of contaminated groundwater. Infiltration systems are generally designed to maintain the pre-development site hydrologic regime, so there should be no increase in the amount of groundwater recharge compared to pre-development conditions. However, management of some contaminated sites might require that there be no groundwater recharge up-gradient of the contamination plume.

It should be noted that the most effective stormwater quality management programs use non-structural BMPs to complement the selected structural BMPs. For example, gross pollutants can be managed through implementing improved site management practices, litter bin provision, street sweeping, litter collection, vegetation selection and maintenance and regulation practices. See Chapter 7 for information on the selection and design of non-structural controls to reduce pollutant sources.

### **Water conservation**

Water sensitive urban design and total water cycle management view stormwater as a resource, and options for collecting and using stormwater for irrigation and non-potable water supply are now being examined in Western Australia.

The reduction in rainfall in the south-west of Western Australia since 1975 and population growth resulting in increased demand throughout most of Western Australia has necessitated the investigation of alternative water sources. A number of structural (such as stormwater harvesting and rainwater tanks) and non-structural (such as 'fit for purpose' use of water) initiatives are being examined.

In considering stormwater conservation and reuse opportunities, it should be noted that stormwater is also an important source of water for maintaining the condition and function of natural wetlands and waterways, and providing for ecological water requirements.

### **1.7.5 Type of pollutant**

An urban catchment is usually made up of multiple land uses (current and historical), which largely determine the stormwater pollutant profile of the catchment. For example, gross pollutants are prevalent in commercial areas, whereas sediments and nutrients are typically more prevalent in developing urban areas. Therefore, the promotion of at-source treatment targeting specific pollutants within the sub-catchment provides a far more efficient approach to stormwater management. Additionally, at-source use or infiltration of stormwater minimises the collection and downstream transportation of pollutants. See Chapter 2 (Section 3.1) for information on pollutants and their environmental impacts.

To effectively manage stormwater, it is necessary to match the selected BMPs with the site characteristics, including target pollutants and their transport pathways, groundwater levels and water quality of the receiving water body. For this selection to be successful, the designer needs to know about the catchment (land use, current stormwater management practices, soil types, hydrology, and groundwater interactions) and its pollutants (typical components, dominant transport pathways). If one of the objectives of the project is to improve water quality, it is essential that the water quality of the stormwater is known (or estimated), as this will influence the choice of BMPs.

Different processes are required for removing different pollutants and their components. If litter is a large problem (i.e. from high traffic or commercial areas), then an at-source gross pollutant trap (GPT) may be useful. If high concentrations of hydrocarbons from street runoff are expected, then an oil and grit trap may be the best solution. Stormwater with a high amount of sediment or nutrients attached to sediment can be treated by using retention/detention areas. Stormwater with a high amount of dissolved nutrients can be treated with BMPs that encourage biofilm growth, such as bioretention systems and constructed wetlands.

BMPs for the treatment of pollutant types can be assessed using the selection matrix in Table 2.

### 1.7.6 Pollutant size

Treatment of stormwater pollutants usually requires the reduction of one or more of the following pollutant sizes:

- gross solids: contaminants larger than 5 mm, such as litter and organic material;
- coarse to medium solids: contaminant particles between 5 mm and 0.125 mm;
- fine particulates: contaminant particles between 0.125 mm and 0.010 mm;
- very fine colloidal particulates: contaminants between 0.010 mm and 0.00045 mm. These contaminants, specifically nutrients, heavy metals, toxicants and hydrocarbons, attach themselves to fine sediments;
- dissolved particulates: contaminants less than 0.00045 mm. Dissolved contaminants include nutrients, metals and salts.

BMPs for the treatment of pollutants of various sizes can be assessed using the selection matrix in Table 2.

### 1.7.7 Public health and safety

#### **Mosquito and midge management**

Structural stormwater management systems should be carefully designed to minimise the risk of chironomid midge and mosquito breeding. These insects cause significant nuisance, affecting lifestyle and amenity and have direct and indirect economic impacts. Some mosquito species that breed in these environments can also be vectors of Ross River virus and other mosquito-borne diseases. Ideally, all components of a stormwater treatment train should be designed to ensure that they do not contribute to or create an environment that increases the opportunity for nuisance or disease vector species breeding on-site. At-source infiltration, ephemeral detention areas, overland flow paths over vegetated surfaces (swales) and living streams are preferred stormwater management options as they minimise the creation of areas of stagnant water.

An overall mosquito and chironomid midge risk and management program will need to be undertaken as part of the overall pre-implementation planning for a development area. There are three stages involved in developing a mosquito management program:

- Stage 1 – Establish a mosquito monitoring program to identify existing levels of mosquito activity, species diversity and density, and public health risks, prior to any ground disturbance. This needs to be conducted at appropriate times of the year and when environmental conditions are favourable for mosquito breeding. Ideally, such baseline surveys should include more than one ‘mosquito season’ to allow for substantial inter-annual variation in mosquito activity.
- Stage 2 – Design the stormwater management system to ensure that constructed waterway and wetland areas, multiple use corridors, road gullies (etc.) do not contribute to on-site mosquito breeding. For

example, infiltration, evapotranspiration or drawing down of the water to prevent pooling for longer than four days will prevent completion of the aquatic (larval) stages of the mosquito life cycle. The four day guideline applies during the warmest months (e.g. late spring, summer and early autumn) in the south-west of WA and throughout the year in the north, as larval mosquitoes develop more rapidly in warmer temperatures. Contact the relevant local government Environmental Health Officer or the Mosquito-Borne Disease Control Branch of Department of Health for information about mosquito breeding risk seasons in different regions in WA. Other more intensive and expensive management approaches will be necessary in areas where infiltration/evapotranspiration of stormwater cannot be achieved within four days during risk times, either due to an impermeable substrate, a high groundwater table, existence of permanent water (e.g. in rainwater tanks and some constructed wetlands) or other factors. See individual BMPs for guidance on how to reduce mosquito breeding risk in these situations.

- Stage 3 – Ongoing inspection, maintenance and management of the stormwater system to ensure that it continues to operate as designed, thereby reducing the risk of conditions likely to promote on-site mosquito breeding.

For detailed advice on reducing the risk of mosquitoes, see the Department of Health (2006) *Mosquito Management Manual* and the Midge Research Group of Western Australia (2006) *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies*.

### **Accident risk**

Steep sided structures present a potential safety risk, particularly for children who play near or attempt to climb into the structure and may fall in. This risk is increased when the structure contains enough water to drown a child. Steep sided structures also present a hazard for maintenance staff. For example, ride-on mowers may tip over on bank grades steeper than 1:6. Therefore, structural controls must be designed to reduce accident risks (e.g. use barrier vegetation or fencing, or design bank grades no steeper than 1:6 on open systems). The location of structural controls within the urban landscape (such as where to site them within public open space or considering their design and location when near schools) should also take account of accident risk.

### **Recreational water quality**

Reduction in recreational water quality is also a public health issue. Stormwater discharged directly into receiving waters used for recreational activities, such as swimming, can reduce the water quality and increase the public health risk by introducing pathogens into bathing waters. Therefore, overflow of stormwater runoff towards receiving water bodies should be by overland flow paths across vegetated surfaces. If overland flow is not possible, then stormwater outlets that discharge directly into a water body should be situated a sufficient distance (e.g. greater than 200 m) from popular bathing beaches.

## **1.7.8 Site suitability review**

Issues such as the area of land available and neighbouring land uses will be a factor in BMP selection.

For example, some BMPs (e.g. constructed wetlands) require significant areas of land, so decisions about the best use of land will need to be made. There must also be adequate room to allow personnel access to clean and maintain a device. Neighbouring land uses will need to be considered, as some BMPs might be incompatible with certain land uses (such as schools).

### 1.7.9 Life cycle costs

Consideration of post-construction costs and differing life expectancies is necessary to compare alternative strategies. The concept of life cycle costing combines the capital and operating costs of devices over their operating life.

It is important that a holistic approach be adopted to adequately assess the economic viability of structural BMPs for urban stormwater management. Cost and benefit analysis should include social and environmental outcomes. Additionally, the assessment should take into consideration the implicit inter-relationship between the three key functions of BMPs: water quantity, water quality and water conservation management.

It is estimated that savings in the life cycle cost of structural BMPs can be achieved by eliminating the use of large ponds/sumps; reducing impervious areas; minimising the use of pipes for conveyance; and reducing the amount of grading and clearing earthworks via retention of the natural landform. Coffman (1997) estimates this approach can reduce stormwater and site development design, construction and maintenance costs by 25-30% compared to conventional approaches.

Taylor (2003) describes how to estimate and document life cycle costs and Taylor (2005) provides literature review information on life cycle costing for various structural controls.

Costs included in the 'Cost' section of each BMP are quoted directly from the source information and have not been adjusted to 2007 prices.

#### **Capital costs**

Capital costs primarily consist of expenditures incurred to construct or install the BMP. Capital costs include all land acquisition, labour, equipment and material costs, excavation and grading, control structures, landscaping and appurtenances. Capital costs should also include professional fees for the design and construction of the BMP.

The cost of constructing a BMP is variable and largely depends on site conditions and the size of catchment that it services. For example, rock encountered during construction may significantly increase excavation costs. Land cost is a critical component as it can surpass all other costs. This is an area where the water sensitive approach to stormwater management has benefits over conventional stormwater management, as land is not excised from community use because stormwater management systems are integrated within streetscapes and public open space.

#### **Operating and maintenance costs**

Operating and maintenance costs are post-construction costs that ensure the continued effectiveness of a BMP during its design life. Annual operating and maintenance costs include labour, materials, energy sources (e.g. to operate pumps) and equipment. Tasks typically carried out in a maintenance program include landscape maintenance, revegetation, weed control, structural maintenance, infiltration maintenance and cleaning.

Operating and maintenance costs can be divided into either aesthetic or functional. Functional maintenance is important for device performance and public safety, while aesthetic maintenance is important for public acceptance of BMPs. Aesthetic appearance is particularly important for visible BMPs.

Operating and maintenance costs can be more difficult to estimate than the capital costs, but they are sometimes the most critical variable. Variations in maintenance techniques and the amount and contamination characteristics of the removed material (thus the disposal costs) all contribute towards maintenance costs. It is therefore important that operating costs are considered and budgeted for during the design phase.

See Section 1.9.1 for more information about maintenance.

## 1.8 Urban water management plans

Documentation of selected BMPs will need to be addressed in urban water management plans (UWMP) prepared for a development area. See Chapter 3 for more information on urban water management plans.

Documentation will need to include characteristics of selected BMPs (e.g. location, size and type), the timing of their implementation, who is responsible for their implementation and maintenance, and how they will be monitored and evaluated.

## 1.9 Implementation

### 1.9.1 Maintenance

Maintenance requirements, from the construction phase through to the expected lifetime of the BMP, need to be factored into the design. A maintenance plan and associated reporting processes must be developed during the design phase as part of the UWMP. Maintenance and asset managers will use these plans to ensure that the BMPs function as designed. The maintenance plan should be reviewed approximately every three years.

The plan should generally address the following topics:

- BMP design details
- costs
- responsibilities
- inspection frequency
- maintenance timing and frequency
- vegetation replacement and weed and nuisance/disease vector insect control
- performance monitoring data collection/storage requirements (i.e. during inspections)
- record keeping requirements
- detailed clean-out procedures (such as equipment, maintenance techniques, occupational safety and health, public safety, environmental management considerations, disposal requirements of removed material, access issues, stakeholder notification requirements and data collection requirements) to remove sediment and litter.

Some devices, such as gross pollutant traps, require regular inspection and monitoring to determine the optimal frequency and timing of cleaning to ensure they do not become a source of pollutants. For example, nutrients in an organic form can be converted to a bioavailable form in the anoxic environment in a poorly maintained trap. Remobilisation of trapped pollutants or bypassing due to a lack of storage volume in an unmaintained trap could result in the supply of pollutants to the stormwater system.

Constructed wetlands and infiltration systems require regular inspection for sediment build-up. Online vegetated systems (i.e. systems that are part of the main stormwater conveyance network) need to be periodically inspected to ensure that prolific plant growth does not block the channel. Branches or plants that are dislodged during high flows and transported downstream may need to be cleared if they become trapped and form a debris dam or block a culvert. Vegetation may also need to be periodically harvested to enhance nutrient removal or re-establish conveyance/storage capacity.

More information about maintenance is provided in each BMP section.

### 1.9.2 Monitoring and evaluation

Monitoring and evaluation should be conducted to determine if the BMP is performing as intended. Chapter 10 provides a process for how to monitor and evaluate structural and non-structural controls.

The pollutant removal effectiveness and performance of some structural controls is not well understood in Western Australia, particularly on the Swan Coastal Plain. This is because most research has been conducted in the eastern states, where the climate and hydrogeology is very different to that of the Swan Coastal Plain. Therefore, where monitoring and evaluation has been undertaken, it would be appreciated if an electronic copy of the final report be sent to the Department of Water, to help disseminate the knowledge of successes and failures to other stakeholders, as part of a continual improvement process for this manual.

## 1.10 Summary of structural controls addressed in this chapter

### Stormwater Storage and Use



*Demonstration domestic rainwater tank. (Photograph: Renee Romyn.)*



*Wastewater aquifer storage and recovery pump at Bolivar, South Australia. (Photograph: CSIRO Land and Water website © CSIRO 2005.)*

Stormwater retention and use on-site is a part of integrated water cycle management in the urban setting. This best management practice is sometimes referred to as stormwater harvesting. Stormwater retention and use within an urban catchment has the potential to mitigate the impacts of development on flow regimes and provide an alternative non-potable water supply source. Capturing stormwater at-source and preventing runoff from small rainfall events also has the benefit of preventing the risk of this runoff picking up and transporting pollutants as it flows through the urban landscape.

Stormwater retention and use BMPs include:

- rainwater storage devices, including rainwater tanks;
- below-ground rainwater/stormwater storage units and media filled storage tanks;
- raingardens, including roof gardens and small bioretention gardens;
- stormwater sculptures and water features; and
- managed aquifer recharge (MAR).

MAR involves the storage of water in suitable aquifers through infiltration or well injection. This additional stored water can be recovered for use during periods of high demand. While formally managed MAR schemes at regional scales are relatively new in WA, use of local infiltration systems and irrigation bores have had widespread application in WA at domestic and local authority scales, operating as informal MAR schemes for non-potable use. Systems which directly infiltrate the collected stormwater on-site are discussed in Section 3 of Chapter 9 (Infiltration Systems).

This manual does not address the use of rainwater storage systems to supply a drinking water source, although it is recognised that in many rural areas of Western Australia, roof water is the main water supply for drinking and domestic use. For more information on using roof water for human consumption, refer to the Department of Health and the Water Corporation.

### Best Management Practices

BMP System		Applicable Scale	Primary and Secondary Functions	Status of Application in Western Australia
2.1	Rainwater Storage Systems	Lot, Street	<i>Water Conservation</i> Water Quantity (Retention)	Traditionally applied in rural/regional areas. Increased recent application as a non-potable supply for urban development.
2.2	Managed Aquifer Recharge	Lot, Street, Precinct, Regional	<i>Water Conservation</i> Water Quantity (Retention)	Lot (domestic) and precinct schemes (local authority public open space irrigation) have widespread use. Use of MAR schemes at the regional scale is being trialled and researched. Some limited application in Perth metropolitan area.

## Infiltration Systems



*Infiltration through pervious paving. (Source: Washington Aggregates & Concrete Association 2006.)*



*Pervious surface under gutterless roof, Shire of Broome. (Photograph: Allan Ralph, Shire of Broome 2005.)*

Infiltration best management practices consist of systems where the majority of the stormwater is infiltrated to the ground, rather than discharged to a receiving surface water body. Infiltration systems cover a wide range of application scales (lot to regional) and include infiltration basins and trenches, soakwells and

pervious pavements. Infiltration can also be simply achieved through the provision of a soil surface or vegetated area allocated for this purpose, for example by directing roof runoff to a garden bed.

Infiltration systems are used at different scales and under different conditions to accomplish the same goals of reducing stormwater runoff peak flows and volumes; minimising pollution conveyance; reducing downstream flooding; managing the hydrologic regime entering receiving environments; and increasing groundwater recharge.

Sandy soils are ideal for infiltration systems. Even in areas where soils are less permeable, infiltration systems may still be an option for stormwater management if other engineering factors dictate the use of more permeable fill to raise the site level, or slow drainage infiltration systems are adopted. Infiltration at-source should be considered in preference to end-of-pipe or end-of-catchment systems where the stormwater has had the opportunity to pick up pollutants.

To prevent infiltration systems from being clogged with sediment/litter during road and housing/building construction, temporary bunding or sediment controls need to be installed. See Section 2.1.1 'Land development and construction sites' of Chapter 7 for information about site management practices.

### Best Management Practices

BMP System		Applicable Scale	Primary and Secondary Functions	Status of Application in Western Australia
3.1	Infiltration Basins and Trenches	Street, Precinct, Regional	Water Quantity ( <i>Retention</i> ) Water Quality Water Conservation	Widespread local application of infiltration basins. Infiltration trenches used to a lesser extent, in many cases as a retrofitting application to existing fenced sumps.
3.2	Soakwells	Lot, Street	Water Quantity ( <i>Retention</i> ) Water Quality Water Conservation	Widespread local application at domestic, local authority and development scales.
3.3	Pervious Pavement	Lot, Street	Water Quantity ( <i>Retention</i> ) Water Quality Water Conservation	Limited previous local application. Recent trials and increasing application in Western Australia.

## Conveyance Systems



*Bannister Creek drain to living stream project, Lynwood, WA. (Photograph: Department of Water 2007.)*



*Grassed swale in parkland, Darglish, WA. (Photograph: Department of Water 2006.)*

Natural and rehabilitated living streams, bioretention systems and swales are increasingly playing a role in stormwater management, providing conveyance of runoff and an opportunity for water quality improvement and detention and retention of flows. These conveyance systems are being applied locally to new development areas and also retrofitted to existing development areas to replace existing steep sided trapezoidal drains and to rehabilitate degraded waterways. In developed urban areas, these systems are also used to supplement or, where feasible, replace piped drainage.

If designed correctly, these conveyance systems can provide aesthetic, recreational and conservation values in the urban environment.

### Best Management Practices

BMP System		Applicable Scale	Primary and Secondary Functions	Status of Application in Western Australia
4.1	Swales and Buffer Strips	Lot, Street, Precinct	<i>Water Quantity (Conveyance, Retention and Detention)</i> Water Conservation Water Quality	Widespread local application, particularly grassed swales. Used as both an infiltration system for frequently occurring events and conveyance of larger storms.
4.2	Bioretention Systems	Street, Precinct	<i>Water Quality</i> Water Quantity (Conveyance, Retention and Detention) Water Conservation	Wide application in eastern states, particularly areas of low infiltration. Limited local use to date with several trial applications in Western Australia currently in progress.
4.3	Living Streams	Precinct, Regional	<i>Water Quantity (Conveyance Retention and Detention)</i> Water Conservation Water Quality	Increased use recently, particularly for development of rural areas with steep sided trapezoidal drains.

## Detention Systems



*Liege Street Wetland, Cannington, during construction in May 2004 and immediately following completion of construction and initial planting in September 2004. (Photographs: Department of Water.)*

Detention best management practices consist of a range of systems in which stormwater is primarily detained (rather than infiltrated) and water then discharged to a receiving environment. The primary detention system types include constructed wetlands, dry/ephemeral detention areas and on-site detention systems.

While the primary function of these systems in many cases is peak flow attenuation and flood protection of downstream environments, in the case of constructed wetlands detention is utilised together with biological processes for pollutant removal.

The Department of Water is currently not including constructed ponds and lakes as a stormwater quality improvement BMP in this manual. Constructed lakes are defined as constructed, permanently inundated basins of open water, formed by simple dam walls or by excavation below ground level. Constructed wetlands are vegetated detention areas that are designed and built specifically to remove pollutants from stormwater runoff. Constructed wetlands are designed to mimic natural wetlands in Western Australia, which are often ephemeral, and avoid the problems often associated with constructed lakes. Constructed wetlands are designed to provide additional environmental benefits, such as valuable native flora and fauna habitat.

For information regarding the Department of Water's current position on the construction of ponds and lakes, the reader is referred to the *Interim Drainage and Water Management Position Statement: Constructed Lakes* (Department of Water 2007).

## Best Management Practices

BMP System		Applicable Scale	Primary and Secondary Functions	Status of Application in Western Australia
5.1	Dry/Ephemeral Detention Areas	Precinct, Regional	Water Quantity (Detention) Water Quality	Widespread local application at subdivisional level, particularly as grassed multiple use areas.
5.2	Constructed Wetlands	Precinct, Regional	Water Quality Water Quantity (Detention)	Limited previous application in WA due to design issues related to local environmental considerations (e.g. areas with high water tables and permeable sands). Design guidelines for constructed ephemeral wetlands on the Swan Coastal Plain have recently been prepared by DoW.
	On-Site Detention Systems	Lot	Water Quantity (Detention)	Refer to the Infiltration Systems and Stormwater Storage and Use BMPs for measures that can be used to retain/detain stormwater on-site.

## Pollutant Control



*Underground chamber device gross pollutant trap, Backshall Place, Wanneroo. (Photograph: JDA Consultant Hydrologists 2004.)*



*Gross pollutant trap chamber following a storm event, near Lake Jualbup, Shenton Park. (Photograph: JDA Consultant Hydrologists 2005.)*

This guideline summarises the range of pollutant control devices being applied in Western Australia to new development areas and also retrofitted to existing development areas. The pollutant control devices presented are litter and sediment management systems (e.g. gross pollutant traps, trash racks, etc.) and hydrocarbon management systems (e.g. oil-water separators). These systems typically operate as one component of an overall stormwater management treatment train protecting the receiving environment. These pollutant control devices are often used where land constraints prohibit the use of other BMPs, or as pre-treatment to other BMPs, such as constructed wetlands.

Litter and sediment management (LSM) devices are primary treatment measures that retain gross pollutants by physical screening or rapid sedimentation techniques. Hydrocarbon management techniques are typically used in commercial, industrial and transportation land uses such as carparks and service stations, where impervious areas are expected to receive high hydrocarbon loadings.

## Best Management Practices

BMP System		Applicable Scale	Primary and Secondary Functions	Status of Application in Western Australia
6.1	Litter and Sediment Management	Lot, Street, Precinct	<i>Water Quality</i>	Generally used as end-of-pipe solution to protect receiving environments, however should usually be applied at-source to target areas with potential for high pollutant runoff. At-source application is usually more cost effective than LSM systems applied in-transit or end-of-pipe. There is a range of LSM devices available in WA designed to target various types of pollutants. Used in new developments and retrofitted applications. Requirement for these devices for new developments has been reduced due to the focus on retention of stormwater at-source and disconnecting pollutant transport pathways.
6.2	Hydrocarbon Management	Lot, Street	<i>Water Quality</i>	Some installations along major roads and intersections in Western Australia to capture potential spills and treat road runoff. Increasingly used at-source in new developments and retrofitting applications to treat runoff from hardstand areas likely to contain hydrocarbon contamination, for example at service stations, carparks and industrial premises. Best used in combination with non-structural controls, such as good house-keeping practices on industrial sites, to minimise pollution of stormwater. Various hydrocarbon traps are available within Western Australia.

## 1.11 Case studies

### Bridgewater South Estate, Mandurah

#### Project description

Bridgewater South Stage 3 subdivision is located between the Indian Ocean and the Peel-Harvey Estuary and is approximately 3.5 km south of Mandurah. The development was completed in 2005. The area has a Mediterranean-type climate, with hot, dry summers and cool, wet winters. The annual rainfall pattern for Mandurah is shown in Figure 1. The subdivision is located predominantly on relatively free draining light grey sands. Despite the generally high permeability soils, some areas have low infiltration capacity due to their proximity to the estuary, which leaves little separation between surface levels and groundwater levels at certain times of the year.

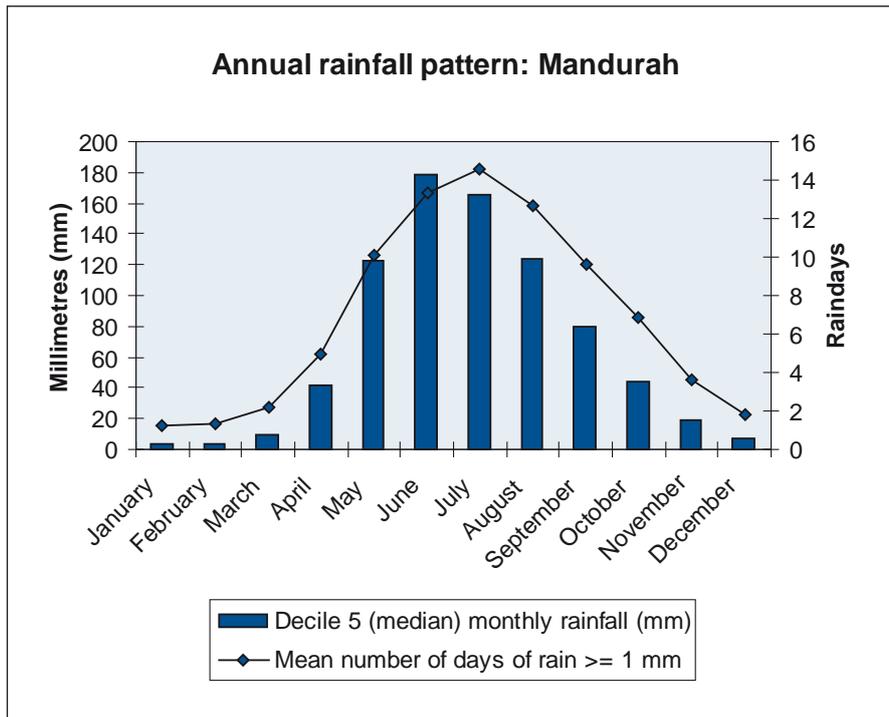


Figure 1. Mandurah annual rainfall pattern. (Source: Bureau of Meteorology 2007.)

The development is located adjacent to a Ramsar registered site (the Peel-Yalgorup system) and a Conservation category wetland (a sumpland within Len Howard Reserve). Protection of these sensitive receiving environments influenced the stormwater management design.

The City of Mandurah is experiencing significant levels of growth. The City aims to achieve the following when undertaking development:

- protection of environmental assets for future generations;
- continuous improvement in achieving best outcomes for the community;
- ensuring environmental and economic wellbeing.

In order to achieve these aims within the Bridgewater South Stage 3 subdivision, the City of Mandurah helped to develop an innovative stormwater management system that utilised a combination of best management techniques that were not commonly applied in Western Australia (Figure 2).

### Approaches implemented

The following structural and non-structural stormwater management practices were implemented at the site:

#### Structural controls:

- flush and broken kerbing
- infiltration, retention and detention at-source
- dry infiltration basins
- infiltration swales (turfed or planted with native vegetation)
- disconnection from receiving water bodies
- overland flows through vegetated buffers
- roads to convey greater than 100 year ARI events
- lot levels set to protect properties from flooding

*Non-structural controls:*

- Proactive guidance provided by the City of Mandurah and consultation with the developer about appropriate stormwater management approaches.
- Signage to promote WSUD and the protection of receiving environments.
- Ongoing commitment by the City of Mandurah to addressing community questions and concerns regarding pooling water and to explain the importance of this water retention in protecting wetlands and the Peel-Harvey Estuary.

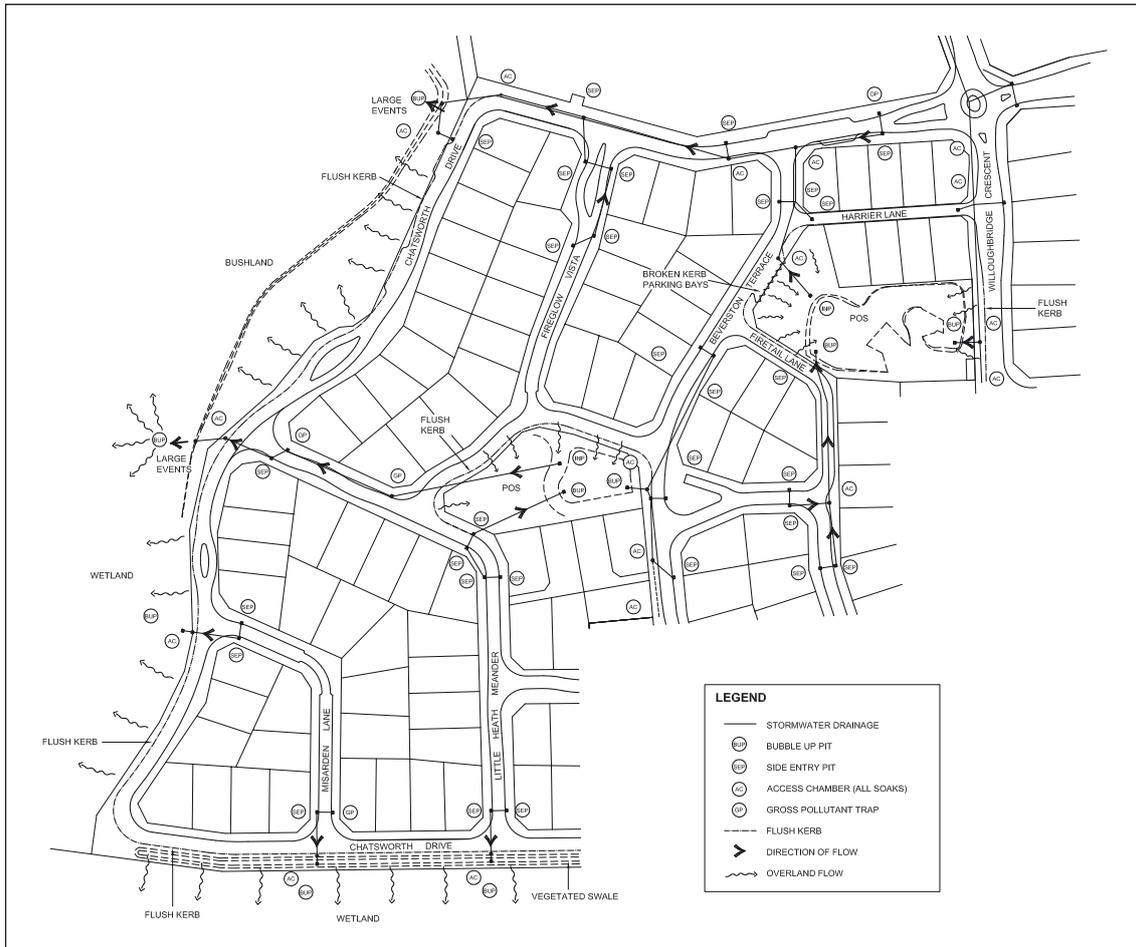


Figure 2. Drainage plan for Bridgewater South Estate inline storage and treatment system. (Source: Department of Water.)

**Piped system:**

The piped system includes leaky access chambers that act as soakwells (these are side entry pits with a permeable base such as blue metal) to capture and infiltrate flows close to source. These chambers intercept small storm events. In several of the sub-catchments, higher flows are conveyed by the piped system to bubble-up pits located in parks (Figure 3).



Figure 3. Bubble-up pit located in a park. (Photograph: Department of Water 2006.)

**Public open space (POS):**

Grassed parks in the subdivision POS have been contoured to capture and detain flows (see Figures 4

and 5). The levels of the inlets and outlets to the detention areas have been designed to capture up to the 1 year ARI event and promote overland flow and infiltration. Levels have been designed to prevent water pooling for longer than 72 hours. Landholders are aware of the parks' role in stormwater management due to public education and signage installed by the City of Mandurah.



*Figure 4. A multiple use park incorporating a landscaped stormwater detention area. (Photograph: Department of Water 2006.)*



*Figure 5. Grassed swale and bubble-up. (Photograph: Department of Water 2006.)*

The POS areas have been developed to provide both recreation and stormwater management functions. Roads have been designed to carry the 100 year flood. At-source infiltration measures, in-transit detention areas and the use of the road system for conveyance of major flows have removed the need for pipes in some road sections and resulted in smaller pipes being required throughout the development. This provided cost savings to the developer in terms of reduced materials and installation outlays.

#### ***Overland flow:***

Where possible, overland flow has been utilised in preference to a piped system to slow flows and provide some treatment of stormwater. This approach has been implemented on the boundaries of parkland where runoff flows off the road, over flush kerbing and through grassed areas, which promotes deposition of particulate matter (see Figure 6). Overland flow at the downstream end of catchments has been achieved through the use of bubble-up pits from small piped catchments (see Figure 7). In the south-west corner of the subdivision, disconnection is achieved through the construction of a swale, which captures runoff from the adjacent road surface and piped areas. If the storage capacity is exceeded, the swale is designed to create a broad weir effect, encouraging lateral overland flow.

#### ***Disconnection:***

Disconnection in the stormwater system has been achieved through providing infiltration points in the piped system for small events, directing runoff into parks for medium events and using overland flow paths to convey large events. There are no pipes discharging into the adjacent water bodies. The development has been broken into five sub-catchments. This decentralisation of the drainage network assists in managing stormwater by decreasing the concentration of flows and pollutants.

#### **Results/achievements**

The development of the Bridgewater South Estate catchment has avoided direct discharge of stormwater into the adjacent estuary and wetland, whereas a traditional drainage planning approach would have resulted in piped discharge to these sensitive water bodies. This has been achieved through a catchment approach to stormwater management, where numerous small management measures have been put in place throughout the catchment to manage stormwater close to source.



Figure 6. Flush kerbing to allow dispersion of road runoff into adjacent parkland. (Photograph: Department of Water 2006.)



Figure 7. Bubble-up pit located within a swale at the downstream end of the catchment. (Photograph: Department of Water 2007.)

The measures implemented individually could not have successfully managed the stormwater for the catchment. However, the cumulative impact of the combination of several measures has ensured that only large events reach receiving water bodies via overland flow.

The outcomes of the stormwater management approach implemented in this development demonstrate the potential environmental benefits, as well as cost savings that can be achieved. Distributing management measures throughout the catchment and utilising overland flow paths, instead of collecting and conveying flow in one centralised system, can result in significant reductions in piping and associated infrastructure requirements.

Located close to the high value environments of the Ramsar recognised Peel-Harvey Estuary and a Conservation category wetland, the Bridgewater South Estate development required a sensitive approach to stormwater management. As the Peel-Harvey Estuary is an iconic landscape that is valued by the community, actions to protect its qualities were supported by residents. Community awareness about the importance of protecting the estuary had been raised by their experiences of the major adverse impacts caused by water quality degradation, such as fish kills and algal blooms.

The levels of bubble-up pits and overflows in the stormwater system required some minor adjustments to fine tune retention and pooling times in the detention areas. These adjustments have resulted in a system that performs well and is acceptable to the community.

### **Acknowledgments**

Information and feedback provided by Mr Grahame Heal, Manager Infrastructure and Services, City of Mandurah.

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## **Beachridge Estate, Jurien Bay**

### **Project description**

Beachridge Estate is the first stage of development of a 2000 hectare coastal bushland estate south of Jurien Bay in the Shire of Dandaragan. Jurien Bay experiences a Mediterranean-type climate, with hot, dry summers and cool, wet winters (Figure 1). The site is characterised by sandy soils and a shallow water

table. Groundwater flows in a westerly direction to the ocean, into the Jurien Bay Marine Park. The Hill River bounds the development to the south. Pre-development, there were no surface drainage lines on the site because all stormwater infiltrated in the highly permeable sands, resulting in no runoff.

Developers have maximised the hydrologic benefit provided by the sandy soils and achieved a drainage system that avoids the use of pipes. This approach has resulted in stormwater from the majority of rainfall events infiltrating at or near its source. This departure from traditional drainage techniques has been combined with non-structural controls, such as incentives for appropriate landscaping and on-site water storage, further reducing the volumes and impacts of runoff from the site.

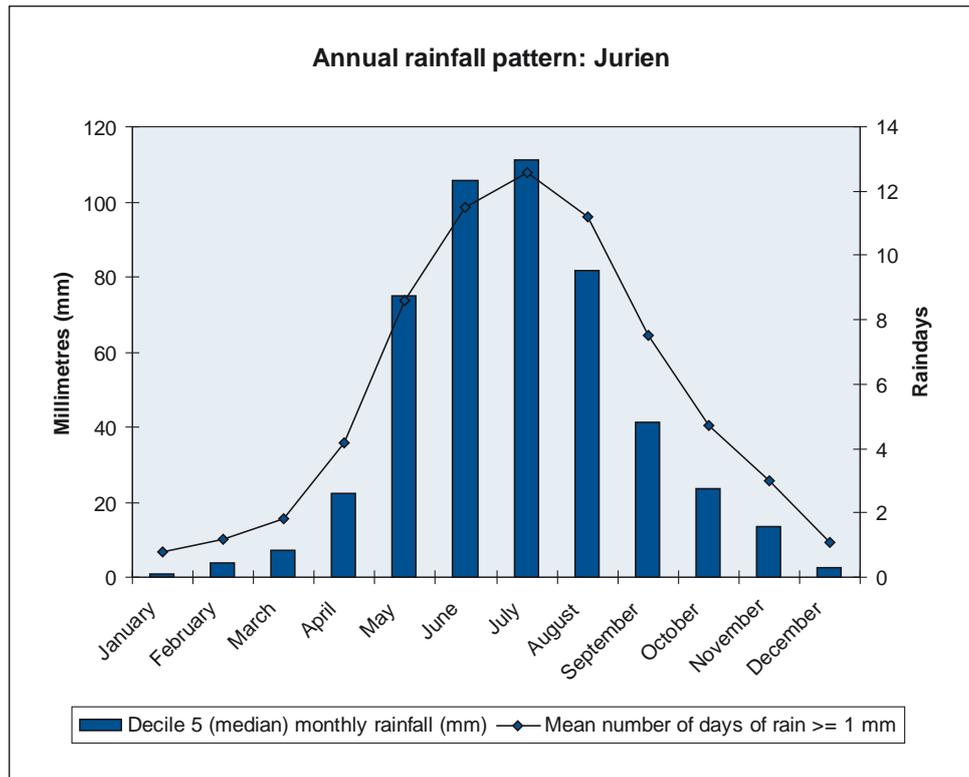


Figure 1. Jurien Bay annual rainfall pattern. (Source: Bureau of Meteorology 2007.)

### Approaches implemented

Due to the high capacity of the soil to infiltrate stormwater, swale systems have been used as the primary structural control method to manage stormwater in this development. The following structural and non-structural controls have been used on the site:

#### Structural:

- swales planted with local native vegetation
- a disconnected drainage plan, where large events are directed to a series of decentralised ‘nodes’ (Figure 2)
- roads graded to direct flow to public open space (POS) for greater than 10 year ARI events

#### Non-structural:

- rainwater tank rebates
- water conservation landscaping
- community education, including provision of local native plants species lists to landowners
- limited turf in POS

- reduced dwelling setback (3 m) to minimise front yard areas
- covenants in place to prevent planting of non-indigenous vegetation in front yards

Landscaped drainage swales built in road medians (Figures 3, 4 and 5) remove the need for traditional sumps and pipes by providing detention/retention opportunities high in the catchment, before flows and potentially associated pollutants are collected and concentrated. Slowing the movement of water promotes infiltration in the highly permeable underlying coastal sands. The aim of the design was to maintain the pre-development catchment hydrology by returning water to the environment as close to its source as possible, while preventing flooding of the urban area.



Figure 2. Overall drainage plan for Beachridge Estate. (Source: SKM 2007.)



Figure 3. Swale concept plan from the Water Management Plan. (Source: MGA Town Planners 2003.)

The swales have been designed to accommodate stormwater from up to the 10 year ARI rainfall event. Flows in excess of this event are directed by overland flow paths to storage areas in public open space for retention, detention and infiltration. The design of the swales has been based on calculations of runoff from hardstand areas, such as roads and pavements, as stormwater from residential lots and parkland areas is retained on-site and does not runoff to the swale network.

Swales are covered with coarse mulch and vegetated with indigenous plant species to avoid the need for irrigation after an establishment period of two years (Figures 4 and 5). This reduces the consumption of water



*Figure 4. Newly constructed and mulched swale. (Photograph: Ardross Developments 2004.)*



*Figure 5. Swale with established native vegetation. (Photograph: Ardross Developments 2007.)*

resources traditionally associated with maintenance of turfed median strips. Additionally, maintenance of the native vegetation does not require the use of fertiliser, which consequently removes one of the sources of nutrient inputs that is commonly associated with urban environments.

Plant species were chosen based on their growth form (low shrub and groundcover) and water requirements. The indigenous plants have deep root systems that assist with maintaining the porosity of swale areas to promote infiltration through the root zone.

Temporary barriers erected around the swales during the construction phase protected the swales from sediment associated with greenfield development, such as from construction and wind erosion of disturbed topsoil. The physical barrier also protected the swales from vehicle access, which can damage the swales and compact the substrate, resulting in decreased infiltration rates.

Roads have been graded to direct flows in excess of the swale capacity to the designated storage node for infiltration (Figure 2).

### **Results/achievements**

The stormwater management system at Beachridge Estate has been in place since 2003 and has achieved the design objectives for stormwater quantity management. All storm events to date, which have been small to moderate, have been successfully infiltrated within the swales.

In planning this project, the Shire recognised an innovative approach was required for development so close to the highly valued coastal environment. Although there were concerns about the function of a system without pipes and potential impacts of stormwater infiltration, for example damage to infrastructure, the benefits offered by the proposed stormwater system outweighed the perceived risks.

The approach to stormwater management implemented at Beachridge Estate demonstrates the ability of non-traditional systems to perform flood protection, enhance aesthetics and more sustainably manage surface and groundwater resources. Vegetation has established well and is protected by temporary low barriers from wind erosion and vehicular access. The vegetation and mulch has successfully stabilised the slopes of the swales.

The construction of narrower roads has provided an additional benefit of encouraging reduced traffic speeds, and therefore improved safety and liveability of the development for pedestrians.

## Challenges/lessons learnt

Stabilisation is required to prevent undermining of hardstand surfaces in areas that will experience higher flows, such as swale end points. Even though flow is dissipated, there has been some erosion at the ends of the swales, where the runoff is concentrated more than along the lateral edges of the swales. The developer is addressing this issue by further armouring (stone-pitching) and planting.

The alternative road layout of swales in the road median and street trees along roadside parking has reduced access to driveways and caused some problems with backing of boat-trailers and caravans, which is a significant issue in an area of high boat ownership.

## Acknowledgments

Information and photos provided by David Kasehagen, Ecoscape, and Daniel Skerratt, Ardross Group of Companies. Diagrams provided by Vikki Wardley, SKM. Information provided by Craig Tuesley, Department of Water, Geraldton.

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## Boronia Ridge Estate, Walpole

### Project description

Boronia Ridge Stage 2A is a subdivision at Walpole in the Shire of Manjimup that was completed in 2002. The Walpole Inlet receives runoff from the development. Like most southern coastal towns in Western Australia, Walpole has a climate where regular rainfall is expected even during the summer months (Figure 1). In southern coastal areas, the winter peak rainfall is less than in the south-western coastal areas and the summer rainfall is higher and more uniform. This is unlike sites further to the north on the coastline, such as Perth.

Due to the more uniform year-round rainfall, a well-established perched groundwater pattern has developed over the site. Climatic and geological conditions have led to the formation of the palismont and palislope wetland types as identified by Semeniuk (1997). These landforms were investigated and found to be the result of water perching over an area of shallow laterite or 'coffee rock', which sustained a vegetation community with wetland properties. The high perched water table was a dominant design consideration at the site. It was important that the stormwater management design did not artificially lower or alter the flow of the perched water table. Installation of services, such as sewers, was designed so that they did not act as subsoil drains across the site slope.

An assessment of the soil profile at the site found moderately to highly permeable sandy surface soils overlaying impermeable or lower permeability clayey subsoils at varying depths. This clay layer contributes to the formation of the perched water table. Shallow infiltration systems were considered suitable in areas with deeper, sandy surface soils. In areas where clayey soils were at the surface, then alternative stormwater management measures, such as rock armoured stilling pools to dissipate flows (Figure 10), were implemented.

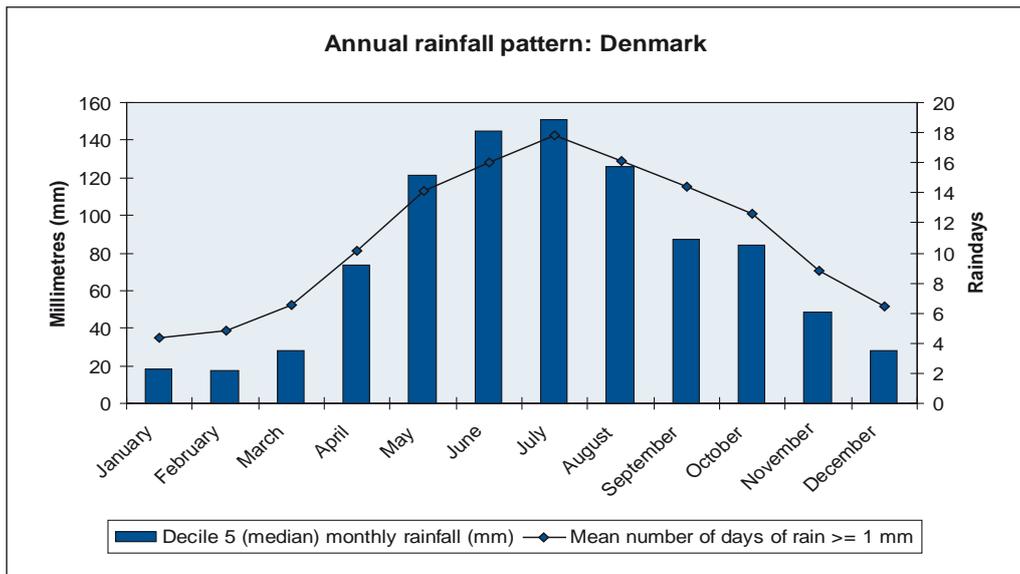


Figure 1. Denmark annual rainfall pattern. (Source: Bureau of Meteorology 2007.)

The year-round rainfall experienced in this region means that less emphasis needs to be placed on treating the first flush events that occur in the drier areas of the State. First flush rains generally carry higher pollutant loads that have built up in urban catchments over the dry season. In regions where year-round rainfall occurs, it is believed that these pollutants are flushed more regularly and so there is less of a concentrated load in the first flush rains. In the southern coastal region, pollutants mobilised by the first major rains of the season are still significant and must be addressed, but it is more important to develop stormwater management systems that will function effectively year-round.

### Approaches implemented

The best management practices introduced in this stage of the subdivision were based on knowledge gathered from earlier stages, site investigations undertaken and the latest practices and principles of WSUD. The implemented stormwater management system consisted of the following structural (Figure 2) and non-structural techniques:

#### Structural:

- kerbed roads elevated above natural surface levels, to not interfere with subsurface flows
- side entry pit collection systems that bubble-up into adjacent detention areas (Figure 3)
- flow retention and detention in soakwells and swale systems capturing up to the 1 in 1 year ARI event
- piped conveyance system for flows exceeding the 1 in 5 year ARI event (Figure 4)
- extended detention basins and flow dissipation structures at the end of each piped system (Figures 9 and 10)

#### Non-structural:

- maintenance of the stormwater system to ensure effective operation of the BMPs

The stormwater management approach that has been developed for this site relies heavily on infiltration of stormwater as close to its source as possible, to maintain the pre-development hydrology of the catchment. Infiltrating stormwater at or near its source has minimised the impact on the water balance of the perched water table system. The at-source treatment of stormwater also reduces the transfer of any pollutants associated with urban development to the final receiving water body, the Walpole Inlet. No single BMP

could be applied to this site to solve all of the stormwater management issues; rather an integrated series of BMPs was required to suit the conditions.

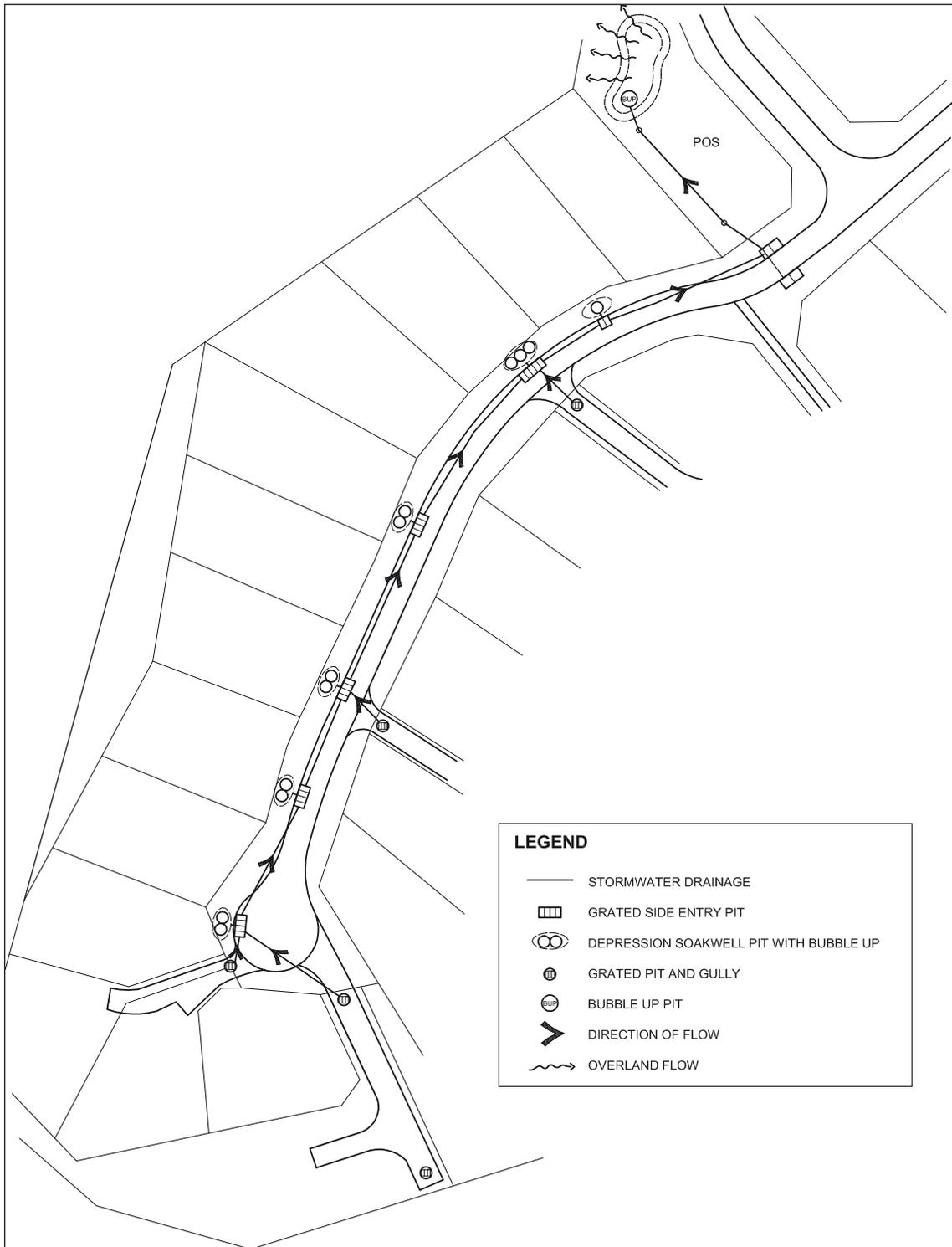


Figure 2. Boronia Ridge drainage plan. (Source: Department of Water.)

**Lot-scale stormwater management:**

Impervious property crossovers were built with flush kerbing so that runoff sheets on site. A series of soakwells, with linked high level overflows, were used when site constraints prevented overland flows. There is no direct flow into the foreshore reserve.



Figure 3. Side entry pit and bubble-up located within mulched detention area. (Photograph: TME 2003.)

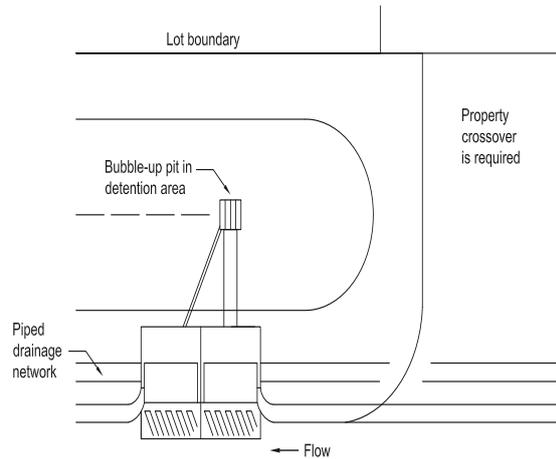


Figure 4. Plan view of the pipe network with bubble-up connection to the piped system. (Source: TME 2003.)



Figure 5. Soakwell construction. (Photograph: TME 2003.)



Figure 6. Construction of side entry pits to capture road runoff and divert it into soakwells that have bubble-up lids and are located within a detention area. (Photograph: TME 2003.)

### **Infiltration:**

In a conventional side entry pit system, stormwater is collected and transferred into a piped system for direct conveyance to the downstream stormwater network or receiving environment. At Boronia Ridge Estate, kerbed roads are used to collect and channel road and verge runoff to the side entry pit collection zones. These pits are used to capture flows and transfer them directly to a soakwell that is located in a detention area within the verge, as shown in Figures 3 and 4. The pit and soakwell systems are located at regular intervals to ensure capture and retention of minor events as close to source as practical (Figure 2).

The soakwells directly infiltrate stormwater into the surrounding permeable surface soils. The soakwells are sized to capture up to the 1 in 1 year ARI event, which effectively captures approximately 99% of all stormwater flows. The stormwater management system is very simple but highly effective at trapping low flows and infiltrating them at-source, hence minimising any impacts on the subsurface hydrology of the site. Locating the soakwells within detention areas allows additional infiltration and storage capacity of stormwater. Construction of the side entry pit and soakwell system is shown in Figures 5 and 6. The detention areas also act as capture zones for runoff from the urban lots and help direct this runoff into the piped system (see Figure 7).

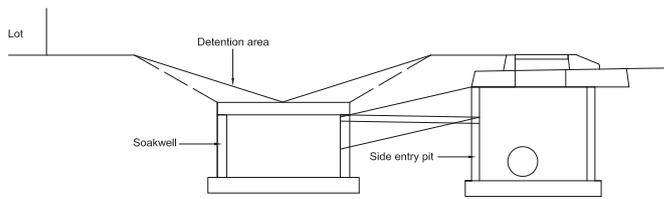


Figure 7. Central drainage linked to soakwells and detention area. (Source: TME 2003.)



Figure 8. Streetscape of constructed system. (Photograph: TME 2003.)

Flow that exceeds the capacity of the detention area overflows into a second side entry pit, where it is directly conveyed by a piped system into a downstream stilling pool prior to overland flow. The piped system is designed to convey up to the 5 year ARI event, and larger events are conveyed within the road reserve. To ensure that the detention area does not remain permanently inundated and create a maintenance problem for the Shire, a small trickle pipe was installed just below the surface level of the detention area to slowly release any excess water back into the piped system connected to the second side entry pit.

The detention areas and road reserve areas have been covered with mulch (see Figure 8) produced from the vegetation cleared from the site. The mulch enhances capture of surface runoff and improves the ability of vegetation to re-establish on the verges. Mulching has also substantially reduced the initial impact of the cleared road verges on the site by protecting these areas from erosion and improving the aesthetics of the development area.

The detention areas were designed to be disconnected so that flow concentration and potential erosion by overland flow in the verges did not occur. Road pavement levels were designed so that excavation during construction was not required in areas that may influence the subsoil flow of water. The roads were designed and constructed to sit above the natural surface levels wherever possible.

#### ***Flood management:***

Flows in excess of the 5 year ARI event are conveyed along the kerbline of the road surface to the downstream end of each sub-catchment. An extended detention basin is located at the downstream end of the eastern catchment (Figure 9) and a flow dissipater has been built at the end of the south-western catchment (Figure 10). The flow dissipation structure captures end-of-system flows, reduces their velocity and then discharges via sheet overland flow over a low weir into the existing adjacent wetland vegetation. The existing vegetation at the outlet further reduces flow velocities, prevents erosion and treats stormwater. This system has worked very well, with no scour or silt transfer observed at the outlet. There is no direct discharge to the foreshore reserve or wetland areas from any of the elements of the stormwater system.

The flow dissipation structure is an effective means of controlling end-of-system flows, requiring only a small land area and minimising any adverse impacts.

The detention basins were designed with a maximum 1 in 6 bank slope and a low profile to minimise the visual impact on the surrounds. However, the gentle bank slope and shallowness of the basin profile, which results in requiring a larger surface area, had to be balanced with the need to minimise clearing of vegetation.

#### ***Maintaining subsurface hydrology:***

Using the knowledge gathered from the previous stages of development, it was necessary to ensure that service trenches did not act as de-facto subsoil drains that would lower or alter the subsurface flow patterns. Where the services were laid in permeable sandy soils they will have little impact on the subsurface flows,



Figure 9. Extended detention basin construction in Stage 2. (Photograph: TME 2003.)



Figure 10. Flow dissipation structure at outlet of sub-catchment. (Photograph: TME 2003.)

but where they were laid in low permeability or clayey soils then some modification to the flow patterns may occur. In these instances, impermeable clay plugs were installed in the service trenches to prevent longitudinal flow along the trenches. The spacing and location of these plugs were set depending on the soil conditions encountered in each trench, and were assessed as the services were being laid on-site. The clay plugs were required to extend to the depth of the low permeability material that was removed and replaced with sand backfill for services installation.

#### **Maintenance:**

Ongoing maintenance is essential for most BMPs to continue to manage the quantity of flows and to effectively remove contaminants from stormwater. The stormwater management system proposed in this development will be readily maintainable by the Shire in conjunction with their routine maintenance practices. This stormwater system will require cleaning out of the soakwells and sweeping of all roads at least once per year. Annual inspection of the extended detention basin, flow dissipation structure, soakwells and detention areas will also be required and any cleaning or repairs be undertaken as necessary.

#### **Results/achievements**

When Boronia Ridge was developed in 2002, it was unique in WA for pioneering the integration of an at-source infiltration system with a piped drainage system to convey larger events. The stormwater management system has performed well during its four years of operation. The experience gained in this stage of development has been extended to the design of the final stages that are due to be constructed in 2007. The success of this system has led to greater acceptance of similar stormwater management systems in subsequent developments by the Shire. Contingency measures implemented in the Boronia Ridge Stage 2 development, such as a piped system to accommodate overflow from greater than 5 year ARI events, provided reassurance to the Shire regarding their concerns about systems that were fully reliant upon infiltration on-site.

Good vegetation regrowth has been observed and there are no noticeable signs that the hydrology of the area and its associated vegetation have been impacted.

#### **Challenges and opportunities for improvement**

Similar projects in the future could be improved by designing a below-ground infiltration device that is cost efficient, but takes up less of the road verge than required for the installation of circular soakwells. Linear infiltration trenches may be more suitable where land space is a constraint.

Overflows onto private property have also been identified as an issue. While this has not caused a major problem or any property damage, residents who are not familiar with WSUD have voiced concerns about

water that does not drain away immediately. Temporary pooling of water in some areas following greater than 1 year ARI events forms part of the designed detention function of the system. The Shire has identified that education of potential residents is crucial to the effective management of the stormwater system adopted in the subdivision. Water sensitive building design and lot-scale water management must also be implemented as part of the catchment approach to stormwater management.

Grouted riprap was used around the banks of the dissipation pool. However, grouting does not allow vegetation and in-stream habitats to establish on the banks, and loose rock riprap would be recommended in the future. The design of the system could also have been enhanced by increasing the permeability of the base of the dissipation pool (designed and constructed with lined bases) to allow for revegetation and increased bioretention and treatment of stormwater prior to infiltration or overflow downstream.

### **Resources**

No specific cost comparisons were undertaken at the design stage, but any additional costs of the system were considered minimal compared to a conventional fully piped system. This was because cost savings were achieved through the use of source controls, such as soakwells, resulting in smaller infrastructure requirements at the downstream ends of the sub-catchments. The soakwells were the only significant additional cost to the stormwater management system constructed in this development.

### **Acknowledgments**

Information and photos provided by Mr Wayne Edgeloe of Thompson McRobert Edgeloe Pty Ltd. Information also provided by Mr Graham Lantzke, Engineer, Shire of Manjimup. The Shire Engineer at the time of the development was Mr Gavin Harris. The developer was Mr Graeme Robertson of RC Developments.

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## **Lake Goollelal, Joondalup, Swan Coastal Plain**

### **Project description**

The City of Joondalup is located in the northern suburbs of Perth, Western Australia. The average rainfall pattern for the closest weather station with suitable data is shown in Figure 1. On the eastern side of the City is the Yellagonga Regional Park, which is 1,400 hectares encompassing the wetlands of Lake Joondalup, Lake Goollelal and Beenyup and Walluburnup swamps. These wetlands are surface expressions of the Gnangara Mound, an important groundwater resource and water supply for the Perth metropolitan area. There are approximately 20 existing stormwater outfalls that discharge directly into Lake Joondalup and Lake Goollelal, allowing significant amounts of particulate matter and pollutants to enter the wetlands system. These pollutant inputs result in increased nutrient loading, algal blooms, litter and sedimentation problems and increased midge and mosquito populations.

Historically, the lands surrounding Yellagonga Regional Park were used for market gardens and horse agistment, which resulted in significant nutrient enrichment of the catchment. The area is now predominantly

used for residential development. Urban development is a significant factor that has caused an increase in peak stormwater flows and runoff volumes, and the deterioration of stormwater quality and environmental amenity. These issues have been ongoing for several years and whilst the City has adopted a policy for new developments to prevent direct stormwater discharge into wetlands, the existing stormwater systems need to be addressed.

Lake Goollelal is part of Bush Forever Site Number 299 and is a Conservation category wetland that is protected under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*. The groundwater

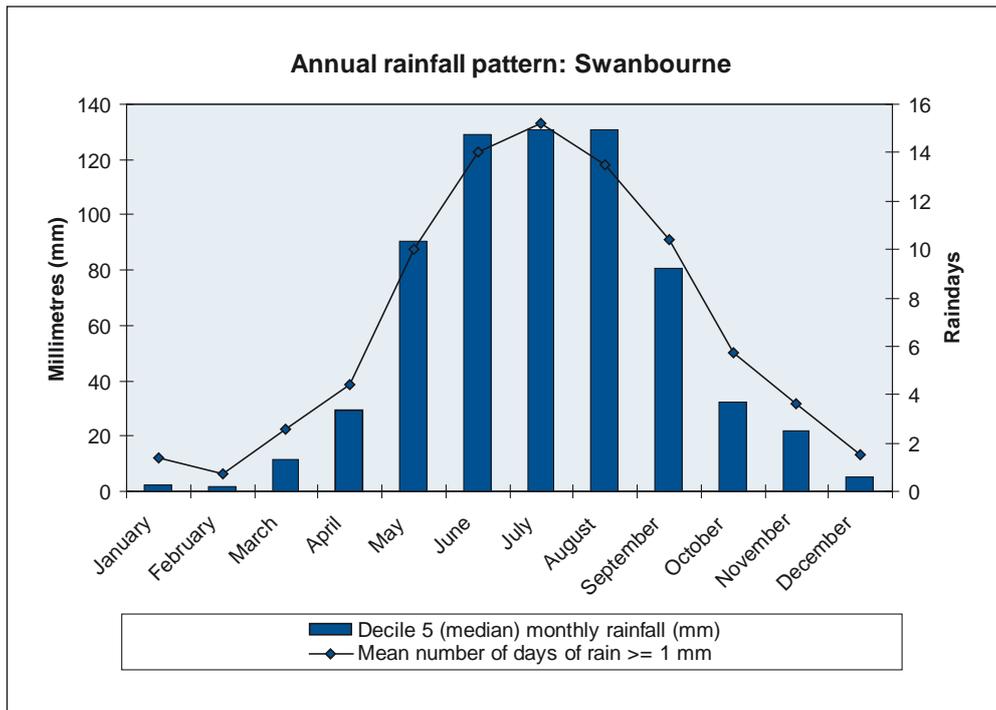


Figure 1. Annual rainfall pattern, Swanbourne. (Source: Bureau of Meteorology 2007.)

flow is in a westerly direction and the soil type is highly permeable Spearwood Sands. Lake Goollelal is located within an area with a high risk of acid sulphate soil disturbance.

A review of the environmental and engineering aspects of the various stormwater outfalls associated with the Yellagonga Regional Park was undertaken in 2003. From these investigations, an overall strategy was prepared with the community and other stakeholders. The strategy proposed retrofitting the various outfalls entering the Regional Park lake system with inline stormwater treatment measures.

Outfall Number 21 is located on the southern extreme of Lake Goollelal, near the arterial road of Hepburn Avenue. The catchment area of Outfall Number 21 is approximately 38 hectares with a mixture of land uses, including natural bushland, parks and reserves, commercial uses, a petrol station and residential development. Stormwater pollutant characteristics are largely determined by the land uses within the catchment. Due to its catchment characteristics, this outfall was selected to be studied in the development of a strategy to improve the water quality of the Yellagonga Regional Park Lake System. A conventional stormwater pipe system that was constructed when the subdivision was developed in the 1970s discharged directly into the lake. The principal source of stormwater discharge and associated pollutants is the impervious surfaces, namely the road reserves and commercial developments, which account for 14% of the catchment area. Approximately 86% of the catchment consists of residential housing and vegetated areas. The highly permeable sands allow the majority of lot stormwater runoff to be infiltrated. Residential roofed and paved areas drain into on-site soakwells.

## Approaches implemented

In order to protect the receiving waters of Lake Goollelal, the following structural and non-structural stormwater management measures have been implemented in the catchment area of Outfall Number 21 (Figure 2):

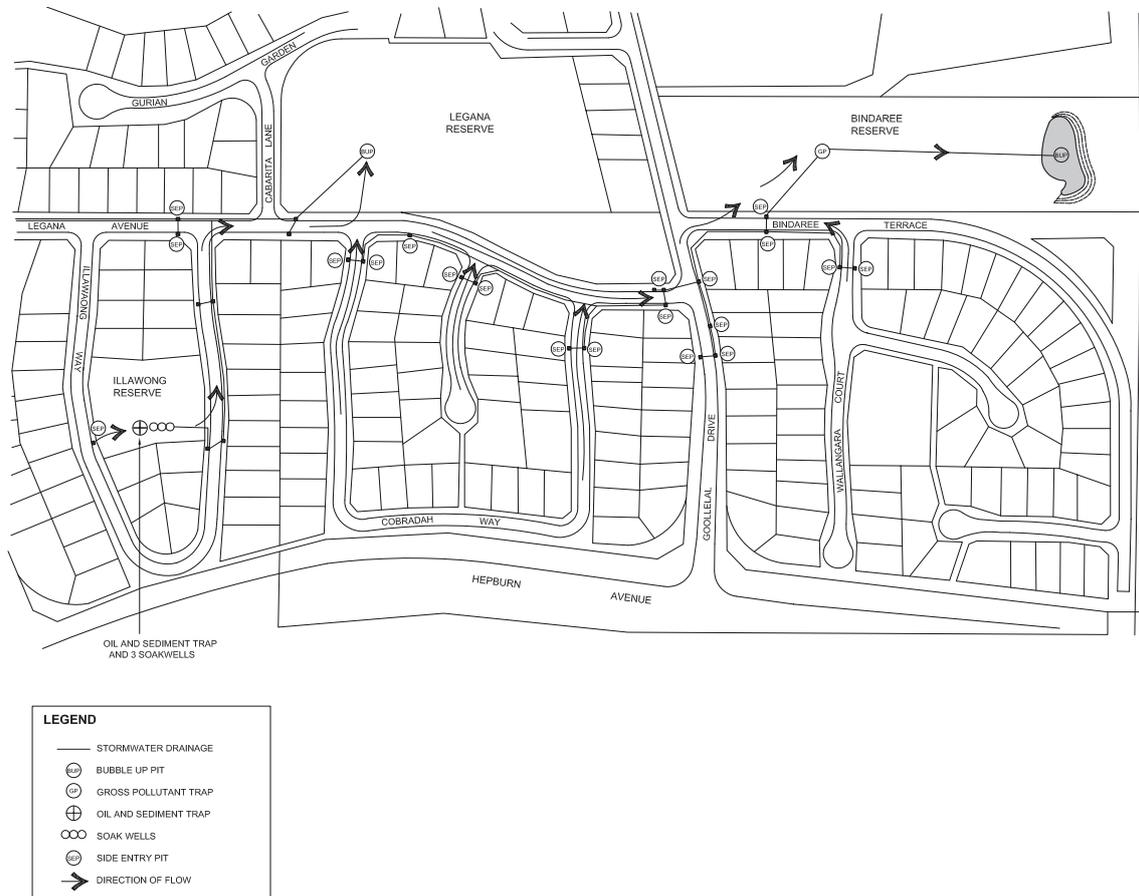


Figure 2. Drainage schematic of the Lake Goollelal area, Joondalup. (Source: Department of Water.)

### Structural controls:

The structural treatment measures implemented in this project are:

- gross pollutant traps
- soakwells and infiltration areas
- bioretention basins
- disconnection of the stormwater system, i.e. isolation of receiving waters from sections of the catchment

### Non-structural source controls:

Non-structural controls are important to minimise the source of pollutants, however it can be difficult to enforce these controls or to engage the community in their implementation. For this reason, a combination of structural and non-structural controls is highly recommended to achieve best practice stormwater management. The following three non-structural controls are considered essential to this project:

- community education and awareness for stormwater management (see BMPs 2.3.2, 2.3.3 and 2.3.5 of Chapter 7, and Chapter 8)
- best management practices on construction and land development sites (see BMP 2.1.1 in Chapter 7)

- best management practice municipal operations such as street sweeping, drainage maintenance, maintenance of parks and reserves, graffiti removal and cleaning activities (see BMPs in Section 2.2 of Chapter 7)

These measures were considered suitable to reduce potential stormwater contaminants identified in the catchment, including:

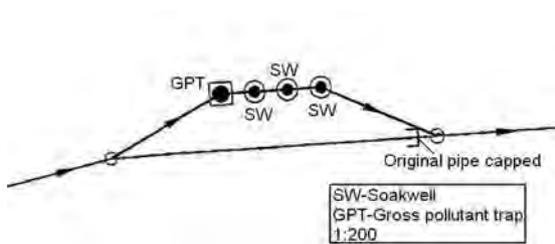
- gross pollutants, such as wrappers, cigarette butts, containers and bottles
- hydrocarbon pollutants from the petrol station and road runoff
- nutrients and sediments from residential areas and parks and reserves
- heavy metals in road runoff due to vehicle brake and tyre wear and fuel combustion

#### ***Sediment and litter control:***

Gross pollutant traps (GPTs) are primary treatment measures that retain litter and coarse sediments by physically screening stormwater and encouraging sedimentation within a chamber or basin. GPTs are suitable for retrofitting existing piped drainage systems. GPTs are usually most cost effective when placed in the stormwater treatment train at-source to target areas with potential high pollutant runoff. However, in retrofitting situations this may not always be feasible due to site constraints, such as land availability or the layout of the stormwater network.

There were two locations in the catchment for Outfall Number 21 that were identified as being optimal for GPT installation. The first location is within the park at Illawong Way. The upstream catchment from this location is predominantly commercial areas along Moolanda Boulevard and includes a petrol station. A GPT with additional oil storage capacity capable of trapping gross pollutants, such as wrappers, cigarette butts, containers and bottles, as well as hydrocarbons, was selected as these pollutants were likely to be generated from this sub-catchment.

Runoff is treated by this GPT before flowing to a series of soakwells (Figure 3). Any overflow continues downstream to an infiltration basin located in the lower catchment (see Figure 2). This GPT reduces the maintenance requirements of other BMPs, as well as forming the first stage in the treatment train process.



*Figure 3. GPT and soakwell configuration at Illawong Way Reserve, Joondalup. (Source: Connell Wagner 2003.)*

The second location selected for installation of a GPT is on Bindaree Terrace, where a 900 mm diameter stormwater pipe enters Bindaree Park. A basic GPT was adequate to trap coarse sediments and litter, which were the main potential pollutants being generated from the residential area and parks in this sub-catchment. This GPT provides pre-treatment of stormwater prior to flowing into an infiltration/retention basin and ultimately the receiving water body downstream.

#### ***Soakwells:***

Soakwells enable stormwater storage and promote infiltration, hence reducing stormwater runoff volumes and velocities downstream and allowing entrained pollutants to be trapped. Off-line soakwells were installed downstream of the GPT within Illawong Way Park. The three soakwells capture and infiltrate low flow events. A high level overflow pipe is connected from the soakwells to the existing stormwater system to provide flood protection for the catchment.

### ***Disconnection:***

Much of the upper catchment has been ‘disconnected’ from Lake Goollelal. This means that stormwater that would have previously directly flowed untreated into Lake Goollelal is now diverted. Stormwater from the commercial areas receives treatment through the GPTs and soakwells. It then bubbles up into an overland flow channel, which further treats the stormwater and conveys it into a bushland area in the park on Legana Avenue (Figure 2).

### ***Infiltration basins:***

Locating the GPT upstream of the infiltration basin reduces the impacts of sedimentation and clogging of the basin. Cleaning out trapped sediment and litter from the GPT is easier and cheaper than having to remove these pollutants from the basin. This is a benefit to the asset manager and contributes to the sustainability of the maintenance regime to ensure the stormwater system continues to function effectively.

Dry infiltration basins and swales were considered the most appropriate stormwater treatments for this catchment as they allow entrapment of nutrients within the substrate, prior to recharging the underlying groundwater. The highly permeable Spearwood Sands of the area are also well suited for infiltration.

The infiltration basin is designed to retain all storms up to the 5 year ARI event (Figure 4). If properly maintained, the basin will continue to reduce downstream runoff volumes and velocities and trap pollutants, thereby protecting Lake Goollelal (Figure 5). Bindaree Park basin has a high flow bypass connection to the original Outfall Number 21 to Lake Goollelal. This protects the basin from erosion and re-suspension of settled materials in large events. However, the piped bypass connection to the lake could be replaced with a vegetated overland flow channel to treat and reduce the velocities of high flows and increase disconnection from the receiving waters.



*Figure 4. Infiltration basin in Bindaree Reserve, upstream of Lake Goollelal, Joondalup. (Photograph: Department of Water 2006.)*



*Figure 5. Bubble-up pit located in Bindaree Reserve, Joondalup, being cleaned using a vacuum truck. (Photograph: Department of Water 2006.)*

The shapes of the infiltration basins were gently integrated into the surrounding landform to maintain the conservation value and landscape amenity of the Lake Goollelal area. The basins were built with depths of 1.2 to 1.5 m and gently graded banks between 1:4 to 1:6. The basins were designed with a length to width ratio of 2:1 and a high surface area to volume ratio to maximise infiltration capacity. Landscaping was done in context with the surrounding bushland and parkland area. The basin fringes were planted with vegetation endemic to the area and further revegetation is planned to mimic natural ephemeral wetlands.

In the planning phase, a constructed wetland was not considered the best treatment option for Outfall Number 21 due to the constrained and small catchment size. A treatment train approach using GPTs, swales and infiltration systems could achieve better water quality outcomes than a constructed wetland, while minimising construction and maintenance costs.

### ***Consultation:***

Consultation with the stakeholder groups that had an interest or were involved in managing the Yellagonga Regional Park was considered essential to the development and successful implementation of the strategy. Once the project had progressed to selecting specific treatments and developing preliminary designs, consultation was undertaken with the residents in the immediate vicinity of the area. The City of Joondalup received positive support from the community for the proposed stormwater treatments.

### **Results/achievements**

The treatment train approach that has been implemented to retrofit the Lake Goollelal catchment has optimised opportunities to manage stormwater within the existing available space and community requirements. The investment in investigating the catchment, strategically planning the project and undertaking community consultation has resulted in cost effective techniques being selected to best manage the pollutants from the contributing catchments.

The implemented stormwater management measures have achieved:

- no direct discharge from Outfall 21 to Lake Goollelal of flows up to the 5 year ARI event without receiving treatment;
- a reduction in the peaks and ‘flashiness’ of flows from the urban catchment; and
- integration of the stormwater management measures in public open space.

Maintenance practices are being monitored and evaluated to assess the required maintenance frequency and to fine tune the ongoing maintenance program. This is important to optimise the allocation of maintenance resources and to reduce the risk of BMP failure due to a lack of maintenance.

The treatment train approach trialled by the City of Joondalup to reduce the impacts of stormwater pollution from Outfall Number 21 on Lake Goollelal will be extended to address other outfalls discharging to this sensitive environment.

### **Challenges and lessons learnt**

At one of the bubble-up pit sites, overland flow has caused erosion and requires repair. Where flows have been directed to areas with bubble-up pits, further ‘soft engineering’ is required, such as the application of organic matting and revegetation, to stabilise overland flow paths. Loose riprap should be applied around the bubble-up pits to dissipate flow energy and prevent erosion. A defined flow channel that is stabilised with organic matting, revegetation and a series of rock riffles (loose rock check structures) could be built to further reduce flow velocities, increase detention in the channel and prevent erosion. These stabilisation works will reduce maintenance requirements in the long term.

Alternatives to the existing piped systems, such as leaky side entry pits and infiltration crates, could be explored to increase infiltration and disconnection in the catchment. Overland flow could also be implemented on a larger scale to increase detention, infiltration and treatment of stormwater. Due to the highly permeable sands, there are significant opportunities to extend these approaches within the catchment to further reduce pollutant inputs to Lake Goollelal.

Achieving a balance between the varying views, values and priorities of the community and the best solutions to achieve the water quality objectives of a project can be a challenge. The City of Joondalup incorporated the issues raised through the public consultation process into the stormwater management strategy for Lake Goollelal. For example, the shape and location of the detention basins were changed to address public concern about the potential impacts on local native vegetation. Designs can often be improved to achieve multiple benefits by incorporating other options or trade-offs identified through consultation with stakeholders.

The City of Joondalup has recognised that to implement the changes required to improve stormwater quality and the health of Lake Goollelal, collaboration between State and local government, as well as industry and community groups, is required. The development of an Integrated Catchment Management Plan incorporating stormwater improvement strategies is also an important tool in achieving best practice stormwater management.

### **Resources**

The cost for implementation of the pilot treatment works for Outfall Number 21 was approximately \$100 000. This included two GPTs, three soakwells, five bubble-up pits and an infiltration basin.

### **Acknowledgments**

Kym Hockley, Principal, Connell Wagner, and Peter Pikor, Manager Infrastructure Management and Ranger Services (previously), City of Joondalup provided information and endorsed this case study. David Djulbic, Director, Infrastructure and Operations, City of Joondalup, also endorsed this case study. Dave Mather, Coordinator Subdivisions/Civil Projects, City of Joondalup, provided additional information on the project progress.

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## 1.12 Acronyms

ARI	Average recurrence interval
ARQ	Australian Runoff Quality
ASS	Acid sulphate soils
ASR	Aquifer storage and recovery
BMP	Best management practice
DIA	Department of Indigenous Affairs
DEC	Department of Environment and Conservation
DoW	Department of Water
DWMS	Drainage and water management strategy
EPA	Environmental Protection Authority
EWR	Ecological water requirement
GPT	Gross pollutant trap
LSM	Litter and sediment management
MAR	Managed aquifer recharge
POS	Public open space
PRI	Phosphorus retention index
SMP	Stormwater management plan
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UWMP	Urban water management plan
WIN	Water Information Network
WSUD	Water sensitive urban design

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## 2 Stormwater Storage and Use

### 2.1 Rainwater Storage Systems

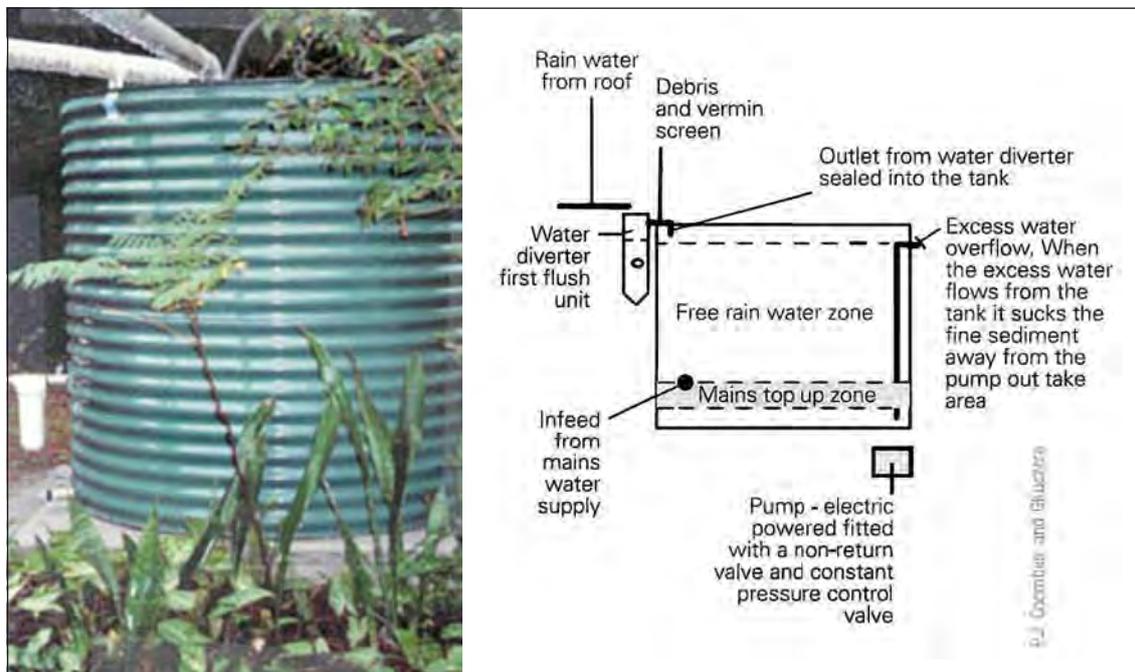


Figure 1. Rainwater tank components. (Coombes and Kuzcera 2001.)

### Background

At the lot scale, rainwater storage tank systems are an effective way of capturing stormwater for non-potable use (such as garden watering, toilet flushing, in washing machines and for car washing) and therefore helping to conserve scheme drinking water supplies. There are increasingly innovative designs which hold rainwater in a range of forms including bags, fences, walls and roof gutters, with these systems designed for different uses, volumes and aesthetic requirements. Slimline plastic or metal tanks are increasingly popular in urban areas due to the unobtrusive form of the tanks adjacent to or beneath buildings.

Rainwater storage systems can also be applied at a larger scale, for example high volume underground storage systems applied to capture runoff from paved or parking areas or the roofs of buildings. There are a number of new below-ground storage propriety devices that are designed for both roof water catchments and impervious surface catchments, such as hardstand areas. The storage systems are modular and their volumes can be anything from 5 kL to 5 ML. These devices have different filtration systems over the inlet for primary treatment and some have a secondary filter, depending on the quality of the runoff and the desired water use. A pump system returns the collected water to provide a non-potable supply for domestic, commercial, industrial and municipal buildings, such as sports centres and community halls. Collected stormwater could be used for irrigation, vehicle washing, art/water features, toilet flushing, cooling water systems and many other applications that currently use high grade potable water. Stormwater used for cooling water systems might have to be treated to a higher standard because nutrients and heavy metals in the water may cause slime formation and microbial growth, while suspended solids could cause blockages and fouling.

In high density urban areas, there is limited space for outdoor gardens, so roof water and stormwater-fed roof gardens or courtyard gardens are an attractive option for outdoor living space. In Western Australia,

these systems are a great opportunity to provide a water sensitive garden in urban environments. Plant species that require irrigation throughout the dry season will not be suitable due to the need for top up water.

Urban space designers can also use harvested stormwater as a feature in the landscape. However, emphasis should be placed on the ephemeral nature of our environment, so these features should be aesthetically pleasing with and without water. Use of groundwater and scheme water to top up water features over summer is not considered water wise or beneficial to the environment.

Rainwater tanks have primarily been used to provide an alternative water supply source and reduce scheme water consumption. However, in areas of limited infiltration (high water table, clay soils) they provide additional benefits of reducing catchment runoff (peak flow and volumes) from smaller rain events, which assists the post-development catchment to replicate its pre-development hydrology.

This BMP has good potential in a retrofitting scenario and can be applied in highly impervious built environments that may preclude the installation of other BMPs.

The quantity of water that can be detained in these systems will depend on the rainfall (amount and annual and seasonal variability). For large-scale harvesting schemes, the ecological water requirements of the catchment need to be considered in determining the volume of water that can be collected.

Unless adequately treated, collected rainwater is not reliably safe to drink due to the possibility of contamination from air-borne chemicals and microorganisms. Department of Health (2003) provides guidelines for urban rainwater collection. There may also be additional State and local government regulations and guidelines for the catchment that will guide the use of roof water and stormwater as a water source.

## Performance efficiency

In urban environments in south-western areas of WA, the Mediterranean climate means that a domestic rainwater storage tank is likely to be dry in the summer months, when garden watering demands are highest.

Using rainwater as an effective alternative source for garden watering is therefore considered limited.

Substantial reductions in the volume of stormwater runoff and the use of scheme water are achieved when stored rainwater is utilised for indoor use, such as washing machine use and toilet flushing (Figure 2). Use of rainwater for these purposes is supported by the Department of Health (2003). By connecting the rainwater storage system to indoor uses, the water is consistently used, freeing up space in the tank to capture more runoff.

Recent research by Fletcher et al. (2006) indicated that modelling stormwater harvesting in Brisbane and Melbourne for three land use scenarios (low, medium and high density) demonstrated that

stormwater retention and use on-site could help restore stormwater flows and water quality towards their pre-development level. In a study of eastern states capital cities, Coombes and Kuczera (2003) found that domestic rainwater tanks with capacities of 1 kL to 5 kL provide considerable reductions in scheme water demand and stormwater runoff. The average retention volumes available in rainwater tanks prior to storm events ranged from 0.25–0.7 kL for 1 kL tanks and 2.3–8.4 kL for 10 kL tanks in a study for Brisbane,

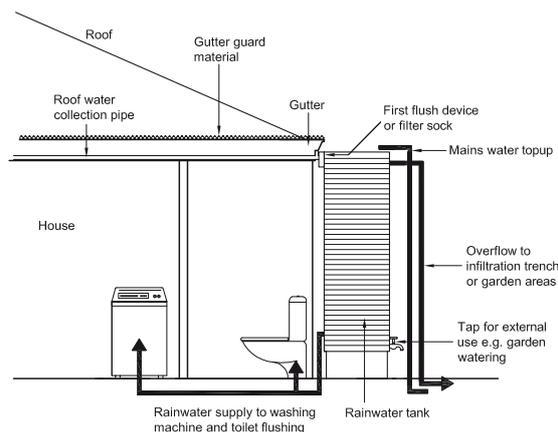


Figure 2. Elements of a domestic rainwater system (the rainwater treatment train).

Sydney, Melbourne and Adelaide. Areas with lower annual rainfall had the largest retention volume available in the tank due to internal use emptying the tank and less rainfall to refill the tank. The same study (Coombes and Kuczera 2003) found the annual scheme water savings ranged from 18–55 kL/year for a 1 kL rainwater tank, increasing to 25–144 kL/yr for a 10 kL tank. However, these results should be applied with caution to WA conditions due to considerable differences in rainfall seasonality between the different regions of WA and eastern Australia.

The *Wungong Urban Water Master Plan District Water Management Strategy* (JDA Consultant Hydrologists, CSIRO & GHD 2006) provides local estimates of scheme water savings through use of 3 kL rainwater tanks (integrated with scheme water) in the Armadale region as approximately 25% of in-house water use requirements, equating to 43 kL of annual demand.

## Cost

Costs of rainwater tanks can vary considerably depending on material, design, size and installation requirements.

With respect to capital costs, Coombes (2004) reports the cost of small rainwater tanks as ranging from:

- \$250 (Aquaplate Round) to \$340 (Polymer) for a 0.5 kL tank
- \$530 (Polymer) to \$1466 (Aquaplate Slimline) for a 2.4 kL tank
- \$1460 (Polymer) to \$7500 (Concrete) for a 9.0 kL tank

Coombes (2004) reports that small household pumps with pressure control cost \$340–\$620. Installation costs are highly variable, with full installation of a 4.5 kL above-ground tank ranging from \$1300 to \$3500 and underground installation an additional \$2000.

Based on costs sourced from WA manufacturers, GHD (2005) reports an estimated net cost for the installation of a rainwater tank system, including a 3.0 kL tank, installation and plumbing alteration costs, an automated controller and first flush device, as between \$1750 and \$2250. It is considered likely that reductions in this unit price would result from broad-scale use at a development.

GHD (2005) estimates annual maintenance costs as unlikely to exceed an average of \$75/year.

Economic benefits derived from the use of rainwater storage systems vary with the price of scheme water and the cost of augmenting scheme water supply systems. The magnitude of economic benefits for the community from widespread installation of rainwater tanks is dependent on real interest rates, the value of stormwater savings that result from the use of rainwater tanks and the installation costs of rainwater tank systems (Coombes 2004). Savings include a reduction in the drainage infrastructure that would otherwise be required to manage stormwater runoff and the reduction in provision of scheme water. Economic benefits of rainwater tanks should be considered in conjunction with the environmental benefits of reduced demand on rivers, dams and groundwater for scheme water sources, improved water quality in the receiving environment and reduced erosion and flood damage to receiving environments caused by flashy peak flows.

In terms of the unit cost of water, the *Guidance on Use of Rainwater Tanks* (enHealth Council 2004) reports that the estimated cost of rainwater from domestic tanks ranges from \$0.3/kL to \$14/kL. Based on GHD 2005 cost estimates and estimated annual scheme water saving of 43 kL for a 3 kL tank (JDA Consultant Hydrologists, CSIRO & GHD 2006), this equates to a unit cost of water of \$4.00-4.90/kL, based on a 6% discount rate and 20 year tank life.

## Design considerations

The design of a rainwater storage system is dependent on the intended uses of the water and the quality required.

There are several factors that contribute to water quality. At the lot, street and precinct scales, the quality of the stormwater will be highly dependant on the type of hardstand area and the use of the surfaces that the runoff flows over. In a lot-scale rainwater supply system, the quality of runoff from the roof depends on roofing materials, the types of materials deposited on the roof and the roof maintenance regime. Storage systems need to consider sediments and organic material as the major contaminants. Physical, chemical and biological processes can improve the quality of the roof water in the storage tank (Coombes & Mitchell 2006). Gutter guards, first flush devices and filter socks can limit the transfer of sediment and debris to rainwater storage systems. Mesh screens on inlets, outlets and overflow devices will exclude animals and mosquitoes and other insects from entering tanks, therefore minimising the risk of harmful microorganisms and disease-carrying mosquitoes entering the tanks. To prevent insects entering the tank, mesh should be no coarser than  $12 \times 12$  meshes/25 mm<sup>2</sup> (Department of Health 2003). Biofilms and sludge in the systems remove organics, microorganisms and metals from rainwater. Further treatment, such as running the water through a hot water system, also improves water quality.

A rainwater storage tank should be fitted with a first flush device or filter sock to limit the transfer of contaminants into the rainwater tank that may have built up between storm events. If collecting roof water, roof gutters should be installed and well maintained. It is recommended that gutter guards or screen mesh be used on buildings to reduce the amount of debris entering the storage tank and minimise the need for maintenance. Leaf diverters are also an important feature in roof water systems. Inline filters or UV disinfection may be used depending on the use of the water. Insect screens on inlets, outlets and overflow pipes and insect proof lids and inspection ports are required to reduce the risk of insect breeding, particularly mosquitoes. Gutters and pipework should be self-draining or fitted with drainage points.

For street- and precinct-scale stormwater storage systems, the maximum amount of water available to be retained and used should be calculated by comparison to the pre-development hydrograph or by appropriate ecological water requirement studies so that the environment continues to receive suitable flows to maintain ecological functions. Further advice should be sought from the Department of Water on any studies to determine ecological water requirements.

Across Western Australia, average rainfall, patterns of rainfall and water usage vary. These factors will impact the optimal storage sizing and performance efficiency of the system.

The harvested rainwater should be used for the purpose identified at the planning stage of BMP selection. Changing the purpose may need a review of the existing storage and treatment systems to ensure that the water quality and quantity available is suitable for the new intended use.

The location of the storage infrastructure will be dependent on aesthetic and space requirements for the chosen device. If the storage system is below-ground, site soil characteristics will need to be considered, in particular if there are salinity or acid sulphate soil concerns which would affect the integrity of the structure. Underground tanks will need to be maintained to ensure that surface runoff does not enter the tank. Refer to Department of Health environmental guidelines *Urban Rainwater Collection* (Department of Health 2003) and *Country Rainwater Collection* (Department of Health 2005), which require that storage tanks are made from materials that are suitable for storage of water for human consumption. There may also be local government policy requirements on pump noise.

The discharge of overflow water should be via overland flow or to an infiltration system.

## Design guidelines

The required capacity of a rainwater storage system will depend on the water use of the premises, as well as the rainfall and roof area. In areas with a scheme water supply available, roof water tanks with capacities of 1–5 kL are generally sufficient for domestic use. Smaller tanks can also provide water conservation benefits.

### Maximum Collection Volume

Maximum volumes of water that can be collected from a roof and annual rainfall are calculated using the formula (enHealth Council 2004):

$$\text{Runoff (litres)} = A * (\text{rainfall} - B) * \text{roof area}$$

Where:

‘A’ is the efficiency of collection. Values of 0.8–0.85 (that is, 80–85% efficiency) have been used (enHealth Council 2004).

‘B’ is the loss associated with absorption and wetting of surfaces, expressed in mm. A value of 2 mm per month (24 mm per year) has been used (enHealth Council 2004).

‘Rainfall’ is expressed in mm

‘roof area’ is expressed in m<sup>2</sup>

The maximum volumes of rainwater that can be collected from various areas of roof at a range of average annual rainfalls are shown in Table 1.

**Table 1. Maximum Volume of Water Collected Based on Roof Area and Annual Rainfall**

Annual rainfall (mm)	Maximum Volumes of Rainwater per Year (kL)*						
	Roof area (m <sup>2</sup> )						
	100	150	200	250	300	400	500
150	10	15	20	25	30	40	50
200	13	21	27	35	42	53	70
250	18	27	36	45	54	72	90
300	22	33	44	55	66	88	110
400	30	45	60	75	90	120	150
500	38	57	76	95	114	152	191
600	46	69	92	115	138	184	230
800	62	93	124	155	186	248	310
1000	78	117	156	195	234	312	390
1200	94	141	188	235	282	377	470

\* These volumes were calculated using a value of 0.8 for A and 24 mm for B (Source: enHealth Council 2004.)

## Tank Size and Security of Supply

Where a tank is to represent the sole source of supply, determining maximum volume is only the first step. The next step is to calculate the size of the tank needed to ensure that the volume of water collected and stored in the tank will be sufficient to meet demand throughout the year, including during the drier months, or through periods of low or no rainfall.

There are several mathematical models available for determining the size of tank needed to provide a defined security of supply. The simplest way of checking an estimated tank size required to provide water throughout an average year is to use monthly rainfall data and to assume that at the start of the wetter months the tank is empty. The following water balance formula should be used for each month:

$$V_t = V_{t-1} + (\text{Runoff} - \text{Demand})$$

Where:

t = number of month

$V_t$  = volume of water remaining in the tank at the end of the month

$V_{t-1}$  = volume of water left in the tank from the previous month

Runoff should be calculated as discussed above. Starting with the tank empty, then  $V_{t-1} = 0$ . If, after any month,  $V_t$  exceeds the volume of the tank, then water will be lost to overflow. If  $V_t$  is a negative figure, then demand exceeds the available water. Providing the calculated annual runoff exceeds the annual water demand,  $V_t$  will only be negative if periodic overflows reduce the amount of water collected so that it is less than the demand.

If water demand is to be met throughout the year, the tank should be large enough so that  $V_t$  is never negative, so calculations should be repeated using various tank sizes until  $V_t$  is  $\geq 0$  at the end of every month. If this cannot be achieved, then the catchment area connected to the tank may need to be increased or demand reduced. The greater the values of  $V_t$  over the whole year, the greater the security of meeting water demand when rainfalls are below average or when dry periods are longer than normal. However, the larger tank size is associated with higher costs.

It may be necessary to have a dual water system to use both roof water and scheme water when the tank level is low due to dry weather or high usage. This ensures a reliable water supply that will still provide significant scheme water savings and stormwater management benefits (Coombes 2004).

## Maintenance

Rainwater storage systems require very little maintenance provided they are correctly installed. Typical maintenance requirements include:

- cleaning of the first flush device every 3–6 months;
- removing leaf debris from gutters and roofs every 3–6 months;
- checking insect screens and other potential mosquito entry points at the onset of warm weather each year (e.g. spring in the south-west of WA) and whenever routine tank inspection and maintenance is undertaken;
- ensuring that water is not pooling beneath overflow outlets or taps whenever routine tank inspection and maintenance is undertaken;
- checking sediment levels every 2 years.

Below-ground stormwater storage devices will require some maintenance of the filters and pumps. Manufacturers' maintenance guidelines should be adhered to, but critically assessed once the system is installed, to ensure that site specific conditions are taken into consideration in the maintenance regime.

Raingardens require normal garden maintenance, including maintaining the plants in a healthy condition and checking that the garden is using up all of the rain and stormwater that it receives. Checking on the garden media to ensure that it is not clogged or waterlogged should occur before each wet season.

Stormwater sculptures and water features will require regular maintenance to ensure that storage capacity is at its maximum, pumps are operating and overflow devices are not blocked.

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# Stormwater Storage and Use

## 2.2 Managed Aquifer Recharge

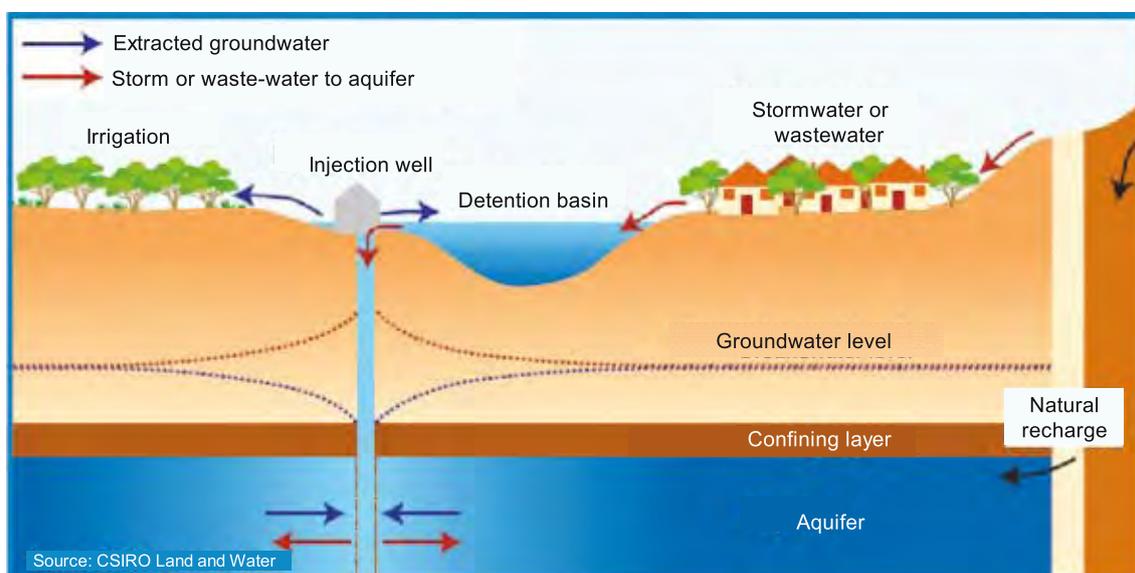


Figure 1. Conceptual Model of Aquifer Storage and Recovery Bore. (Source: CSIRO 2000.)

### Background

Managed aquifer recharge (MAR), also known as artificial recharge, is the infiltration or injection of water into an aquifer (EPA 2005). The water can be withdrawn at a later date, left in the aquifer for environmental benefits, such as maintaining water levels in wetlands, or used as a barrier to prevent saltwater or other contaminants from entering the aquifer. As the water infiltrates or is injected into the soil, natural biological, chemical and physical processes may assist in removing pathogens, chemicals and nutrients from the water, and thus improve water quality (Source: <<http://www.csiro.au>>).

MAR may be used as a means of managing water from a number of sources, including stormwater and wastewater. A number of pilot studies of MAR schemes using treated wastewater have been conducted. For example, a Water Corporation MAR scheme in Halls Head, Mandurah, has demonstrated significant improvements in secondary treated wastewater following MAR (Toze et al. 2004). Groundwater replenishment by MAR is currently being investigated as a future drinking water source for Perth using reverse osmosis treated wastewater. For further discussion of MAR using treated wastewater, see the Environmental Protection Authority Bulletin 1199 *Strategic Advice on Managed Aquifer Recharge using Treated Wastewater on the Swan Coastal Plain* (EPA 2005).

This document considers only MAR using stormwater. The lot-scale infiltration of runoff via soakwells is not considered to be a form of MAR in this document. Soakwells are addressed in BMP 3.2 Soakwells.

### Scope and viability of MAR

MAR schemes can range in complexity and scale from the precinct scale, through local authority infiltration systems for road runoff and public open space irrigation bores, through to the regional scale, which involves infiltration or well injection of stormwater and provision of third pipe non-potable water supply for domestic use.

Formal MAR schemes at a regional scale are relatively new in WA. Examples of MAR at the precinct scale include stormwater infiltration and irrigation systems adopted by the City of Geraldton and Town of

Mosman Park. The Town of Cottesloe, supported by the Water Smart Australia Programme, is implementing MAR using stormwater to replenish the Cottesloe groundwater aquifer. A number of local governments are also currently investigating MAR using stormwater for the irrigation of public open space.

A MAR scheme can be designed to incorporate BMPs such as vegetated swales, bioretention systems and constructed wetlands for pre-treatment purposes. At the regional scale, MAR can assist a post-development catchment to replicate its pre-development hydrology through reducing runoff to the receiving environment and by reducing the importation of scheme water. MAR can also contribute to reducing the size and hence capital cost of stormwater infrastructure. This is particularly the case where stormwater is infiltrated at-source, resulting in reduced design runoff rates.

The viability of a MAR scheme is firstly dependent upon the quality of water available to be used, or level of treatment required to achieve the necessary water quality. Stormwater can contain contaminants such as oil, grease, metals and pesticides, which build up on surfaces in urban areas. These come from sources such as pavement deterioration, tyre and brake-pad wear, vehicle emissions and spills. MAR may improve water quality for a number of contaminants as a result of filtration in the aquifer, and through biochemical processes in the soil or aquifer. It is however noted that there are a number of contaminants that may not be removed by MAR, and that there exists the potential for MAR to cause contamination of the aquifer if improperly designed or managed. The potential for contamination of the soil or aquifer through which the water moves also requires consideration.

The aquifer characteristics must also be well understood and mapped before implementation of a MAR scheme. Knowledge of the aquifer characteristics is required to predict the flow and fate of injected water. Understanding and monitoring of the aquifer and injected water is required so that recovery bores can be located to ensure that sensitive receptors, such as bores, wetlands and acid sulphate soils, are not affected.

The quantity of water available for abstraction following MAR will be dependent upon a number of factors, including the potential for impacts to the regional groundwater system. The Department of Water is currently developing an allocation policy for MAR. At times, either due to recovery efficiencies or due to environmental water allocations, the volume of water available to be recovered will be less than the volume of water which has been recharged to the aquifer in the scheme.

## Regulatory requirements

Managed aquifer recharge systems may require approvals from a number of government agencies, including the Department of Water, Department of Environment and Conservation, Department of Health and local government. In the case of large schemes or those with the potential for significant impacts, all relevant agencies must be consulted prior to proceeding with detailed design. Any MAR proposal that is likely, if implemented, to have a significant effect on the environment must also be referred to the Environmental Protection Authority under section 38 of the *Environmental Protection Act 1986*. Currently, MAR in public drinking water source areas is not supported.

MAR proposals should be assessed using a risk management framework, as set out in the *National Guidelines for Water Recycling – Managing Health and Environmental Risks* (NRMMC/EPHC 2005). Specific modules for MAR and for recycling stormwater are currently being developed as Phase 2 of these Guidelines.

A consultation and communication program should run in parallel with development of any MAR proposal. This is discussed in the *National Guidelines for Water Recycling – Managing Health and Environmental Risks* (NRMMC/EPHC 2005).

## Design considerations

At the MAR planning stage it is necessary to compile an inventory of existing environmental values attributed to the groundwater system, such as drinking water, aquatic ecosystem values and primary industries. This inventory may be included within an urban water management plan (UWMP) or a stormwater management plan (SMP). This should provide design objectives for planning the MAR system and identify the location of existing bores, their intended uses (e.g. monitoring, public open space irrigation) and groundwater dependent ecosystems (phreatophytic vegetation, caves, wetlands and waterways). As the aquifer may already be providing beneficial uses to others, quality, quantity and flow requirements of these users need to be considered in the aquifer selection.

### Stormwater Quality

Quality of the stormwater is a primary design consideration. Water quality treatment may be required prior to infiltration or injection into groundwater. MAR that uses infiltration as the recharge method may need little or no pre-treatment prior to recharge. The level of treatment depends on factors including the quality of the water used for the recharge, the local groundwater conditions, the intended use of the recovered water and local regulation. One of the key issues is the variability of stormwater, through factors such as the timing between rainfall events, rainfall intensity and distribution, and variability in catchment land uses. Treatment also has the added benefit of removing sediment and reducing the risk of ‘clogging’ the infiltration or injection system.

Each MAR proposal must identify potential pollution sources within the catchment and plan risk management strategies, including pollution contingency plans. An evaluation of the pollutants that may be present within the injected water needs to be carried out on a catchment basis as pollutants vary with land use. The concentrations of pollutants typically have seasonal or within-event patterns, and heavy pollutant loadings can be avoided by being selective in the timing of diversions. Comparisons with the aquifer water quality and environmental values will indicate the requirements for treatment of water detained for injection. Knowledge of the potential pollutant profile helps to define water quality sampling and analysis costs when determining the viability of the MAR project.

The Beach Health Program 2004-06 (Department of Water 2007) conducted a baseline study of the types and concentrations of contaminants in and around 65 traditional coastal stormwater drains in the Swan Region. The study found that stormwater at Perth’s marine beaches is contaminated predominantly with microbes and heavy metals. Nutrients, petroleum hydrocarbons, organic chemical compounds and suspended solids are also present in stormwater but to a lesser extent. Proposals must evaluate the need for pre-treatment of stormwater prior to MAR to address these potential contaminants.

Many structural BMPs are suitable as pre-treatments for MAR schemes. In general, methods that have long detention times are advantageous to reduce pathogenic microorganisms in addition to other pollutants. An advantage of using treatment with large storages (e.g. constructed wetlands) is the dilution effect if an isolated pollution event occurs, thus reducing the risk of aquifer contamination. See the BMPs in Chapter 7 for non-structural controls to reduce pollution and treat stormwater quality.

### Aquifer Characterisation

The in-situ water quality of the aquifer also requires consideration. Groundwater salinity, acidity, total dissolved solids and hydrogen sulphide levels may limit the potential for MAR; conversely MAR may dilute problematic local groundwater qualities. Infiltration or injection of stormwater may not be suitable in areas with high groundwater levels. Acid sulphate soils should be investigated, as these may decrease the quality of recovered water. There is the potential for MAR to increase the concentration of some

contaminants by leaching these from the aquifer; it is therefore crucial that both the stormwater and aquifer are fully characterised, physically, chemically and biologically, prior to approval or implementation of a MAR scheme.

Water quantity issues include the recoverable volume and the impact on the surrounding environment. Under pre-development conditions, groundwater entering or recharging an aquifer system is in equilibrium with the groundwater discharge from the system. Groundwater flows are generally discharged into waterways, wetlands, oceans or deeper aquifers. When groundwater withdrawal takes place, a hydraulic gradient due to pumping changes the base flow regime. Detailed hydrologic investigations must be carried out as part of the MAR design process, including identification of ecological water requirements (EWRs) sufficient to maintain and protect groundwater dependent ecosystems under drying climatic conditions.

Factors to consider in evaluating the suitability of an aquifer include:

- environmental values of the aquifer including ecosystem maintenance of caves, wetlands, phyreatophytic vegetation, surface water systems and human uses (irrigation, drinking water supply)
- adverse impacts on the environment and other aquifer users (e.g. reduced pumping pressure for nearby irrigators)
- an existing and/or future drinking water source area
- sufficient permeability and storage within the receiving aquifer
- depth of abstraction from the aquifer
- existing allocation of the aquifer and groundwater resource
- existing ambient groundwater quality and contaminant concentrations
- loss of aquifer permeability and/or infiltration due to precipitation of minerals or clogging
- possible damage to confining layers due to pressure increases
- higher recovery efficiencies of porous media aquifers
- aquifer mineral dissolution, if any
- potential for local aquitard collapse or distortion

### **System Controls and Monitoring**

Controls should be incorporated to shut down an injection pump or valve if any of the parameters determined for the project exceed the criteria for the environmental values of the aquifer. Examples of parameters to be measured include:

- standing water level in the well
- injection pressure
- electrical conductivity (salinity)
- turbidity
- temperature
- pH
- dissolved oxygen concentrations
- volatile organics
- other pollutants likely to be present in injected water that can be monitored in real time

Other ongoing monitoring should include monitoring water levels in valuable groundwater dependent ecosystems.

Protection of the treatment and detention system from contamination is a necessary part of the MAR system design. This includes constructing treatment systems away from flood-prone land, taking care with or avoiding the use of herbicides and pesticides within the surrounding catchment, minimising planting of deciduous vegetation, and preventing mosquitoes and other pests breeding in the storage pond. Contingency

plans should be developed to cater for the possibility of contaminated water being inadvertently recharged into the aquifer. These include how to determine the duration of recovery pumping (to extract contaminated water), what sampling intervals are needed and how to manage recovered water.

A monitoring system should be designed to ensure that any treatment system is performing as expected, and that MAR is not causing any adverse impacts to the receiving aquifer. The scope and complexity of the required monitoring system will be dependent on the potential impacts of the proposal.

## Components of a MAR system

The following material has been reproduced from *WSUD Engineering Procedures – Stormwater* (Melbourne Water 2005) with the permission of the author, to provide an overview of the main components of an MAR system.

As an example, a MAR scheme for infiltration of treated stormwater into a shallow aquifer contains the following structural elements (Figure 2):

- soakwells, swales or infiltration basins used to detain runoff and preferentially recharge the superficial aquifer with harvested stormwater
- an abstraction bore to recover water from the superficial aquifer for reuse
- a reticulation system (in the case of irrigation reuse) (will require physical separation from potable water supply)
- a water quality treatment system for recovered water depending on its intended use (e.g. removal of iron staining minerals)
- systems to monitor groundwater levels and abstraction volumes
- systems to monitor the quality of groundwater and recovered water

In addition to the above elements, an MAR system may also incorporate the following (Figure 2):

- a diversion structure from a drain
- a control unit to stop diversions when flows are outside an acceptable range of flows or quality
- some form of treatment for stormwater prior to injection
- a constructed wetland, detention pond, dam or tank, part or all of which acts as a temporary storage measure (and which may also be used as a buffer storage during recovery and reuse)
- a spill or overflow structure incorporated in the constructed wetland or detention storage
- well(s) into which the water is injected (may require extraction equipment for periodic purging)
- an equipped well to recover water from the aquifer (injection and recovery may occur in the same well)
- a treatment system for recovered water (depending on its intended use)
- sampling ports on injection and recovery lines
- a control system to shut down recharge in the event of unfavourable conditions

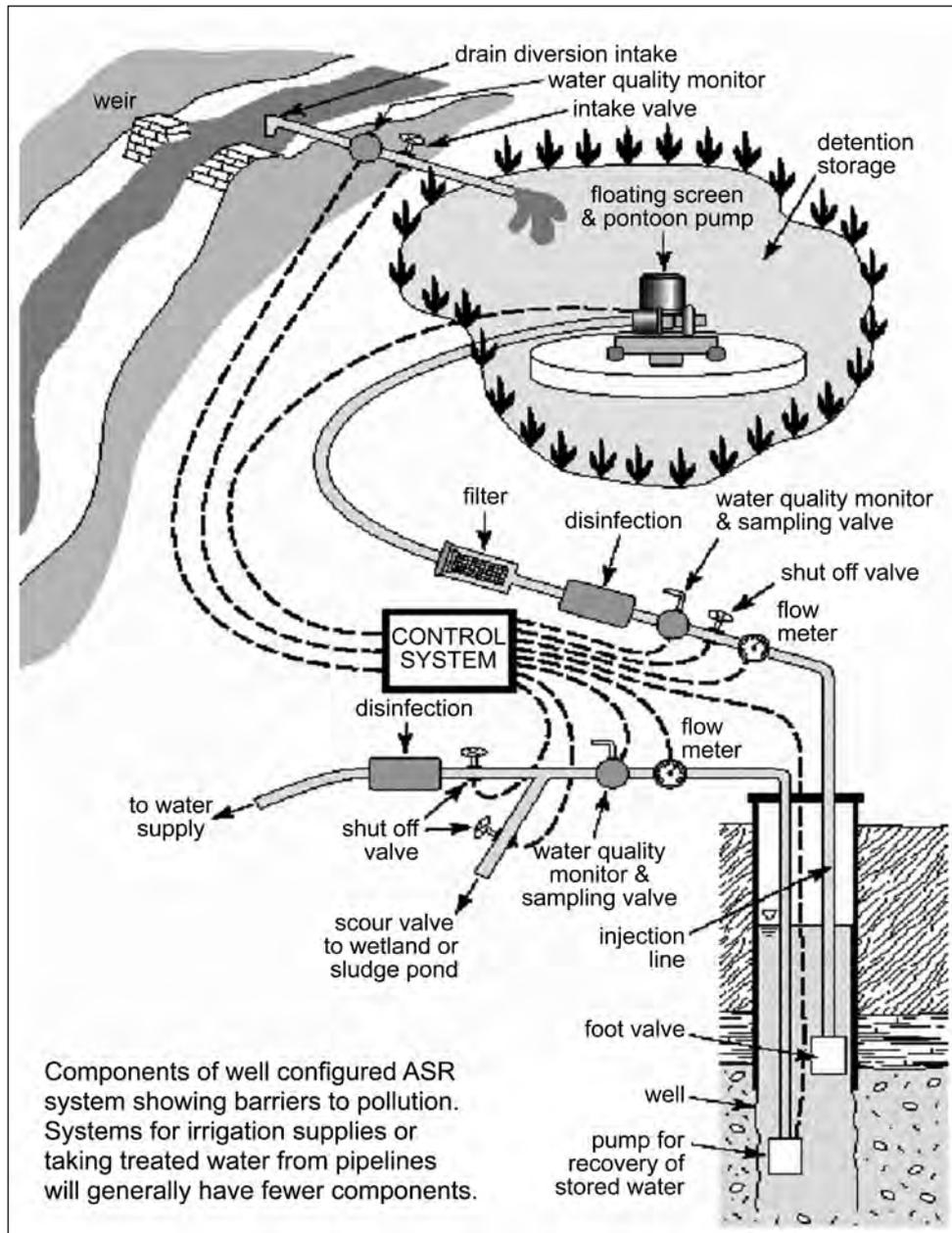


Figure 2. Components of a well-configured MAR system. (Source: adapted from Department of Water, Land and Biodiversity Conservation, undated.)

Refer to the Infiltration Systems, Conveyance Systems and Detention Systems BMPs for design guidelines for soakwells, swales, infiltration basins, dry/ephemeral detention areas and constructed wetlands. As this manual does not provide guidelines for ponds or constructed lakes, refer to the *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies* (Midge Research Group of Western Australia 2006) and the *Mosquito Management Manual* (Department of Health 2006) for pond design parameters to minimise mosquito breeding risk.

## Cost

The cost of implementing MAR systems varies significantly, depending on the level of pre- and post- MAR treatment required, peak demand on the system (and therefore the capital infrastructure costs), size of the area to be serviced, and extent of recharge and recovery infrastructure requirements. For example, injection wells tend to be much more expensive to establish and maintain than infiltration basins.

A recent analysis of a 400-lot MAR system for a residential area at Forrestdale detailed operating cost estimates as shown in Table 1. The operating unit cost of the MAR system (for garden watering only) is comparable to the current price of scheme water. It should be noted however that this MAR cost estimate does not include any capital infrastructure costs.

**Table 1. Operating Unit Cost of Water from Forrestdale MAR System (400 lots)**

<b>Operations and Maintenance Items (Irrigation Use Only)</b>	<b>Annual Cost (\$)</b>
Energy cost – bores and transfer pumps	5 200
Operations and maintenance	50 000
Administration costs (50%)	27 600
<b>TOTAL</b>	<b>82 800</b>
<b>Operating Unit Cost of Non-Potable Groundwater Supply</b>	<b>\$0.67/kL</b>

(Source: Parsons Brinckerhoff 2005.)

GHD (2005) provide feasibility level cost estimates for a 2.3 GL/yr MAR scheme injecting and recovering stormwater from the Leederville Aquifer for the Wungong Urban Water Project at Brookdale. Total unit costs are detailed as ranging between \$0.94/kL to \$1.41/kL inclusive of capital, energy, maintenance and administration costs (excludes distribution costs). Capital costs for the injection scheme were estimated as ranging between \$1.0–\$1.4 million, with annual operating costs between \$0.36–\$0.60 million/yr. Recovery costs were estimated based on a separate series of bores distributed throughout the development as ranging between \$0.75–\$1.10/kL. However, as this proposal involves injecting water into a confined aquifer against a positive head, it would be more expensive than a scheme involving gravity feed and a smaller head (Toze, S. 2007, pers. comm.<sup>1</sup>).

## Maintenance

The developer, local authority and service provider (typically Water Corporation) are three key stakeholders in the ownership and management of the MAR systems at precinct and regional scales.

In a conventional urban subdivision, the developer enters into an agreement with the service provider on fulfilling WA Planning Commission conditions for a designated area of subdivision. The developer provides water supply, sewerage and drainage infrastructure for the subdivision. The service provider assumes ownership of the assets upon completion of the works and incorporates them into the service provider's schemes. The service provider then operates and maintains these assets in line with their operating licence conditions.

Opportunities exist for local governments (or alternative water service providers) to undertake the management of non-potable MAR schemes as they usually manage the operation and maintenance of the public open space within shire boundaries. There are numerous examples of successful management of reuse schemes by local shires throughout regional Australia.

Monitoring equipment should be recalibrated at manufacturer's specified intervals. Pumps and pre-treatment equipment need to be maintained (e.g. by replacing filter media at manufacturer specified intervals or volumes). Keeping maintenance records is a component of good management practice.

<sup>1</sup> Personal communication with Simon Toze, Principal Research Scientist, CSIRO Land and Water, 2007.

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## 3 Infiltration Systems

### 3.1 Infiltration Basins and Trenches



Figure 1. Landscaped POS Infiltration Basin, Quandong Park, City of Mandurah. (Photograph: Department of Water 2007.)



Figure 2. Crate cell infiltration basin system below POS, City of Mandurah. (Photograph: Grahame Heal, City of Mandurah 2004.)

#### Background

Two primary infiltration systems used at larger scales are infiltration trenches and infiltration basins.

Infiltration basins are typically used in applications such as public open space parklands (see Figure 1). They consist of a natural or constructed depression designed to capture and store the stormwater runoff on the surface prior to infiltrating into the soils. Basins are best suited to sandy soils and can be planted out with a range of vegetation to blend into the local landscape. The vegetation provides some water quality treatment and the root network assists in preventing the basin floor from clogging. Pre-treatment of inflows may be required in catchments with high sediment flows.

An infiltration trench is a trench filled with gravel or other aggregate (e.g. blue metal), lined with geotextile and covered with topsoil. Often a perforated pipe runs across the media to ensure effective distribution of the stormwater along the system. Crate systems are modular plastic open crates or cells which can be laid out in a trench or rectangular basin, typically around 0.5 to 1.5 m deep, surrounded by geotextile and covered with topsoil (see Figure 2). Piped stormwater enters the system, often via a pre-treatment system, depending on the catchment characteristics, and flows into the trench or crates where the water seeps into the surrounding soil. Systems usually have an overflow pipe for larger storm events. There are a range of products which have various weight-bearing capacities so that the surface of the system can be used for parkland or vehicle parking areas. These systems can be combined to treat a large area.

#### Performance efficiency

Data on the performance efficiency of individual types of infiltration systems is limited, particularly in WA.

Fletcher et al. (2003) reports pollutant removal efficiencies for infiltration systems, as reproduced in Table 1. It should be noted that the expected removal shown in Table 1 refers to changes as a result of in-situ pollutant reduction, and hence does not consider flow loss due to the proportion of mean annual flow that is infiltrated. Removal efficiencies viewed in the context of the receiving surface water bodies would therefore be greater than the estimates shown in Table 1, particularly for sandy soils with high infiltration capacity. The decrease in surface flow results in a decrease in potential pollutant transport to the receiving environment.

The effectiveness of infiltration systems for nutrient removal is dependent upon the vegetation used in landscaping the system and the phosphorus retention index (PRI) of the soil or infiltration medium. Soil amendment may be necessary to achieve a high rate of phosphorus removal, due to the low PRI of most naturally occurring sands in WA.

**Table 1. Typical Annual Pollutant Load Removal Efficiencies for Infiltration Systems**

Pollutant	Expected Removal	Comments
Litter	>90%	Expected to trap all gross pollutants, except during high-flow bypass.
Total suspended solids	65–99%	Pre-treatment required to reduce clogging risk.
Total nitrogen	50–70%	Dependent on nitrogen speciation and state (soluble or particulate).
Total phosphorus	40–80%	Dependent on phosphorus speciation and state (soluble or particulate).
Coarse sediment	90–100%	May pose a clogging risk. These systems should have pre-treatment to remove coarse sediment prior to entry to the filter media.
Heavy metals	50–95%	Dependent on state (soluble or particulate).

(Source: Fletcher et al. 2003.)

## Cost

Construction costs associated with these facilities can vary considerably. Cost variability factors include topography, whether installed as part of new construction or implemented as a retrofit, varying subsurface conditions, and the degree and extent of landscaping.

Local cost data for infiltration basins is limited. An alternative method of costing these systems is to examine the costs of similar systems, such as ponds and swales. Taylor (2005) reported costs for ponds (sourced from limited data in Australia) ranging from \$2,000/ha of catchment to \$30 000/ML of pond volume, and \$60 000/ha of pond area. Taylor (2005) also reported costs for vegetated swales of approximately \$4.50/m<sup>2</sup>, which included earthworks, labour and hydro-mulching. For swales with rolled turf the cost was approximately \$9.50/m<sup>2</sup> and for a vegetated swale with indigenous species the cost was approximately \$15–20/m<sup>2</sup>.

It would be expected that the above costs for both these systems would be comparable to the components of a landscaped infiltration basin.

With respect to infiltration trenches, cost estimates based on eastern states examples provide a construction cost range of \$46–\$138 per linear metre (based on a 1 m wide, 1 m deep trench) (Taylor 2005).

It is important to consider the longevity of the infiltration system and budget for maintenance costs. Calculation of the ‘lifespan’ and the effect of sediment accumulation on permeability should be done at the design phase to help estimate these costs. As reported by the Center for Watershed Protection (1998) cited in Taylor (2005), annual maintenance costs would be expected to typically be in the range of ~5–20% of the construction cost.

## Design considerations

Soil types, surface geological conditions and groundwater levels determine the suitability of infiltration systems.

These devices should not be placed in loose Aeolian wind-blown sands. However, well-compacted sands are suitable. At the other extreme, infiltration devices should not be sited in rock or shale, although site specific permeability should be investigated as some limestone and sandstone permeability can be comparable to medium clays. Care should also be taken at sites with shallow soil overlying impervious bedrock, as the water stored on the bedrock will provide a stream of flow along the soil/rock interface.

Soils must be sufficiently permeable to ensure that collected runoff can infiltrate quickly enough to reduce the potential for flooding and mosquito breeding (i.e. water ponding for no more than four days). See Section 1.7.7 'Public health and safety' of the Introduction section of this chapter for more information on mosquito management. Infiltration techniques can be implemented in a range of soil types, and are typically used in soils ranging from sands to clayey sands. Soils with lower hydraulic conductivities do not necessarily preclude the use of infiltration systems, but the size of the required system may typically become prohibitively large, or a more complex design approach may be required, such as including a slow drainage outlet system.

The presence of a high groundwater table limits the potential use of infiltration systems in some areas, but does not preclude them. There are many instances of the successful application of infiltration basins on the Swan Coastal Plain where the basin base is located within 0.5 m of the average annual maximum groundwater level. The seasonal nature of local rainfall and variability in groundwater level should also be considered. For example, the groundwater table may only be at its maximum for a short duration, and greater capacity for infiltration may be available throughout most of the year. However, infiltration in areas with rising groundwater tables should be avoided where infiltration may accelerate the development of problems such as waterlogging and rising salinity.

Infiltration basins and trenches typically take up a relatively small percentage (2–3%) of the contributing catchment. Additional space may be required for buffers, landscaping, access paths and fencing. Trenches have the advantage of being able to fit into thin, linear areas, such as road verges and medians. Due to their flexibility in shape, trenches can be located in a relatively unusable portion of the site. However, design will need to consider clearance distances from adjacent building footings or boundaries to protect against cracking of walls and footings.

Root barriers may need to be installed around sections of infiltration systems that incorporate perforated/slotted pipes or crate units where trees will be planted, to prevent roots growing into the system and causing blockages.

Generally, infiltration is not recommended for stormwater collected at industrial and commercial sites that have the potential to be contaminated. Where infiltration BMPs are adopted in industrial sites, pre-treatment may be required. Stormwater collected at industrial and commercial sites that do not have the potential for contamination (e.g. roof runoff and runoff from staff carparks) can be infiltrated on-site.

Generally, stormwater runoff should not be conveyed directly into an infiltration system, but the requirement for pre-treatment will depend on the catchment. Treatment for the removal of debris and sediment is recommended to prevent clogging. It may also be necessary to achieve a prescribed water quality standard before stormwater can be discharged into groundwater. Pre-treatment measures include the provision of leaf and roof litter guards along roof gutters, vegetated strips or swales, litter and sediment traps, sand filters and bioretention systems. To prevent basins/trenches from being clogged with sediment/litter during road and housing/building construction, temporary bunding or sediment controls need to be installed. See Section 2.1.1 'Land development and construction sites' of Chapter 7 for information about site management practices.

## Design guidelines

*The calculations contained in this section for sizing the storage volumes and determining emptying time are based on Engineers Australia (2006) and Argue (2004) and the assumed simplified hydrograph detailed*

in Figure 3. The calculations should be applied with caution to the sizing of infiltration systems where shallow groundwater is present. This approach does not consider the impacts of shallow groundwater in its calculation, which may reduce infiltration capacity. Detailed modelling of shallow groundwater situations is recommended. Designers should take into account the maximum groundwater level, and hence the minimum infiltration potential, in determining their flood detention design. However, designers should also consider maximum infiltration opportunities to achieve aquifer recharge when the groundwater table is below its maximum level (refer to Design Considerations section of this BMP for further discussion).

### Hydrologic Effectiveness

The hydrologic effectiveness of an infiltration system defines the proportion of the mean annual runoff volume that infiltrates. Hydrologic effectiveness is used for sizing infiltration systems in the eastern states and this method can to some extent be applied in WA. However, in most instances in WA, infiltration basins are designed for capturing and infiltrating flows up to a particular design event, and the Design Storm Method is used.

### Field Investigations

Field investigations must be undertaken to determine the soil type; hydraulic conductivity; presence of soil salinity, rock and other geological limitations; slope of the terrain; and groundwater level, depth and quality.

A combination of poor soil conditions (e.g. sodic and dispersive soils), steep terrain and shallow saline groundwater can render the use of infiltration systems inappropriate. Dryland salinity is caused by a combination of factors, including leaching of infiltrated water and salt at 'break-of-slope' terrain. Soil with high sodicity is generally not considered to be suited for infiltration as a means of managing urban stormwater. Sodic soils (soils with a relatively high proportion of exchangeable sodium) cause increased soil dispersion and swelling of clays, which adversely impacts the soil structure and results in reduced infiltration, reduced hydraulic conductivity and the formation of surface crusts.

Infiltration into steep terrain can result in the stormwater re-emerging as spring flow downstream. The likelihood of this occurring is dependent on the soil structure, for example where soils intersect a less permeable layer in the area of re-emergence. This situation does not necessarily preclude stormwater infiltration, unless leaching of soil salt is associated with this process. This issue will need to be taken into consideration at the design stage.

Field hydraulic conductivity tests are essential to confirm the assumptions of soil hydraulic conductivity adopted during the concept design stage. Saturated hydraulic conductivities for various soil types based on Engineers Australia (2006) are shown in Table 2.

**Table 2. Hydraulic Conductivity for Various Soil Types (Engineers Australia 2006)**

Soil Type	Saturated Hydraulic Conductivity	
	mm/hr	m/s
Sand	> 180	$> 5 \times 10^{-5}$
Sandy Clay	36 – 180	$1 \times 10^{-5} - 5 \times 10^{-5}$
Medium Clay	3.6 to 36	$1 \times 10^{-6} - 1 \times 10^{-5}$
Heavy Clay	0.036 to 3.6	$1 \times 10^{-8} - 1 \times 10^{-6}$

Soils are inherently heterogeneous and field tests can often misrepresent the areal hydraulic conductivity of a soil. Field tests of point soil hydraulic conductivity often lead to underestimating the areal hydraulic

conductivity of clayey soils and overestimating sandy soils. Engineers Australia (2006) recommends that a soil moderation factor be applied to field hydraulic conductivity values (Table 3).

**Table 3. Soil Moderation Factors (Engineers Australia 2006)**

Soil Type	Soil Moderation Factor (U) (to convert point $k_h$ to areal $k_h$ )
Sand	0.5
Sandy Clay	1.0
Medium and Heavy Clay	2.0

### Estimating Design Flows and Hydrographs

Infiltration systems can be subject to a range of performance criteria including that of peak discharge attenuation and volumetric runoff reduction.

The *Decision Process for Stormwater Management in Western Australia* (Department of Environment & Swan River Trust 2005) requires up to the 1 year ARI event to be retained on-site. One of the main methods by which this can be achieved is through on-site infiltration (where possible). Infiltration systems could be designed to accommodate larger events, depending on the site specific conditions and catchment management objectives.

Two flows need to be considered in the design of infiltration systems:

- the peak inflow rate to the infiltration system for design of the inlet structure; and
- major flow rates for design of a submergence, conveyance or bypass system.

Design flows and hydrographs for particular storm events can be estimated using a range of hydrologic methods and models with varying complexity. For small simplistic catchments, the Rational Method is suitable for peak flow estimation.

Engineers Australia (2006) details a simplified alternative to hydrologic modelling to determine an inflow hydrograph that will provide a satisfactory design solution. It is based on assuming a simplified shape of the inflow hydrograph that can be used to estimate the temporary storage volume for an infiltration system, as shown in Figure 3, where :

- $i$  = average rainfall intensity (mm/hr)
- $t$  = critical (design) storm duration (hr)
- $t_c$  = site time of concentration (hr)
- $\tau$  = time base of the design storm hydrograph (hr)
- $Q_{\text{peak}}$  = maximum flow rate in response to the rainfall event ( $\text{m}^3/\text{s}$ )
- $\nabla$  = volume of stormwater runoff that enters the device ( $\text{m}^3$ )

Engineers Australia (2006) indicates use of this simplified approach is likely to result in a conservative estimate of infiltration storage volume requirements in comparison to detailed mathematical modelling.

Determination of an appropriate  $t$  (critical design storm duration) is essential in this calculation. Engineers Australia (2006) defines a range of potential interpretations/definitions of this parameter, which may be used as a basis for design.

For further details regarding the implementation of this approach, the user is referred to Engineers Australia (2006).

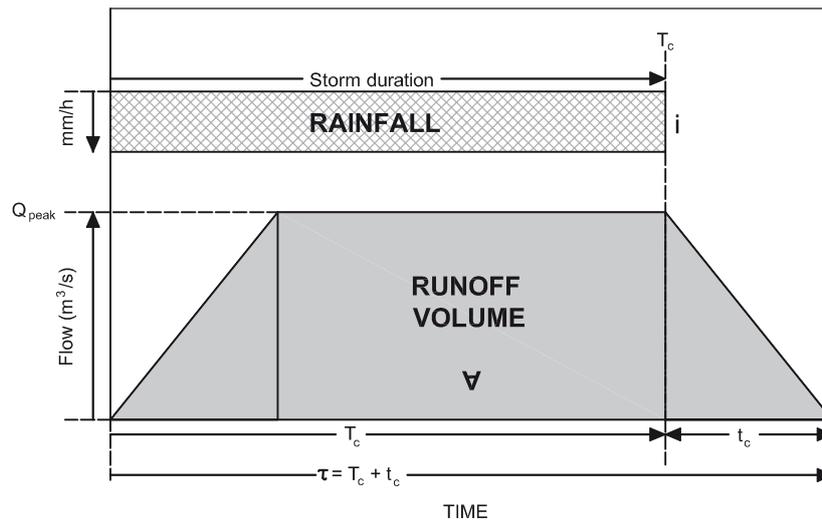


Figure 3. Simplified inflow hydrograph (for use in design without hydrologic modelling).

### Siting of Infiltration Systems

Infiltration systems should not be placed near building footings, as continually wet subsurface conditions or greatly varying soil moisture contents can impact on the structural integrity of these structures.

Engineers Australia (2006) recommends minimum distances from structures (and property boundaries to protect possible future buildings in neighbouring properties) as shown in Table 4 for various soil types.

Identification of suitable sites for infiltration systems should also include avoidance of steep terrain and areas of shallow soils overlying largely impervious rock (non-sedimentary rock and some sedimentary rock such as shale).

An understanding of the seasonal and inter-annual variation of the groundwater table is also an essential element in the design of these systems.

**Table 4. Minimum Set-Back Distances (Engineers Australia 2006)**

Soil Type	Minimum Distance from Building Footings for Infiltration System
Sand	1.0 m
Sandy Clay	2.0 m
Weathered or Fractured Rock e.g. sandstone	2.0 m
Medium Clay	4.0 m
Heavy Clay	5.0 m

### Sizing Storage Volume (Design Storm Method)

The required storage volume of an infiltration system is defined by the difference in inflow and outflow volumes for the duration of a storm. The inflow volume is a product of the rainfall, runoff coefficient and contributing area connected to the infiltration system, i.e:

$$\text{Inflow Volume} = \frac{CiAD}{1000}$$

Where:

C = runoff coefficient

i = probabilistic rainfall intensity (mm/hr)

A = contributing area connected to the infiltration system (m<sup>2</sup>)

D = storm duration (hours)

Outflow from the infiltration system is via the base and sides of the infiltration system and is dependent on the area and depth of the system. In computing the infiltration from the walls of an infiltration system, Engineers Australia (2006) suggests that pressure is hydrostatically distributed and thus equal to half the depth of water over the bed of the infiltration system, i.e:

$$\text{Outflow Volume} = \frac{\left[ A_{\text{inf}} + \left( \frac{Pd}{2} \right) \right] Uk_h D}{1000}$$

Where:

k<sub>h</sub> = point saturated hydraulic conductivity (mm/hr)

A<sub>inf</sub> = infiltration area (m<sup>2</sup>)

P = perimeter length of the infiltration area (m)

d = depth of the infiltration system (m)

U = point soil hydraulic conductivity moderating factor

D = storm duration (hours)

Approximation of the required storage volume of an infiltration system can be computed as follows:

Required Storage = Inflow Volume – Outflow Volume

Computation of the required storage will need to be carried out for the full range of probabilistic storm durations, ranging from 6 minutes to 72 hours and this calculation is usually performed using spreadsheet analysis. The critical storm event is the one which results in the highest required storage.

### **Infiltration Trench Sizing**

To determine the length (L) of a gravel filled or crate-box trench:

$$L = \frac{\nabla}{\left( e_s bH + 60k_h \tau \left( b + \frac{H}{2} \right) U \right)} \quad (\text{refer Argue 2004 for derivation})$$

Where:

L = length of the trench (m)

∇ = Inflow volume (m<sup>3</sup>)

e<sub>s</sub> = void space

b = width of the trench (m)

H = depth of the trench (m)

$k_h$  = soil saturated hydraulic conductivity (m/s)

$\tau$  = time base of the design storm runoff hydrograph (min)

U = soil moderation factor (Table 3)

Typical values for  $e_s$  are 0.35 for gravel, 0.95 for plastic milk-crate units and 0.50–0.75 for trenches part-occupied by perforated pipes.

In low permeability soils, the above equation results in trenches of impractical lengths. In such cases, it is recommended to build the infiltration device as a ‘soakaway’, that is a trench with a relatively larger plan area where length (L) is approximately equal to width (b). To determine the plan area (a) of this arrangement, the above equation reduces to:

$$a = \frac{\nabla}{(e_s H + 60k_h \tau U)} \quad (\text{refer Argue 2004 for derivation})$$

Where:

a = required infiltration plan area (m<sup>2</sup>)

$\nabla$  = Inflow volume (m<sup>3</sup>)

$e_s$  = void space

H = height/thickness of the system (m)

$k_h$  = soil saturated hydraulic conductivity (m/s)

$\tau$  = time base of the design storm runoff hydrograph (min)

U = soil moderation factor (Table 3)

The above equations assume the device is empty at the commencement of flow. Application of these equations must be followed by a check on the emptying time of the system’s storage.

### Emptying Time

Emptying time is defined as the time taken to completely empty a storage associated with an infiltration system following the cessation of rainfall. This is an important design consideration as the computation procedures previously described assume that the storage is empty prior to the commencement of the design storm event. Continuous simulation modelling for a range of catchments is required to provide reliable emptying time criteria. In the absence of this modelling, Engineers Australia (2006) recommends the interim emptying time criteria outlined in Table 5.

**Table 5. Interim Criteria for Emptying Time of an Infiltration System for Different ARI**

Average Recurrence Interval (ARI)	< = 1 year	2 years	5 years	10 years	20 years	50 years	100 years
Maximum emptying time in days	0.5	1.0	1.5	2.0	2.5	3.0	3.5

Emptying time is computed simply as the ratio of the volume of water in temporary storage (dimension of storage × porosity) to the infiltration rate (hydraulic conductivity × infiltration area).

The following formulae calculate the emptying time of infiltration basins and trenches, assuming draining

by infiltration or percolation only. If assisted drainage is incorporated into the system, for example by provision of a slow drainage outlet pipe, then this needs to be taken into account.

The calculated emptying time should be compared to the values provided in Table 5 for the appropriate ARI to determine whether the acceptable emptying time criterion is exceeded. If so, the design should be amended, for example by distributing the flow to a greater number of infiltration units or larger area, or by providing a slow drainage outlet.

For a gravel-filled (or similar) trench, the emptying time is:

$$T = -\frac{4.6Lbe_s}{2k_h(L+b)} \log_{10} \left[ \frac{Lb}{Lb + 2H(L+b)} \right] \quad (\text{refer Argue 2004 for derivation})$$

Where:

T = emptying time (s)

L = trench length (m)

b = trench width (m)

H = trench depth (m)

$e_s$  = void space ratio (volume of voids/total volume occupied)

$k_h$  = soil saturated hydraulic conductivity (m/s)

Where infiltration trenches have length (L) approximately equal to width (b), this equation simplifies to:

$$T \approx \frac{2He_s}{k_h} \quad (\text{refer Argue 2004 for derivation})$$

Where the parameters are defined as above.

This equation can also be used for an open infiltration basin, by setting  $e_s = 1.0$ .

### **Inlet Hydraulic Structure**

The inlet hydraulic structure is required to perform two functions for infiltration systems: provision of energy dissipation and bypass of above design discharges.

Bypass can be achieved in a number of ways, most commonly using a surcharge pit, an overflow pit or discharge into an overflow pipe connected to a stormwater system.

### **Maintenance**

Regular maintenance is required for proper operation of infiltration systems.

Maintenance plans should identify owners and parties responsible for maintenance, along with an inspection schedule. The use and regular maintenance of pre-treatment BMPs will significantly minimise maintenance requirements for infiltration systems.

Depending on the specific system implemented, maintenance should include at least the following:

- inspect and clean pre-treatment devices biannually (i.e. before and after the wet season) and ideally after major storm events;
- once the infiltration system is operational, inspections should occur after every major storm for the initial

few months to ensure proper stabilisation and function. Attention should be paid to how long water remains standing after a storm; standing water within the system for more than 72 hours after a storm is an indication that soil permeability has been over-estimated;

- after the first wet season, infiltration systems should be inspected at least biannually (i.e. before and after the wet season). Important items to check and clean or repair if required include: accumulated sediment, leaves and debris in the pre-treatment device, signs of erosion, clogging of inlet and outlet pipes and surface ponding;
- when ponding occurs, corrective maintenance is required immediately.

In the case of infiltration trenches, clogging occurs most frequently on the surface. Grass clippings, leaves and accumulated sediment should be removed routinely from the surface. If clogging appears to be only at the surface, it may be necessary to remove and replace the first layer of filter media and the geotextile filter.

The presence of ponded water inside the trench after an extended period indicates clogging at the base of the trench. Remediation includes removing all of the filter media and geotextile envelope, stripping accumulated sediment from the trench base, scarifying to promote infiltration and replacing new filter media and geotextile. Vegetation can assist in prevention of clogging as the root network breaks up the soil and thereby promotes infiltration.

In the case of infiltration basins, sediment should be removed when it is sufficiently dry so that the sedimentation layer can be readily separated from the basin floor. Refer to BMP 2.2.2 *Maintenance of the stormwater network* in Chapter 7 for further guidance on managing sediments removed from the stormwater system.

## Worked example

*The following worked example is based on a WSUD Workshop held by John Argue in Perth, November 2005.*

An on-site stormwater retention system is to be designed for runoff from a roof located in Perth. The site is located in an elevated area with good clearance to groundwater, hence application of the formulae contained in the design guideline for this BMP is considered appropriate. Given the layout of the site, an infiltration trench with length (L) approximately equal to width (b) is required to be designed. Two styles of trench are compared in the design process to determine which is most suitable for the site.

The design parameters are listed below:

- roof area,  $A = 400 \text{ m}^2$
- soil saturated hydraulic conductivity,  $k_h = 1.6 \times 10^{-4} \text{ m/s}$  (sandy)
- gravel filled infiltration trench void space  $e_s = 0.35$
- crate system infiltration trench void space,  $e_s = 0.95$
- gravel filled infiltration trench depth,  $H = 0.40 \text{ m}$
- crate infiltration trench height,  $H = 0.40 \text{ m}$

Based on spreadsheet analysis, for a required design average recurrence interval (ARI) of 2 years:

- site  $t_c = 15$  minutes (calculated site time of concentration)
- site  $t = 30$  minutes (critical design storm duration selected for protection of a location downstream of the site that is subject to erosion and flooding – refer Engineers Australia (2006) for methods of ‘t’ calculation.)
- $\tau = 15 + 30 = 45$  minutes (time base of the design storm runoff hydrograph – see Figure 3)

Based on the above, the design rainfall intensity  $i_2 = 31.7$  mm/hr (refer to Rainfall Intensity–Frequency–Duration curves for Perth, available from Bureau of Meteorology).

### Runoff Volume

$$\text{Inflow Volume } \nabla = \frac{CiAD}{1000}$$

From *Australian Rainfall and Runoff* Book VIII (Institution of Engineers Australia 2001):

$$C_y = F_y \cdot C_{10}$$

Where:

$C_y$  = runoff coefficient for a 'Y' year ARI

$F_y$  = frequency factor for rational method runoff coefficients

$C_{10}$  = 10 year ARI runoff coefficient (= 0.9 where the fraction impervious = 1)

Therefore, for ARI = 2 years:

$$C_2 = F_2 \cdot C_{10} = 0.85 \times 0.90 = 0.765$$

$$\text{Inflow volume } \nabla = 0.765 \times \frac{31.7}{1000} \text{ m/hr} \times 400 \text{ m}^2 \times \frac{30}{60} \text{ hr}$$

$$\nabla = 4.85 \text{ m}^3$$

### Gravel Filled Infiltration Trench

Determine the plan area (a) for the gravel filled infiltration trench:

$$a = \frac{\nabla}{(e_s H + 60k_h \tau U)}$$

$$a = \frac{4.85}{(0.35 \times 0.4 + 60 \times 1.6 \times 10^{-4} \times 45 \times 0.5)}$$

$$a = 13.6 \text{ m}^2$$

Determine the emptying time (T):

$$T = \frac{2He_s}{k_h}$$

$$T = \frac{2 \times 0.4 \times 0.35}{1.6 \times 10^{-4}}$$

$$T = 1750 \text{ seconds}$$

$$T = 29 \text{ minutes}$$

The acceptable maximum emptying time for a 2 year ARI event is 1 day (Table 5), therefore the gravel filled infiltration trench design is suitable.

### Crate Infiltration Trench

Determine plan area (a) for the crate infiltration trench:

$$a = \frac{\nabla}{(e_s H + 60k_h \tau U)}$$

$$a = \frac{4.85}{(0.95 \times 0.4 + 60 \times 1.6 \times 10^{-4} \times 45 \times 0.5)}$$

$$a = 8.14m^2$$

Determine the emptying time (T):

$$T = \frac{2He_s}{k_h}$$

$$T = \frac{2 \times 0.4 \times 0.95}{1.6 \times 10^{-4}}$$

$$T = 4750 \text{ seconds}$$

$$T = 1 \text{ hour } 19 \text{ minutes}$$

The emptying time is less than the maximum acceptable emptying time of a 2 year ARI event, therefore the design of the crate infiltration trench is suitable.

Given that both the gravel filled and crate system infiltration trenches emptied within an acceptable time, a crate system is selected for this site as it requires a smaller plan area.

## References and further reading

Agriculture Western Australia 1998, *Soilguide: a handbook for understanding and managing agricultural soils*, Bulletin No 4343, Agriculture Western Australia, Perth, Western Australia.

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# Infiltration Systems

## 3.2 Soakwells



Figure 1. PVC Soakwell. (Source: Reln Pty Ltd. 2006.)

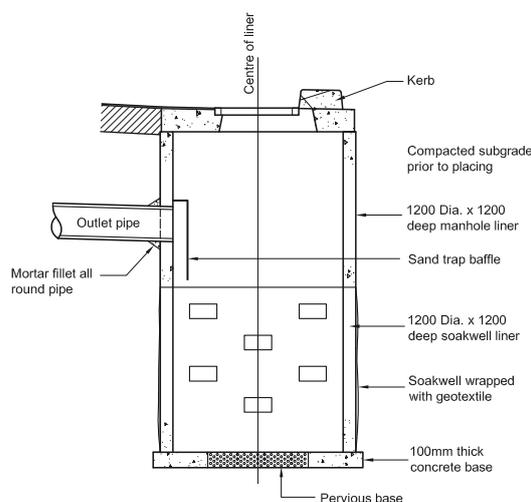


Figure 2. Standard Combination Gully/Soakwell. (Source: Glover, City of Bayswater.)

### Background

An alternative method for infiltration is using soakwells. These systems are used widely in Western Australia as an at-source stormwater management control, typically in small-scale residential and commercial applications, or as road side entry pits at the beginning of a stormwater system. Soakwells can be applied in retrofitting scenarios and existing road side entry pits/gullies can be retrofitted to perform an infiltration function. See Section 6.2.2 of Chapter 6: Retrofitting for further information.

Soakwells consist of a vertical perforated liner, with stormwater entering the system via an inlet pipe at the top of the device (Figure 3). The base of the soakwell is open or perforated and usually covered with a geotextile. Alternatively, pervious material, such as gravel or porous pavement, can be used to form the base of the soakwell.

Where source water may have a high sediment load, there should be pre-treatment, such as filtering, as soakwells are susceptible to clogging.

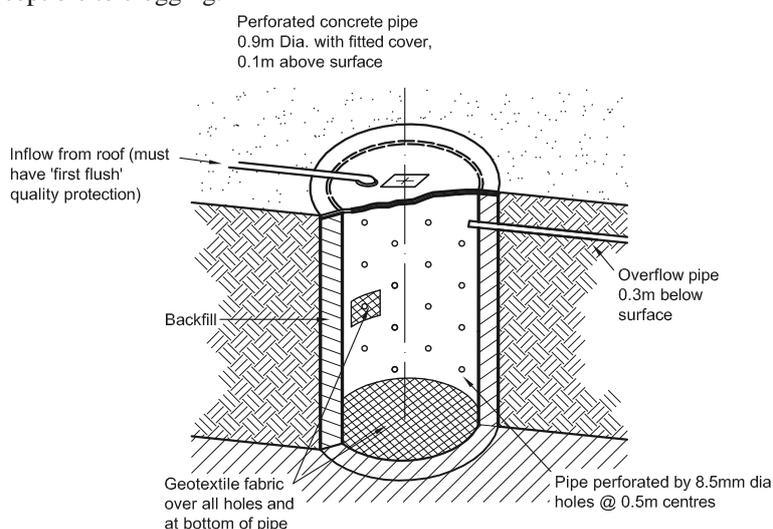


Figure 3. Leaky well infiltration system.

## Performance efficiency

Data on the performance efficiency of infiltration systems is presented in the Performance Efficiency section and Table 1 of the Infiltration Basins and Trenches BMP, based on Fletcher et al. (2003).

## Cost

The cost for soakwell systems can vary considerably according to the type of soakwell to be installed, site-specific conditions (including soil type), configuration, location, storage volumes, and landscaping and restoration requirements.

See Chapter 6: Retrofitting, Case Study 7.1 ‘Town of Mosman Park – Total Water Cycle Project’ for further information on the costs of a catchment-wide infiltration project. An example of the techniques used in the Town of Mosman Park to maximise infiltration in the catchment is the installation of combination gully/soakwells, as shown in Figure 2. The cost of installation and materials for each 2.4 m deep soakwell was approximately \$1 300 per unit (2004/05 prices) (Glover, M. 2007, pers. comm.<sup>1</sup>).

Installation and other associated works are a significant proportion of the cost of these systems. Soakwells are a relatively cheap stormwater management measure for lot-scale application.

## Design considerations

Design considerations for soakwells are similar to those for other infiltration systems.

Soil type and stability, topography, separation to groundwater, setback to buildings and pre-treatment to remove sediment, litter and other pollutants must all be considered. These issues are discussed in the Design Considerations section of the Infiltration Basins and Trenches BMP.

## Design guidelines

*The calculations contained in this section for sizing the storage volume of soakwells and determining emptying time are based on Engineers Australia (2006) and Argue (2004). The calculations should be applied with caution to the sizing of infiltration systems where shallow groundwater is present. This approach does not consider the impacts of shallow groundwater in its calculation, which may reduce infiltration capacity. Detailed modelling of shallow groundwater table situations is recommended. Designers should take into account the maximum groundwater level, and hence the minimum infiltration potential, in determining their flood detention design. However, designers should also consider maximum infiltration opportunities to achieve aquifer recharge when the groundwater table is below its maximum level (refer to the Design Considerations section of the Infiltration Basins and Trenches BMP for further discussion).*

### Inflow Volume

The required storage volume is defined by the difference in inflow and outflow volumes for the duration of a storm. The inflow volume is a product of the rainfall, runoff coefficient and contributing area connected to the infiltration system, i.e.:

$$\text{Inflow Volume} = \frac{CiAD}{1000}$$

Where:

C = runoff coefficient

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<sup>1</sup> Personal communication with Martyn Glover, City of Bayswater, 2007.

- $i$  = probabilistic rainfall intensity (mm/hr)
- $A$  = contributing area connected to the infiltration system (m<sup>2</sup>)
- $D$  = storm duration (hours)

### Soakwell Sizing

Note that the following equation is based on an approximation where  $d \approx H$  and may not be valid for other design situations.

Argue (2004) provides the following formula for sizing of a soakwell:

$$d = \sqrt{\frac{\nabla}{\frac{\pi}{4}(H + 120k_h\tau U)}} \quad (\text{refer to Argue 2004 for derivation})$$

Where:

- $d$  = well diameter (m)
- $\nabla$  = Inflow volume (m<sup>3</sup>)
- $H$  = well height (m)
- $k_h$  = soil saturated hydraulic conductivity (m/s)
- $\tau$  = time base of the design storm runoff hydrograph (min)
- $U$  = soil moderation factor (Table 3 in the Infiltration Basins and Trenches BMP)

The above equation assumes the device is empty at the commencement of flow. Application of this equation must be followed by a check on the emptying time of the system's storage.

### Emptying Time

Emptying time is defined as the time taken to completely empty a storage associated with an infiltration system following the cessation of rainfall. This is an important design consideration as the computation procedures previously described assume that the storage is empty prior to the commencement of the design storm event.

Argue (2004) provides the following formula for calculating the emptying time for soakwells:

$$T = -\frac{4.6d}{4k_h} \log_{10} \left[ \frac{\frac{d}{4}}{H + \frac{d}{4}} \right] \quad (\text{refer to Argue 2004 for derivation})$$

Where:

- $T$  = emptying time (s)
- $d$  = well diameter (m)
- $H$  = well height (m)
- $k_h$  = soil saturated hydraulic conductivity (m/s)

Further discussion regarding emptying times is contained in the Design Guidelines section of the Infiltration Basins and Trenches BMP.

### Maintenance

Soakwells require maintenance for efficient operation and to reduce the risk of mosquito breeding, including regular inspection and cleaning to prevent clogging by sediments and litter. Pre-treatment BMPs can significantly reduce the maintenance requirements by preventing sediments and litter from entering the system. To prevent road/carpark soakwells from being clogged with sediment/litter during road and

housing/building construction (see Figure 4), temporary bunding or sediment controls need to be installed (see Figure 5 for an example of a sediment fence). See Section 2.1.1 'Land development and construction sites' of Chapter 7 for information about site management practices.

A maintenance plan for infiltration systems is described in the Maintenance section of the Infiltration Basins and Trenches BMP.



Figure 4. Soil entering a side entry pit that has a soakwell at the base; located within a pipeless subdivision within the City of Mandurah, WA. (Photograph: Department of Water 2007.)



Figure 5. Silt fence for controlling sediment during land development. (Photograph: André Taylor, Ecological Engineering Pty Ltd.)

## Worked example

The following worked example is based on a WSUD Workshop held by John Argue in Perth, November 2005.

An on-site stormwater retention system is to be designed for runoff from a roof located in Perth. The site is located in an elevated area with good clearance to groundwater, hence application of the formulae contained in the design guideline for this BMP is considered appropriate.

The design parameters are listed below:

- Roof area,  $A = 400 \text{ m}^2$
- Soil saturated hydraulic conductivity,  $k_h = 1.6 \times 10^{-4} \text{ m/s}$  (sandy)
- Standard soakwell effective height,  $H = 2.30 \text{ m}$

Based on spreadsheet analysis, for a required design average recurrence interval (ARI) of 2 years:

- Site  $t_c = 15$  minutes (calculated site time of concentration)
- Site  $t = 30$  minutes (critical design storm duration selected for protection of a location downstream of the site that is subject to erosion and flooding – refer Engineers Australia (2006) for methods of 't' calculation.)
- $\tau = 15 + 30 = 45$  minutes (time base of the design storm runoff hydrograph – see Figure 2)

Based on the above, the design rainfall intensity  $i_2 = 31.7 \text{ mm/hr}$  (refer to Rainfall Intensity–Frequency–Duration curves for Perth, available from Bureau of Meteorology).

### Runoff Volume

$$\text{Inflow Volume } \nabla = \frac{CiAD}{1000}$$

From *Australian Rainfall and Runoff* Book VIII (Institution of Engineers Australia 2001):

$$C_y = F_y \cdot C_{10}$$

Where:

$C_y$  = runoff coefficient for a 'Y' year ARI

$F_y$  = frequency factor for rational method runoff coefficients

$C_{10}$  = 10 year ARI runoff coefficient (= 0.9 where the fraction impervious = 1)

Therefore, for ARI = 2 years:

$$C_2 = F_2 \cdot C_{10} = 0.85 \times 0.90 = 0.765$$

$$\text{Inflow volume } \nabla = 0.765 \times \frac{31.7}{1000} \text{ m/hr} \times 400 \text{ m}^2 \times \frac{30}{60} \text{ hr}$$

$$\nabla = 4.85 \text{ m}^3$$

### Soakwell Sizing

Determine the diameter (d) of the soakwell:

$$d = \sqrt{\frac{\nabla}{\frac{\pi}{4}(H + 120k_h \tau U)}}$$

Where  $U = 0.5$  for sandy soils.

$$d = \sqrt{\frac{4.85}{\frac{\pi}{4}(2.3 + 120 \times 1.6 \times 10^{-4} \times 45 \times 0.5)}}$$

$$d = 1.50 \text{ m}$$

### Emptying Time

Determine the emptying time (T):

$$T = -\frac{4.6d}{4k_h} \log_{10} \left[ \frac{\frac{d}{4}}{H + \frac{d}{4}} \right]$$

$$T = -10781 \times -0.8533$$

$$T = 9199 \text{ seconds}$$

$$T = 2 \text{ hours } 33 \text{ minutes}$$

The acceptable maximum emptying time for a 2 year ARI event is 1 day (Table 5) of the Infiltration Basins and Trenches BMP), therefore the soakwell design is suitable.

## References and further reading

- Argue, J. R. (Editor) 2004, *Water Sensitive Urban Design: basic procedures for 'source control' of stormwater – a handbook for Australian practice*, Urban Water Resources Centre, University of South Australia, Adelaide, South Australia, in collaboration with Stormwater Industry Association and Australian Water Association.
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- Fletcher, T.D., Duncan, H.P., Poelsma, P. and Lloyd, S.D. 2003, *Stormwater Flow, Quality and Treatment: literature review, gap analysis and recommendations report*, NSW Environmental Protection Authority and Institute for Sustainable Water Resources, Department of Civil Engineering, Monash University, Melbourne, Victoria.
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# Infiltration Systems

## 3.3 Pervious Pavement



Figure 1. Pervious paving in a commercial carpark, Burswood. (Photograph: Department of Water 2006.)

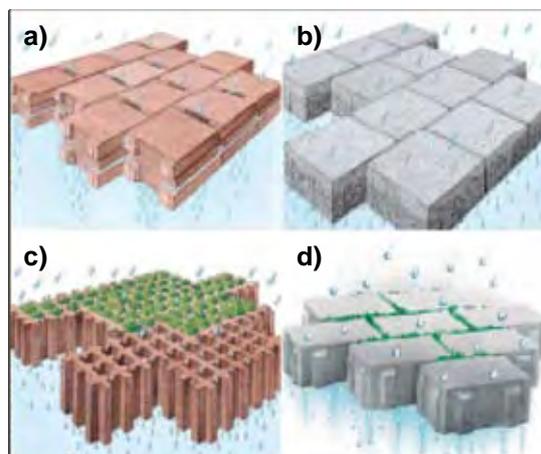


Figure 2. Types of permeable paving: a) pavers with canals b) porous pavers c) greened permeable pavers with small apertures d) greened permeable pavers with wide joints. (Dierkes et al. 2002.)

### Background

Permeable/porous (collectively termed pervious) paving can be used as an alternative to traditional impervious hard surfaces, such as roads, carparks, footpaths and public squares. Bitumen, concrete and other hard surface areas (such as paving surrounding buildings) are typically impermeable and result in high runoff rates during a storm event. This runoff can be reduced by interspacing permeable material, such as lawn or pebbles, between widely spaced impermeable pavers, or by installing porous paving.

There are different types of porous pavements, including porous asphalt pavement, porous concrete pavement and modular interlocking concrete bricks with internal or external drainage cells. Porous pavement comprises a thick layer of highly porous material, for example an asphaltic layer of gap-graded coarse aggregate held together with bitumen, or a well-compacted mixture of graded sand and gravel (Argue 2004).

The porous pavement is typically laid on top of a high-void aggregate or gravel base layer, with a geotextile in between (Figure 3). The stormwater passes through the pore spaces of the pavement, through the geotextile and into the aggregate/gravel layer, which provides temporary storage as the water gradually infiltrates into the subsoil. Where the subsoil has low permeability, the water can be removed by providing a slow drainage outlet to the receiving stormwater system.

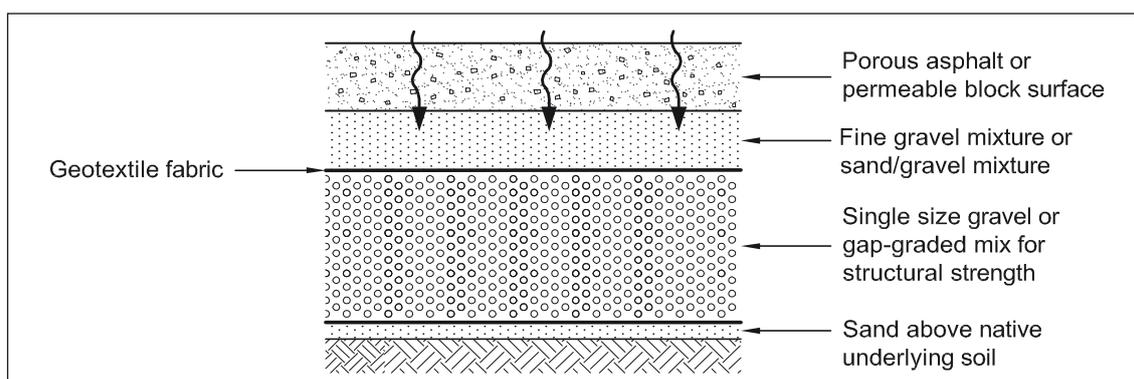


Figure 3. Schematic of a section through pervious pavement.

## Performance efficiency

Pervious pavements can remove sediments and some nutrients, heavy metals and hydrocarbons from polluted stormwater via the processes of adsorption, filtering and biological decomposition.

A field study by Brattebo and Booth (2003) of four different types of porous paving installed in a parking area found no oil, fuel or lead in the water infiltrated through the paving, even though these pollutants were present in the direct surface runoff from the impermeable asphalt control sample.

Field studies have also shown pervious pavement to be very effective at retaining dissolved metals (Dierkes et al. 2002).

Rankin and Ball (2004) found that the impervious area on a road surface reduced from 45% to 5% when pervious pavements were used. Subsequent monitoring found that surface runoff water quality improved and there was no increase in groundwater contaminants.

## Cost

Summary costs for pervious paving are presented in Table 1. These costs are inclusive of excavation and profiling and installation of gravel, sand and geofabric liners.

Fletcher et al. (2004) reported that the typical annual maintenance costs of permeable paving in California (when converted from US dollars) were approximately \$9 700/ha.

**Table 1. Pervious Paving Installation Costs (Boral 2003 cited in Taylor 2005)**

Pervious Paving Method	Construction Cost
Porous paving allowing infiltration	\$111/m <sup>2</sup>
Porous paving over sealed sub-grade allowing water collection	\$119/m <sup>2</sup>
Augmentation with porous paving (i.e. mixing porous with normal pavers)	\$98/m <sup>2</sup>
Porous paving with asphalt	\$67/m <sup>2</sup>
Porous paving with concrete slab	\$90/m <sup>2</sup>

## Design considerations

As with other infiltration systems, designing pervious pavement systems requires consideration of the site conditions and potential contamination of the receiving groundwater environment. A detailed discussion of these considerations is provided in the Design Considerations section of the Infiltration Basins and Trenches BMP.

There are some specific considerations for the design of pervious pavement. Some pervious pavement systems have a high failure rate that is attributed to poor design, clogging by fine sediment and excess traffic use (USEPA 1999).

Pervious pavement systems are not suitable for areas with slopes greater than 5% or high wind erosion rates (USEPA 1999). Soils that feature a rising water table, saline conditions, dispersive clay or low hydraulic conductivity are not suitable for pervious pavement.

Pervious pavement systems require regular vacuum sweeping to prevent clogging by fine sediment and maintain porosity (Water and Rivers Commission 1998). Alternatively, sediment traps and vegetation filter strips can be used to prevent sediment entering the system (Coombes 2003). Excessive vehicle traffic is also a common cause of failure. Pervious pavement should be used for low volume parking and roads with light vehicle use (USEPA 1999). To prevent pervious pavement from being clogged with sediment/litter during road and housing/building construction, temporary bunding or sediment controls need to be installed. See Section 2.1.1 'Land development and construction sites' of Chapter 7 for information about site management practices.

## Design guidelines

*The following method for calculation is based on Argue (2004). The equations are applicable where the overall value of the hydraulic conductivity for the product and its underlying sub-structure is known. This method should be applied with caution to the sizing of infiltration systems where shallow groundwater is present. This approach does not consider the impacts of shallow groundwater in its calculation, which may reduce infiltration capacity. Detailed modelling of shallow water table situations is recommended. Designers should take into account the maximum groundwater level, and hence the minimum infiltration potential, in determining their flood detention design. However, designers should also consider maximum infiltration opportunities to achieve aquifer recharge when the groundwater table is below its maximum level (refer to the Design Considerations section of the Infiltration Basins and Trenches BMP for further discussion).*

The required infiltration capacity of a soil surface, vegetated area or pervious pavement for a selected design storm event (with zero overflow) is calculated by:

$$Q_{peak} = k_h A_{inf}$$

Where:

$Q_{peak}$  = peak design runoff rate from the contributing catchment (m<sup>3</sup>/s)

$k_h$  = design hydraulic conductivity (m/s)

$A_{inf}$  = surface area available for infiltration (m<sup>2</sup>)

Hence:

$$\frac{CiA}{1000 \times 60^2} = k_h A_{inf}$$

Where:

C = runoff coefficient as defined in Institution of Engineers Australia (2001)

i = probabilistic rainfall intensity (mm/hr)

A = total defined catchment area (m<sup>2</sup>), i.e. the area of the treatment surface plus the surrounding contributing catchment area

This equation applies where the infiltration surface is located within the total defined catchment area (A), as shown in Figure 4, the paving is uniformly porous and the overall value of the hydraulic conductivity for the product and its underlying sub-structure is known. However, for permeable paving where part of the pavement area is impervious (for example, area taken up by lattice work) and this has not been accounted for in the overall value of the hydraulic conductivity, a blockage factor must be applied. The blockage factor accounts for the surface area of the pavement that is not contributing to infiltration (as shown in Figure 5).

Hence:

$$\frac{CiA}{1000 \times 60^2} = k_h(1 - \psi)A_{\text{inf}}$$

Where:

$\Psi$  = infiltration surface blockage factor

Note: this equation applies where the infiltration surface is located within the total defined catchment area (A).



Figure 4. Example definition of a catchment area where the infiltration surface is located within the defined site area.

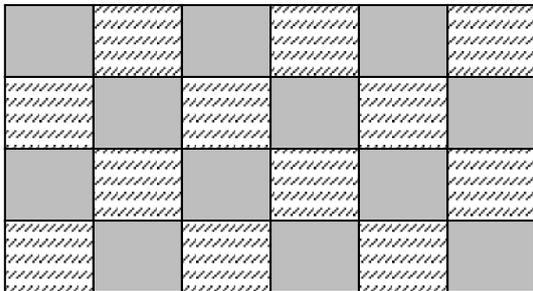


Figure 5. A blockage factor of 0.5 would need to be applied to account for the impervious concrete pavers interspaced with grass squares in this illustration of permeable paving.

Where the infiltration surface is external to the impervious area from which it is receiving runoff (as shown in Figure 6),  $Q_{\text{peak}}$  passing to the infiltration surface must also take into account the rainfall input to the surface itself.

Hence, total peak inflow:

$$Q_{\text{peak}} = \frac{CiA}{1000 \times 60^2} + \frac{A_{\text{inf}}i}{1000 \times 60^2} \quad [\text{m}^3/\text{s}]$$

The flow capacity of the pervious area:

$$Q_{\text{inf}} = (1 - \psi)A_{\text{inf}}k_h \quad [\text{m}^3/\text{s}]$$

To determine the required area of the pervious surface:

$$\frac{CiA}{1000 \times 60^2} + \frac{A_{\text{inf}}i}{1000 \times 60^2} = (1 - \psi)A_{\text{inf}}k_h$$

$$A_{\text{inf}} = \frac{CiA}{1000 \times 60^2 \left[ (1-\psi)k_h - \frac{i}{1000 \times 60^2} \right]} \quad [\text{m}^2]$$

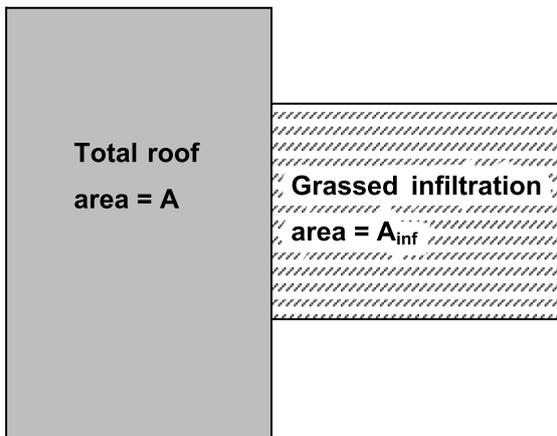


Figure 6. Example definition of a catchment area where the infiltration surface is located external to the defined site area.

Note that in the previous equations, if the soil hydraulic conductivity has been determined by small test pits and boreholes,  $k_h$  should be multiplied by the moderation factor  $U$  (see Table 3 in the Infiltration Basins and Trenches BMP). Where the long-term or life span hydraulic conductivity is used (as described below),  $U = 1$  may be applied.

The design of pervious paving should consider the reduction in permeability of the pervious surface over time due to sediment accumulation and clogging. Laboratory testing found that the permeability decreased to around 30-50% of the original 'new' product value after a period of approximately 30 modelled years (Argue 2004). Over the lifespan of the paving, it is anticipated the permeability reduces to approximately 20% (Argue 2004). Therefore, the design of pervious infiltration systems should adopt a hydraulic conductivity equal to 20% of the 'new' value to ensure acceptable lifespan performance. The lifespan of a pervious paving system will depend on the ratio of impervious to pervious area of the contributing catchment surface, and the catchment characteristics, e.g. the amount of trees and sediment in the catchment. Partial blockage over time of a permeable paving system adjacent to an impervious catchment is illustrated in Figure 7.

The lifespan of vegetated porous surfaces is around five times the lifespan of pervious pavement. Further design information, including estimated lifespans of pervious paving systems under different conditions, is provided Argue (2004).

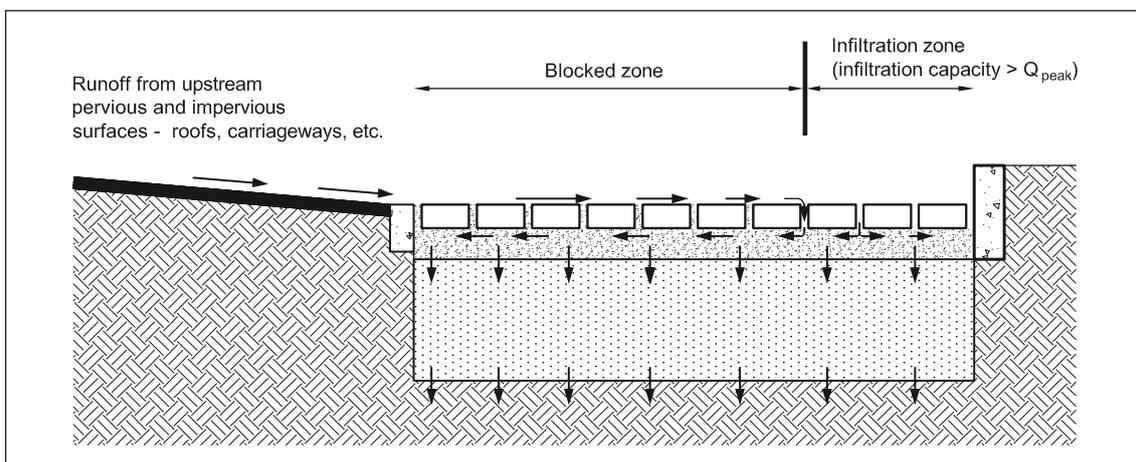


Figure 7. Partial blockage over time of a permeable paving system adjacent to an impervious catchment.

## Maintenance

Maintenance of pervious pavement systems requires regular inspection and cleaning to maintain porosity, repair of potholes and cracks and replacement of clogged areas (Water and Rivers Commission 1998).

Regular vacuum sweeping can improve the efficiency of the system. It is recommended that cleaning be undertaken every 3 months (Coombes 2003). Overseas experience in the use of pervious paving has shown that complete clogging can occur between five and ten years after installation, so cleaning of the paving is essential (Dierkes et al. 2002).

A maintenance schedule similar to conventional road surfaces, involving retaining the pavers and replacing part of the underlying sand to remove contaminants, is also recommended for concrete grid, ceramic and plastic modular blocks (Coombes 2003).

## Worked example

Assess the use of a reinforced turf courtyard to infiltrate runoff from a 200 m<sup>2</sup> adjacent bitumen carpark.

- carpark impervious surface area,  $A = 200 \text{ m}^2$
- blockage factor for the reinforced turf product selected,  $\Psi = 0.1$
- hydraulic conductivity of the 'new' reinforced turf,  $k_h = 2.5 \times 10^{-4} \text{ m/s}$
- the 'lifespan' hydraulic conductivity = 20% of the 'new' value, i.e. lifespan  $k_h = 5 \times 10^{-5} \text{ m/s}$
- site time of concentration,  $t_c \text{ site} = 5 \text{ minutes}$
- ARI = 2 years
- runoff coefficient for a 2 year ARI event,  $C_2 = 0.765$  (see Worked Example section of the Infiltration Basins and Trenches BMP for calculation of C)

Based on  $t_c = 5 \text{ minutes}$  and ARI = 2 years, the rainfall intensity  $i_2 = 78.0 \text{ mm/hr}$  (from Rainfall Intensity – Frequency – Duration curves for Perth, available from the Bureau of Meteorology).

The required area of the courtyard is estimated as:

$$A_{\text{inf}} = \frac{CiA}{1000 \times 60^2 \left[ (1 - \Psi)k_h - \frac{i}{1000 \times 60^2} \right]}$$
$$A_{\text{inf}} = \frac{0.765 \times 78.0 \times 200}{1000 \times 60^2 \left[ (1 - 0.1)(5 \times 10^{-5}) - \frac{78.0}{1000 \times 60^2} \right]}$$

$$A_{\text{inf}} = 142 \text{ m}^2$$

## References and further reading

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## 4 Conveyance Systems

### 4.1 Swales and Buffer Strips



*Figure 1. Flush kerbing and broken kerbing used to allow flow from a carpark into a swale at Point Fraser, Perth. (Photograph: Department of Water 2006.)*



*Figure 2. Vegetated swale in Gosnells, making use of native species in a parkland setting. (Photograph: Department of Water 2004.)*

### Background

Swales are very important for disconnecting impervious areas from downstream surface water bodies and receiving environments. These systems convey stormwater, promoting infiltration and reducing stormwater runoff peak flow, velocity and volume, and remove coarse and medium sediments, including suspended solids and trace metals. Swales also assist in protecting surface water bodies from frequent storm events by reducing flow velocity compared to discharges from hydraulically efficient piped drainage systems.

A vegetated swale is a broad, shallow channel with vegetation covering the side slopes and base. Vegetation can range from grass to native sedges and shrubs, depending on hydraulic and landscape requirements.

Vegetated swales are used instead of the conventional piped system as part of stormwater conveyance. They are usually placed in public open space (Figure 2), or within the median or along the shoulders of main roads, rather than within residential lots and verges. Typically combined with buffer strips and/or bioretention systems, vegetated swales are reliant on hydraulic roughness and gentle slopes to retard flow velocities. Swales also have lower capital costs than traditional piped systems and enhance biological diversity and create beneficial habitat, as well as improve visual aesthetics within a community.

The treatment efficiency of swales is variable for different pollutants and swales may not provide sufficient treatment on their own to meet water quality objectives. However, when used as part of the overall stormwater management system, swales are a useful at-source and in-transit water quantity management tool, whilst providing initial treatment for water quality outcomes.

Buffer strips are areas of vegetation through which runoff passes while travelling to a discharge point and are therefore aligned perpendicular to the direction of flow. They reduce sediment loads by passing a sheet flow of shallow depth through vegetation. The vegetation acts to slow the flow and trap coarse sediments. Buffer strips typically require uniformly distributed flow, such as sheet flow that comes off a road, carpark or other impervious area. Buffer strips also can be applied around other structural BMPs, such as living streams and constructed wetlands.

The processes which occur in vegetated swales and buffer strips are quite complex, and involve physical and biochemical components. Physical processes for particulate removal (and consequently particle-bound pollutants, such as phosphorus) include infiltration, deposition and filtration. Nitrogen removal is a function of denitrification, biostorage (plant and animal uptake) and changes in soil storage.

While providing water conveyance, vegetated swales and buffer strips will often retain and detain water at different times of the year, due to the seasonal nature of local rainfall and variability in groundwater levels. For example, in summer, autumn and early winter in the south-west of WA (when groundwater levels are at their lowest), a swale in sandy soils may perform as a retention/detention system, with the majority of storm events infiltrating and little or no flow occurring.

## Performance efficiency

While essentially a conveyance based system, one of the major roles of swales is to provide disconnection from the receiving environment. Research and past experiences suggest that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quantity and quality. While limited local WA performance data exists for vegetated swales, it is known that riffles, gentle slopes, permeable soil, dense vegetation cover and slow velocity all contribute to successful pollutant removal by the swale system.

Monitoring in the United States of America showed that even vegetated strips adjacent to major roads that were not intended for treatment of stormwater runoff played an important part in reducing the concentrations of pollutants and reducing the volume of stormwater discharged to surface waters as a result of infiltration into the soil (Lantin and Barrett 2005). Studies in the United States of America showed that vegetated swales were capable of removing many pollutants found in stormwater, with reported removal efficiencies of 83% for sediment, 75% for hydrocarbon, 67% for lead, 63% for zinc and 63% for aluminium (Schueler 1995). Removal of heavy metals appears to be directly related to removal of sediment.

Observations in Aberdeen (Scotland) and Brisbane found grass swales and filter strips to be effective means for removal of sediment from urban stormwater runoff (Deletic and Fletcher 2006). An exponential decrease for total suspended solids (TSS) along the grass length was recorded. The removal of TSS along the grass swale is a primarily physical process (sedimentation and filtration), reflecting the balance between flow and particle settling velocity. The higher the flow rate, the longer the distance (and therefore grass length) required to remove suspended solids. Removal of total nitrogen (TN) and total phosphorus (TP) also occurred in the form of exponential decay along the grass length. As the removal performance of grass swales and filter strips is a function of flow rate, grass density, particle size and density, the above conclusions therefore, may not apply in different field situations.

*Australian Runoff Quality* (Engineers Australia 2006) provides estimates of typical expected annual pollutant load removal efficiencies for vegetated swales, as shown in Table 1, based on research of eastern states catchments. Actual swale performance will vary depending on individual design parameters such as temporal variation in flow and pollutant input concentration, vegetation height, infiltration capacity, length of swale and detention (contact) time.

Swale performance in WA is often likely to vary from the efficiencies of swales in the eastern states shown in Table 1, particularly at sites with sandy soils and shallow groundwater. Additionally, infiltration is more likely to be a dominant process at sandy sites. Annual pollutant load removal efficiencies for swales on sandy soils would usually be expected to be higher than shown in Table 1 due to the increased infiltration rate reducing surface water discharge.

**Table 1. Typical annual pollutant load removal efficiencies for vegetated swales**

Pollutant	Expected removal	Comments
Litter	>90%	Should be 100%, provided there is adequate vegetation cover and flow velocities below 0.5 m/s.
Total suspended solids	60–80%	Assumes low level of infiltration. Will vary with varying particle size distribution.
Total nitrogen	25–40%	Depends on speciation and detention time.
Total phosphorus	30–50%	Depends on speciation and particle size distribution.
Coarse sediment	>90%	Assumes re-suspension and scouring prevented by controlling inflow velocity <0.8 m/s and maintaining dense vegetation.
Heavy metals	20–60%	Highly variable, depends on particle size distribution, ionic charge, detention time, etc.

(Source: Engineers Australia 2006)

## Cost

Standard cost data for construction of swales and buffer strips in Western Australia is not readily available.

As a guide, a range of costs for swale and buffer strip construction and maintenance for eastern states areas is presented in Table 2, based on data contained in Taylor (2005). Note: The dollar values quoted in this table have not been adjusted for inflation. For example, if the source of a cost estimate is a 2002 reference, the dollar values are in 2002 Australian dollars.

**Table 2. Cost estimates for swales and buffer strips**

Publication/ Data source	Construction (\$/m <sup>2</sup> )	Annual Maintenance (\$/m <sup>2</sup> /yr)	Location	Description
<b>Swales</b>				
Lloyd et al. (2002)	-	\$2.50	-	Grass swale
	-	\$9.00		Vegetated swales (initial)
	-	\$1.50		Vegetated swales (after 5 yrs)
Fletcher et al. (2003)	\$4.50		Melbourne	Hydromulching, earthwork and labour
	\$9.50			Rolled turf
	\$15 – \$20			Vegetated swale
URS (2003)	\$10	-	Western Sydney	Grass swale (seeded)
	\$18	-		Rolled turf
<b>Buffer Strips</b>				
Walsh (2001)	\$3.50	-	Melbourne	Turf buffer strip
	\$7.50	-		Sedge/mulch buffer strips
URS (2003)	\$10 – \$15	-	Sydney	Grass buffer strip
	\$20 – \$50	-		Native grasses and shrubs

## Design considerations

The most important design consideration for a swale drain is the longitudinal slope. It is important to ensure flow velocities along a swale are kept sufficiently low to avoid scouring of vegetation and collected pollutants. Typically, the slope is considered to be most efficient between 1% and 4% to ensure that velocities do not scour the channel or compromise public safety, whilst at the same time limit ponding at low flows.

Where the longitudinal slope exceeds 4%, riffles along swales can help to distribute flows evenly across the swale as well as reduce velocities. The riffles maximise the retention time within the swale, further decreasing the velocities and better promoting particulate settling.

Vegetated swales can be used for water quality treatment wherever the local climate and soils permit the establishment and maintenance of a dense vegetative cover. The principal selection criteria for swales should firstly address the function of conveyance and secondly ensure that the system has features that will maximise treatment objectives and habitat and aesthetic values.

Pre-treatment for swales may include litter traps at point source inlets and buffer strips parallel to the top of the banks to pre-treat sheet flows entering the swale.



*Figure 3. Bollards used to prevent vehicular access onto a swale for conveying road runoff in Mandurah. (Photograph: Grahame Heal, City of Mandurah.)*

The selection of vegetation can impact the overall performance of the swale. Vegetation should be designed to cover the entire width of the swale, be capable of withstanding peak flows and be sufficiently dense to provide good filtration. For best performance, the vegetation height should be above the treatment flow water level. To ensure that swales are both functional and aesthetically pleasing, they should be incorporated into landscaping features. Using local species, vegetated swales can be low maintenance and be hardy enough to withstand long periods without water once established. Types of suitable vegetation that can be used in a swale include grasses, sedges and tussock grasses and other ground covers (e.g. herb form plants).

Swales are most effective when located within public open space or within the centre medians or verges of roads. Swales should not be located within residential verges if other options are available, due to maintenance and safety issues, as well as the need to provide driveway crossings. To protect the vegetation and thus the integrity of the swale, it is imperative that traffic movements along the swales be prevented. Traffic (including parking) can ruin the vegetation, compact the swale, cause rutting and harden the surface to provide preferential flow paths that do not allow infiltration. Traffic controls can be achieved by selecting swale vegetation along the edges that discourage vehicular movements or by providing physical barriers such as bollards (Figure 3) and non-mountable kerbing.

Another key consideration is the provision of road (median) or driveway crossings. Where possible, the location of the swale should minimise the need for crossovers. 'At grade' crossings follow the profile of the swale. Crossings when constructed 'at grade' reduce the maximum allowable swale batter slopes to approximately 1:9 (vertical to horizontal) to ensure that vehicles can traverse the crossing.

Most crossings are elevated with a culvert system to alleviate low flows. The disadvantage with elevated crossings is cost, particularly in dense urban developments. In addition, safety concerns with traffic movement under potential flood conditions due to blockages or when flows exceed the culvert capacity need to be addressed. For swales located on steep grades, crossings can be designed as a form of riffle to control flows.

Another consideration when locating a swale is to ensure that it will not be in the line of other services, such as sewers and underground electricity. These services will need regular maintenance and as such should not be within swales. Temporary bunding or sediment controls should be installed to protect the swale during road and housing/building construction.

Standing water in poorly designed vegetated swales can result in potential safety, odour and mosquito problems. There is also some potential for unstable conditions and erosion in extreme events that exceed the design event for the system. Therefore, other structural controls within a catchment should be designed to manage stormwater quantity, so that excessively large flows are not conveyed into the swale.

## Design guidelines

Swales can be designed for greenfield applications or in retrofitting scenarios to replace a proportion of the traditional piped network.

Design of vegetated swales needs to consider three types of storm events:

- frequent storm flows (typically up to 6 months to 1 year ARI) for water quality treatment;
- minor storm flows (typically up to 5 year ARI) for conveyance and prevention of nuisance flooding; and
- major flood flows (up to 100 year ARI) to check flow velocities, velocity depth criteria, conveyance within the road reserve and freeboard to the adjoining properties.

Design flows for particular storm events can be estimated using a range of hydrologic methods with varying complexity. For small simplistic catchments, the Rational Method is suitable for peak flow estimation, while for large more complex catchments, use of hydrologic/hydraulic models may be more appropriate for design.

A description of buffer strips is contained in the Inlet structures subsection.

### Swale geometry

The swale's geometrical design is an iterative process that needs to take into consideration the site's constraints including topography, development layout and density, how flow reaches the swale and available reserve width. Design considerations are outlined below:

- The longitudinal slope of a swale is typically controlled by catchment topography. To maintain conveyance and prevent ponding during low flows, the longitudinal slope should not be less than 1%, unless additional treatments such as subsoil drains are present or swales are located in soils providing infiltration opportunities. For more information about prevention of ponding (and therefore reducing mosquito breeding risks), see the Design Considerations and Design Guidelines sections of the Infiltration Basins and Trenches BMP. Where slopes are steeper than 4%, riffles should be constructed at regular intervals to prevent scouring and reduce flow velocities.
- Swale dimensions and contributing catchment area should be selected to ensure 1 year ARI flow velocities for the swale are maintained at less than 0.5 m/s. Swales located within road reserves can be subjected to velocities associated with major flood flows being conveyed along the road corridor. The resultant velocities within the swale should be checked to ensure that the maximum velocity does not exceed 1.8 m/s to prevent scour.
- Riffles are typically low level (e.g. 100 mm) porous rock weirs that are constructed across the base of a swale. A rule of thumb for locating riffles is to ensure that the maximum grade taken from the toe of the

upstream riffle to the crest of the downstream riffle does not exceed 4% (Figure 4). Further information about riffle design is provided in the Living Streams BMP in this chapter.

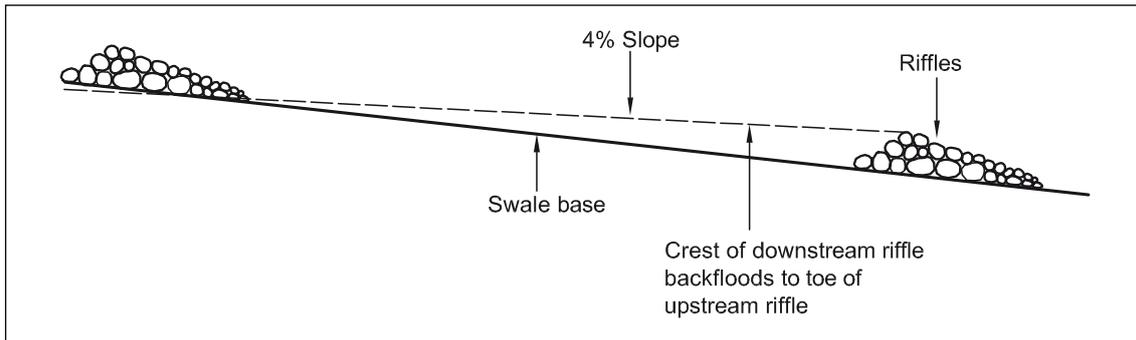


Figure 4. Location of riffles in a swale.

- Side batters should be constructed at 1:6 where possible and should not be steeper than 1:3. The batter slope needs to be able to cater for the design flow, as well as providing a suitable grade for vegetation establishment, access for maintenance, crossovers for lot access and public safety. Typically, the side batter is limited by the available reserve width.

The required width of the swale is that which can adequately contain the design flow within the banks of the swale, given the above design considerations.

### Hydraulic capacity

The hydraulic capacity of a swale can be determined by use of hydraulic models or, for areas not subject to backwater effects, by application of Manning's equation for open channel flow:

$$Q = \frac{1}{n} \cdot A \cdot R^{2/3} \cdot S^{1/2}$$

Where:

Q = flow (m<sup>3</sup>/s)

n = roughness coefficient

S = longitudinal slope (m/m)

A = Cross sectional area of flow (m<sup>2</sup>)

R = Hydraulic Radius (m), defined as A/P, where P is the wetted perimeter (m)

Application of Manning's equation allows both the flow rate and depth to be determined for a range of geometric configuration and vegetation types. The discharge calculations from this equation are significantly influenced by the roughness coefficient, which varies with flow depth, channel dimensions and vegetation type. Typically, between 0.15 and 0.40 is considered reasonable for flow depths less than the vegetation height. The trade-off with planting taller, denser vegetation to increase water quality treatment is that greater setback areas for the swale are required. As flow depth extends beyond the full vegetation height, a sharp reduction in the roughness coefficient can be expected and a corresponding increase in velocity. Figure 5 shows the relationship between the roughness coefficient and the flow depth, with reference to a medium-length sod-forming grass tested in a swale with 5% bed slope. It can be reasonably expected that this relationship will remain consistent with other swale configurations, though there may be a marginal reduction in Manning's n for sheet flows. Manning's n values can also be estimated from tables (e.g. refer to Report No. 9 of Water and Rivers Commission/Department of Environment 1999–2003).

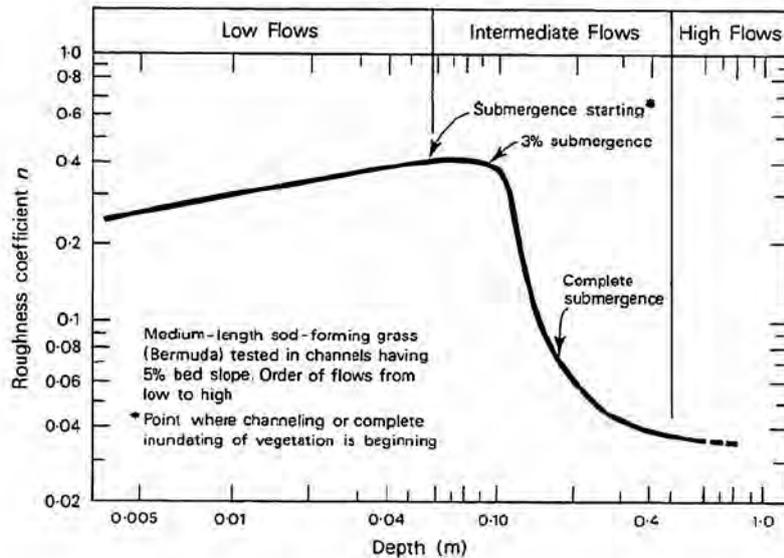


Figure 5. Impact of flow depth on hydraulic roughness. (Source: Engineers Australia 2006.)

### Inlet structures (including buffer strips)

Inlets for swales can either be distributed (via buffer strips) or via point sources such as kerb breaks (Figure 1), pipes and bubble-up manholes.

For distributed flows such as buffer strips, it is essential to provide an area for coarse sediment to accumulate. Typically, the top of vegetation should be at least 40–50 mm below the flush kerb (Figure 6). This would require the top of ground surface (before turf is placed) to be between 80–100 mm below the flushed kerb.

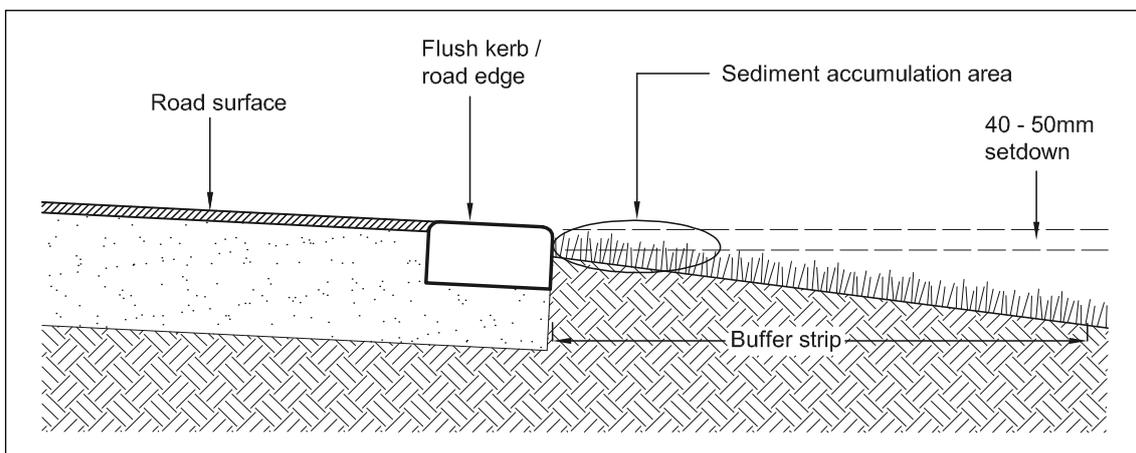


Figure 6. Edge setdown details for buffer strips.

Point source entry can either be from overland flow (e.g. kerb breaks) or from a pipe system. The main consideration for point source entrances into swales is the dissipation of energy at the inlet point to minimise erosion potential. This can usually be achieved with rock beaching and/or dense vegetation.

Bubble-up structures need to be made accessible for maintenance purposes so that any build-up of coarse sediment and debris can be monitored and removed if necessary (Figure 7). The use of bubble-up structures must ensure that residual runoff stored in the manhole can be dissipated, to reduce the risk of mosquito breeding. This can be achieved by making the base of the structure permeable, subject to the nature of the underlying soil permeability. If swales are installed within public open space, it is preferable for them to be

installed within a garden bed rather than in the middle of a grassed area, to improve the recreational amenity and aesthetics of the swale.

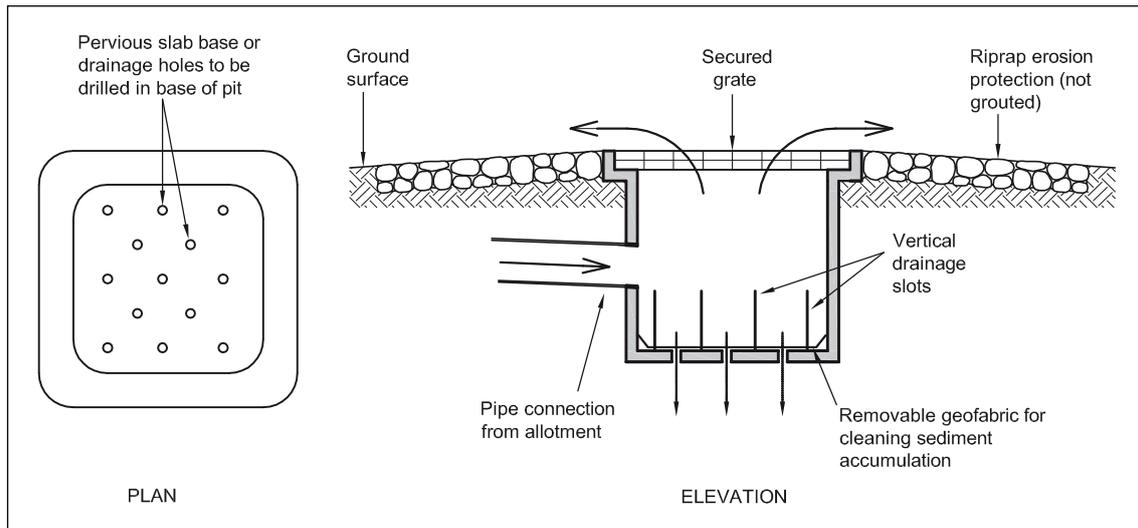


Figure 7. Example bubble-up structure for discharging to a swale.

## Vegetation

Swales can use a variety of vegetation including turf, sedges and tufted grasses.

Vegetation is required to cover the whole width of a swale in order to have a water quality filtering function, rather than simply a conveyance and/or infiltration function. For a turf swale, a fine, close growing, water resistant grass should be selected to increase the surface area of the vegetation exposed to the runoff and thereby improve the effectiveness of the system. Turf swales (see Figure 3 for an example) are useful in residential areas but need to be mown and maintained regularly.

Swales vegetated with sedges and tufted grasses (see Figures 1 and 2 for examples) have a higher hydraulic roughness and require a larger area and more frequent inlet pits to convey the flows compared to turf swales. The dense form and height of tuft grasses or sedges can provide an attractive landscape feature. Pollutant removal efficiency varies greatly depending on the specific plants involved. Selection should therefore emphasise pollution control, but must also ensure that vegetation will be able to thrive under local conditions. Sedges and tuft grasses should preferably be native and should not be weed species.

A description of common rushes, sedges, bulrushes and submergents of the south-west of WA is contained in Report No. 8 of the *River Restoration Manual* (Water and Rivers Commission/Department of Environment 1999-2003). The manual provides details of common species and those available commercially for rehabilitation projects, including details of appearance, location, soil type, water quality, water depth and propagation.

## Maintenance

A monitoring and maintenance plan should be developed for the swale. The maintenance objectives for a vegetated swale system include retaining the hydraulic and pollutant removal efficiency of the channel, and maintaining a dense, healthy vegetation cover. A well-designed and maintained vegetated swale can have a long operating life.

Maintenance should include frequent inspection during the first few months to ensure vegetative cover is establishing well. If required, reseed or plant an alternative species. Once established, continue to inspect biannually for signs of erosion. Weed control and periodic mowing of grass swales (typically biannually),

with grass never cut shorter than the design flow depth, are recommended. Cuttings should be removed from the channel and disposed in a local composting facility. Similarly, vegetated swales should be pruned and harvested in place of mowing. Information on maintenance of vegetation is provided in Water and Rivers Commission/Department of Environment (1999–2003) and BMP 2.2.7 of Chapter 7.

Before winter and after major storm events, debris and blockages should be cleared. Accumulated sediments should be removed to avoid the transportation of resuspended sediments during periods of high flow and to prevent a damming effect from sand bars. Repair of damaged areas within the channel should be undertaken as required. For example, if the channel develops ruts or holes, it should be repaired utilising a suitable soil that is properly tamped and seeded. The vegetation cover should be thick and reseeded as necessary. Swales should also be inspected regularly for ponding, as it can become a nuisance due to mosquitoes breeding in standing water if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or slopes of swales are too flat and inadequately maintained, allowing water to pool for more than four days.

Appropriate traffic control solutions must also be maintained so that correct driving paths are taken and to prevent parking on swales.

### Worked example

As part of a residential development, runoff from a street surface and footpath is to be collected and conveyed in a grassed swale system, located within the verge adjacent to parkland, to downstream treatments. An additional exercise in this worked example is to investigate the consequences on flow capacity of using a vegetated swale with vegetation height up to 300 mm.

The street and footpath will have a one-way crossfall with flush kerbs, to allow for distributed flows into the swale system across the side batter (buffer zone). The swale is to convey minor flood events, including all flows up to 5 year ARI. The width of the swale is fixed at 4.5 m. There will be a maximum catchment area the swale can accommodate, above which an underground pipe will be required to preserve the conveyance properties of the downstream swale. The maximum slope of the swale banks is 1:9 (11%) to allow for easy access for maintenance and safe access for pedestrians to the adjacent parkland.

The contributing catchment area includes a 7 m wide road pavement surface, a 1.5 m wide footpath and a 4.5 m wide swale easement (Figure 8). The area is 250 m long with the top 100 m having a 6% slope and the bottom 150 m having a 3% slope (Figure 9).

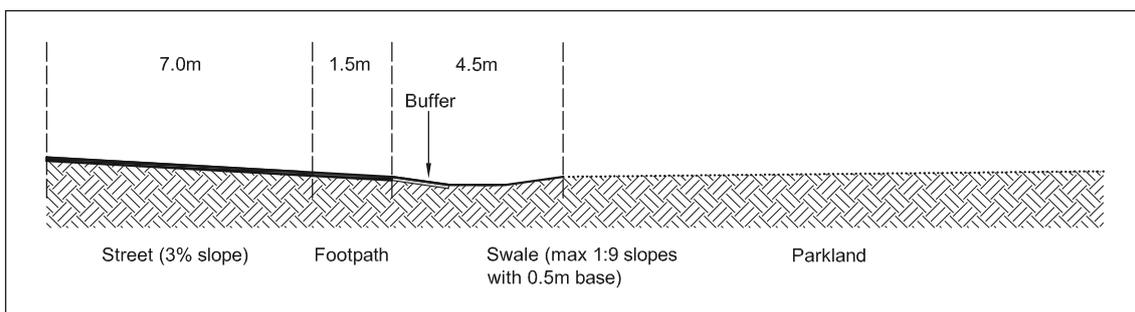


Figure 8. Cross section of proposed buffer/swale system.

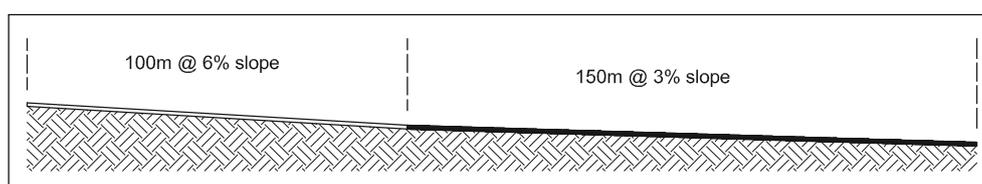


Figure 9. Long section of proposed buffer/swale system.

## Design objectives

This worked example focuses on the design of conveyance properties for the buffer strip and vegetated swale. Analyses to be undertaken include the following:

- design the swale system, including riffles where required
- select vegetation such that the hydraulic capacity of the swale is sufficient
- determine the required capacity of the swale to convey 5 year flows
- check velocities are maintained to acceptable levels
- design the overflow structure from the swale to an underground pipe (if required)
- configure the street kerb details so sheet flow is achieved through the buffer strip
- select suitable buffer strip vegetation

## Site characteristics

Catchment area	Roads and concrete footpath: $250 \text{ m} \times (7 \text{ m} + 1.5 \text{ m}) = 2\,125 \text{ m}^2$ Swale easement: $250 \text{ m} \times 4.5 \text{ m} = 1\,125 \text{ m}^2$ TOTAL = $3\,250 \text{ m}^2$ (i.e., 0.325 ha)
Overland flow slope:	Total main flowpath length = 250 m Upper section = 100 m at 6% slope Lower section = 150 m at 3% slope
Soil type:	Clay
Fraction impervious:	Roads/footpath = 1.00 Swale easement = 0.10

## Estimating design flows

The following example uses calculation methods from *Australian Rainfall and Runoff* (Institution of Engineers Australia 2001). Alternatively, this analysis could be performed using a hydrologic model.

The time of concentration ( $t_c$ ) is estimated assuming overland flow across the allotments and along the swale. From procedures in *Australian Rainfall and Runoff* (Institution of Engineers Australia 2001) Book VIII,  $t_c$  is estimated to be 10 minutes.

Based on Intensity Frequency Duration calculations for Perth Airport, consistent with Institution of Engineers Australia (2001) Book II, rainfall shown in Table 3 is adopted for design purposes.

**Table 3. Design rainfalls for calculated time of concentration**

$t_c$	6 month ARI	5 year ARI
10 min	34 mm/hr	66 mm/hr

Based on Institution of Engineers Australia (2001) Book VIII, the overall runoff coefficient for the catchment is calculated as follows:

$$C_{10}^1 = 0.1 + 0.0133 ({}^{10}I_1 - 25) \quad C_{10}^1 = \text{pervious runoff coefficient}$$

$$C_{10} = 0.9f + C_{10}^1 (1-f) \quad C_{10} = 10 \text{ year ARI runoff coefficient}$$

$f$  = fraction impervious

${}^{10}I_1$  = 10 year ARI 1 hour rainfall intensity

$$f = (2125 \times 1 + 1125 \times 0.1)/3250 = 0.69$$

$${}^{10}I_1 = 29.0 \text{ mm/hr (Perth Airport)}$$

$$C_{10}^1 = 0.15 \quad C_{10} = 0.67$$

Runoff coefficients for various ARI are then calculated as  $C_y = F_y C_{10}$ , with the frequency factor  $F_y$  defined in Table 1.6 of Institution of Engineers Australia (2001) Book VIII.

$$C_1 = 0.8 \times 0.67 = 0.53$$

$$C_5 = 0.95 \times 0.67 = 0.63$$

As the minimum ARI considered for runoff coefficients is 1 year in Institution of Engineers Australia (2001) Book VIII, this is conservatively adopted for calculation of 6 month ARI peak design flows.

Using the Rational Method, peak design flows for the catchment are calculated as:

$$Q = 0.00278.C.I.A$$

Where :

I = rainfall intensity (mm/hr)

C = runoff coefficient

A = catchment area (ha)

$$Q_{6\text{mth}} = 0.00278 \times 0.53 \times 34 \times 0.325 = 0.016 \text{ m}^3/\text{s}$$

$$Q_{5\text{yr}} = 0.00278 \times 0.63 \times 66 \times 0.325 = 0.038 \text{ m}^3/\text{s}$$

### Swale design

To facilitate access, the cross section shown in Figure 10 is proposed.

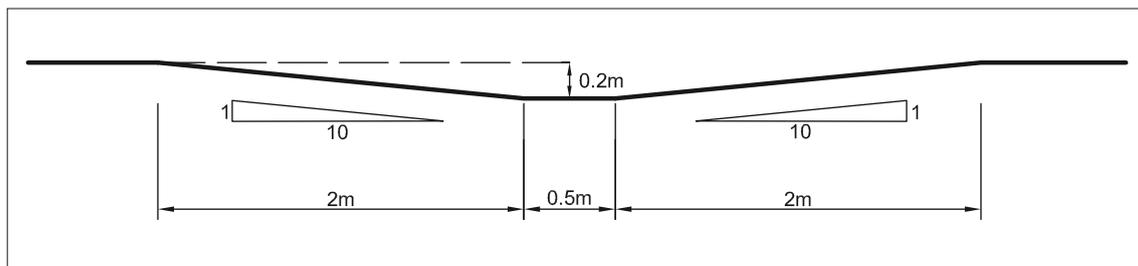


Figure 10. Proposed swale cross section.

The capacity of the swale is then estimated at the most downstream point. This is considered to be the critical point in the swale as it has the largest catchment and has the mildest slope (it is assumed that the dimension of the swale will be the same for both the steep and gentle sloped areas for aesthetic reasons). Flow velocities will also need to be checked at the downstream end of the steep section of swale.

The worked example considers the swale capacity using a grass surface with a vegetation height of 50 mm. A range of roughness coefficients (Manning's  $n$ ) are selected for different flow depths appropriate for grass (Table 4). The height for a flow at the channel capacity will be above the vegetation and therefore Manning's  $n$  is quite low and a figure of 0.04 is adopted (refer to Figure 5). Manning's  $n$  is varied according to the flow depth with reference to the vegetation height (as shown in Figure 5) and the corresponding discharge can be calculated simply in a spreadsheet application using the following procedure:

Flow rate at channel capacity:

Adopted slope = 3% (minimum longitudinal slope)

Manning's  $n = 0.04$  (at 0.2 m depth)

Side slopes 1:10

Area  $A = 0.5 \text{ m}^2$

Wetted perimeter  $P = 4.52 \text{ m}$

Hydraulic radius  $R = A/P = 0.111$

Manning's equation:

$$Q = (AR^{2/3}S^{1/2})/n$$

$$Q_{\text{cap}} = 0.50 \text{ m}^3/\text{s}$$

**Table 4. Manning's  $n$  and flow capacity variation with flow depth – Turf**

Flow Depth (m)	Manning's $n$	Flow Rate ( $\text{m}^3/\text{s}$ )
0.05	0.30	0.003
0.10	0.30	0.01
0.15	0.10	0.10
0.20	0.04	0.50

The capacity flow for the swale ( $Q_{\text{cap}} = 0.50 \text{ m}^3/\text{s}$ ) is greater than the required peak flow rate ( $Q_5 = 0.038 \text{ m}^3/\text{s}$ ). Therefore, the nominated swale has sufficient capacity without any requirement for an additional piped drainage system. From Table 4, it can be seen that both the 6 month and 5 year ARI flow depths are above the vegetation height.

For the purposes of this worked example, the capacity of the swale is also estimated when using 300 mm high vegetation (e.g. sedges). The higher vegetation will increase the roughness of the swale (as flow depths will be below the vegetation height) and therefore a higher Manning's  $n$  should be adopted. Table 5 presents the adopted Manning's  $n$  values and the corresponding flow capacity of the swale for different flow depths.

Table 5 demonstrates that the swale with dimensions shown in Figure 10 is capable of conveying a 5 year ARI flow.

This worked example continues using grass for the remainder of its analysis.

**Table 5. Manning's  $n$  and flow capacity variation with flow depth – Sedges**

Flow Depth (m)	Manning's $n$	Flow Rate ( $\text{m}^3/\text{s}$ )
0.05	0.35	0.003
0.10	0.32	0.01
0.15	0.30	0.03
0.20	0.30	0.07

### Inlet details

Flows reach the swale directly from the road and footpath surface.

Direct runoff from the pavement enters the swale via a buffer (the grass edge of the swale). The pavement surface is set 50 mm higher than the start of the swale and has a taper that will allow sediments to accumulate in the first section of the buffer off the pavement surface. Traffic control is achieved by using traffic bollards between the road and the footpath.

### Velocity checks

Two velocity checks are performed to ensure vegetation is protected from erosion at high flow rates. Velocity is checked to be kept below 0.5 m/s for the 5 year ARI flow event. Velocities are estimated using Manning's equation.

Firstly, velocities are checked at the most downstream location (slope = 3%). From Table 4,  $d_{5\text{-year}} = 0.12$  m, i.e., the flow depth for the 5 year ARI flow event ( $Q_5 = 0.038$  m<sup>3</sup>/s), and the corresponding Manning's  $n = 0.24$ .

Therefore, to calculate the velocity:

$$\begin{aligned} A &= 0.204 \text{ m}^2 \\ P &= 2.91 \text{ m} \\ R &= A/P = 0.070 \text{ m} \\ V_{5\text{-year}} &= \frac{0.07^{2/3} \times 0.03^{1/2}}{0.24} \\ &= 0.12 \text{ m/s} < 0.5 \text{ m/s, therefore OK} \end{aligned}$$

Secondly, velocities are checked at the bottom of the steeper section (i.e. slope = 6% with reduced catchment area).  $Q_5 = 0.015$  m<sup>3</sup>/s for this section.

$$\begin{aligned} d_{5\text{-year}} &= 0.10 \text{ m} \\ n &= 0.30 \\ A &= 0.15 \text{ m}^2 \\ P &= 2.51 \text{ m} \\ R &= 0.060 \text{ m} \\ V_{5\text{-year}} &= 0.12 \text{ m/s} < 0.5 \text{ m/s, therefore OK} \end{aligned}$$

For larger storm events, when the swale is flowing at full capacity, the maximum velocity will be 1.0 m/s. Some scour may occur that would require repair following these infrequent large flow events.

### Vegetation specification

To complement the landscape design of the area, a turf species is to be used in the swale. For this application, a turf with a height of 50 mm has been assumed. Selection of a suitable species will be determined by the landscape architect, consistent with application requirements and design assumptions.

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# Conveyance Systems

## 4.2 Bioretention Systems



*Figure 1. Bioretention swale, soon after construction and planting in Dawesville. (Photograph: Grahame Heal, City of Mandurah, 2006.)*



*Figure 2. Bioretention area constructed in the Treendale development, Australind. (Photograph: Wayne Edgeloe, Thompson McRobert Edgeloe (TME) Consultants, 2006.)*

### Background

Bioretention systems consist of an excavated basin or trench that is filled with porous media and planted with vegetation. These systems provide water quality treatment by removing fine sediment, trace metals, nutrients, bacteria and organics (Davis et al. 1998). Bioretention systems are structural stormwater controls that capture and either retain or temporarily detain stormwater runoff before the water is released to the environment. These systems can reduce the volume of runoff from a drainage area, reducing the required size and cost of downstream stormwater management facilities, by promoting at-source infiltration.

Bioretention swales operate by filtering stormwater runoff through the surface vegetation of a swale, followed by the stormwater percolating into filter media, where filtration, extended detention treatment, denitrification and some biological uptake occurs. Bioretention basins operate in a similar way; however, flows in excess of the design flow bypass the basin to prevent scour, rather than flowing over the surface as occurs in a swale.

Bioretention systems have numerous design applications. These include use as off-line facilities adjacent to parking lots, along highway and road drainage swales, within larger landscaped pervious areas, and as rain gardens and landscaped islands in impervious or high-density environments. Layout of bioretention systems can be very flexible, including linear systems (Figure 1), basins (Figure 2) and planter boxes. The selection of plant species can provide for a wide variety of landscape designs. When properly designed and maintained, these systems are aesthetically pleasing due to the incorporation of plants.

A benefit of bioretention systems over some other structural controls is that they can be applied under a range of different climatic and geological conditions, as the design includes the replacement of the existing soil with an engineered filtration media.

Bioretention systems can be classified as either pervious or impervious. Pervious bioretention systems refer to systems that promote direct infiltration into highly permeable surrounding soils post-treatment. Impervious bioretention systems describe systems in low permeability soils where treated surface runoff can not be effectively infiltrated and is therefore conveyed out of the system via a subsoil or base drain.

While formal use and recognition of bioretention systems as a BMP is relatively new in WA, various techniques and combinations of using infiltration and subsoil drainage systems (with the primary aim of

limiting seasonal groundwater rise), have resulted in informal use of bioretention as a form of stormwater treatment over many years.

### Performance efficiency

Little data exists in WA regarding the performance of bioretention systems locally, particularly in areas with high water tables, where the system performance will vary seasonally with groundwater levels.

The following review of bioretention performance efficiency is provided as an indicative guide only, based on eastern states research with different hydrologic conditions to WA.

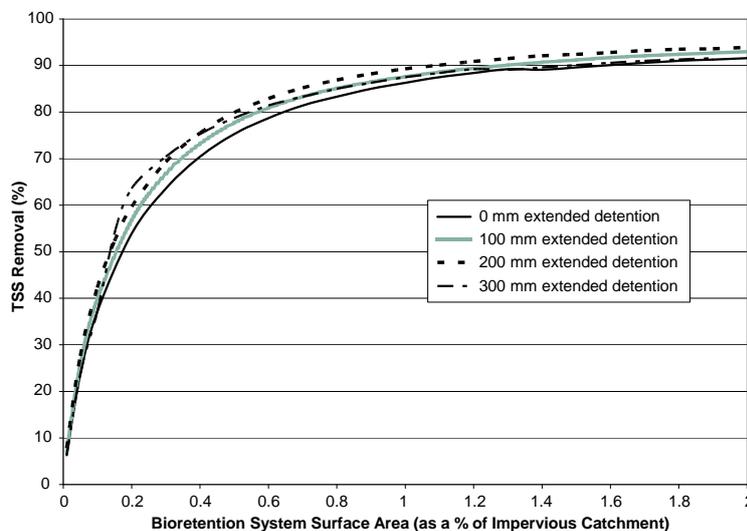
Bioretention systems are generally considered highly effective in removing total suspended solids in typical urban post-development runoff. When sized, designed, constructed and maintained in accordance with the recommended specifications, bioretention systems can expect to have 80% removal efficiency for TSS.

Typical pollutant removal rates for bioretention systems are shown in Table 1 as conservative average pollutant reduction percentages for design purposes derived from efficiencies detailed in Davis et al. (1998), and local Australian sampling data and research by the Cooperative Research Centre for Catchment Hydrology (eWater) based on eastern states conditions using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) (Cooperative Research Centre for Catchment Hydrology 2003).

**Table 1. Effectiveness of bioretention systems**

Pollutant	Effectiveness	Mean % Removal
Litter	-	-
Coarse sediment	High	90%
Total suspended solids	High	80%
Total nitrogen	Medium	50%
Total phosphorus	Medium	60%
Heavy metals	High	80%

Figures 3 to 5 provide example pollutant removal performance efficiencies (TSS, TP, TN) for bioretention systems (either swales or basins) with varying depths of ponding (denoted extended detention in Figures 3 to 5).



*Figure 3. Bioretention system TSS removal performance.*

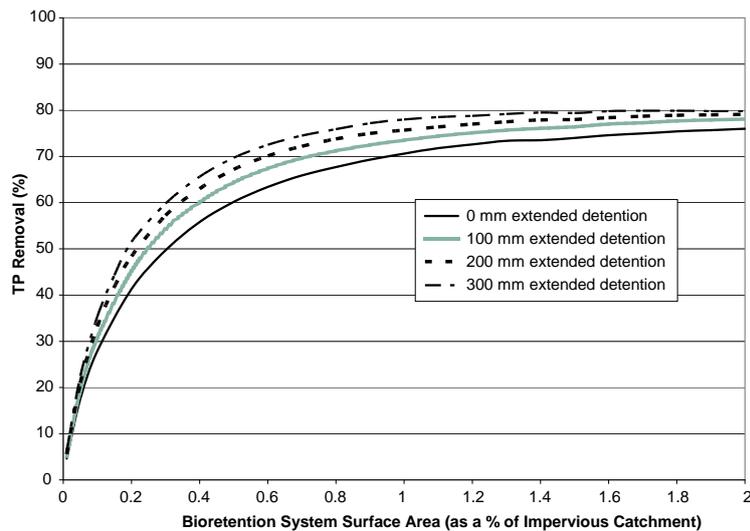


Figure 4. Bioretention system TP removal performance.

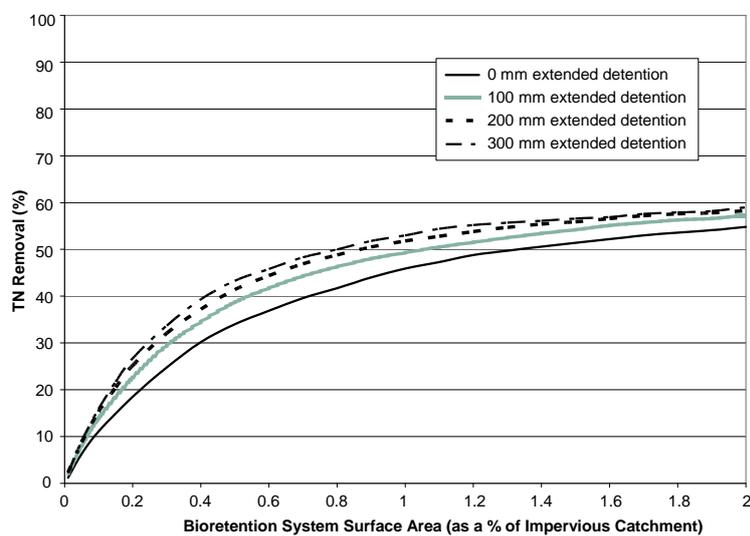


Figure 5. Bioretention system TN removal performance.

The above curves were derived using MUSIC modelling and assume a bioretention system receiving direct runoff without any pre-treatment. The following parameters were used to derive the curves:

- all standard MUSIC defaults were used
- impervious area assumed to be 100%
- filter area = surface area
- seepage = 0 mm/hr
- saturated hydraulic conductivity of 180 mm/hr (corresponding to a sandy loam)
- filtration media depth of 600 mm
- filter media particle size (d50) of 0.45 mm

However, MUSIC has not been fully calibrated in Western Australia for local hydrogeological conditions and BMP performance. Bioretention performance in WA is often likely to vary from the efficiencies of bioretention systems in the eastern states shown in Table 1 and Figures 3 to 5, particularly at sites with sandy soils and shallow groundwater. Additionally, infiltration is likely to be a dominant process at sandy sites. Annual pollutant load removal efficiencies for bioretention systems on sandy soils would usually be expected to be higher than shown in Table 1 and Figures 3 to 5 due to the increased infiltration rate reducing surface water discharge.

Further research is currently being undertaken to benchmark the performance efficiency of bioretention systems in WA. The above curves can be used in the meantime to assist the design process, however caution should be exercised and consideration given to the degree to which the local conditions vary from the modelled parameters.

## Cost

Bioretention systems are relatively expensive to implement compared to some other BMPs. However, the land take required is relatively small in comparison to some BMPs, such as constructed wetlands. A summary of bioretention system costs presented in Taylor (2005) are shown in Table 2.

In any bioretention system, the cost of plants can vary substantially and can account for a significant portion of the expenditure. Costs are likely to be higher than typical landscape treatments due to higher planting densities, additional soil excavation, backfill material, use of subsoil drains, etc.

The operation and maintenance costs for a bioretention system will be comparable to those of typical landscaping for a site. Costs beyond the normal landscaping fees will include the cost for testing the soils and may include costs for a sand bed and planting soil. Taylor (2005) estimated typical annual maintenance costs as 4.3% of the total acquisition cost.

An important consideration when evaluating the costs of bioretention is that it often replaces an area that would otherwise be landscaped. Therefore, the true cost of the bioretention system may be less than has been reported.

**Table 2. Cost estimates for bioretention systems**

Publication/ Data source	Construction (\$)	Maintenance (\$/m <sup>2</sup> /yr)	Location	Description
<b>Basins</b>				
Leinster (2004)	\$125–\$150/m <sup>2</sup>	-	South East	> 100 m <sup>2</sup> area
	\$225–\$275/m <sup>2</sup>		Queensland	< 100 m <sup>2</sup> area
<b>Swales</b>				
Leinster (2004)	\$100-\$120/m	-	South East Queensland	3-4 m top swale width
Fletcher et al. (2003)	\$135/m	\$2.50	South East	Grassed system
		\$1.50	Melbourne	Vegetated system (Natives)
Lane (2004)	\$350/m	-	NSW	-
URS (2003)	\$410/m	-	Western Sydney	3 m wide

## Design considerations

Considerations for selecting a bioretention system are the catchment area to be treated, the slope at the location of the system and of the catchment that drains to it, soil and subsurface conditions, and the depth of the annual maximum groundwater level.

Bioretention systems should ideally be used at or close to source to treat small catchments. When used to treat larger catchment areas, they tend to clog. In addition, it can be difficult to convey flow from a large catchment to the system. When designing for catchments with high sediment loads, pre-treatment devices may be required to capture sediment prior to flows entering the bioretention system.

Bioretention systems can be used in a greenfields development or retrofitting scenario. The advantage of bioretention systems over some other BMPs in a retrofitting scenario is that the relatively small land take and flexibility in shape of the systems enable them to be incorporated into existing road verges, median strips, parkland or landscaped areas. They are generally best applied to areas of flat terrain (< 2%) to allow uniform flow distribution so that water infiltrates the filter medium evenly (Engineers Australia 2006). These systems are therefore most typically applied to parking lots or residential landscaped areas, which generally have gentle slopes.

Bioretention systems can be applied in almost any soils, since they are designed with runoff percolating through a constructed bed of soil and then returning to the stormwater system. However, it is also possible to design a bioretention system to function like an infiltration system, where runoff percolates into the native soil below the system. This infiltration option is considered likely to have widespread application in WA, however it should only be applied when soils and other site characteristics (such as existing groundwater quality and levels) are appropriately considered. In areas where significant infiltration is not intended and the hydraulic conductivity of the local soil is high (similar to the filter media), user of a liner should be considered.

A decision on permeable or impermeable bioretention systems will depend on factors such as potential interaction with groundwater, salinity, and the proximity and sensitivity to water of nearby infrastructure.

Designers need to consider conditions at the site and must incorporate design features to improve the longevity and performance of the system, while minimising the maintenance burden. Plants that are appropriate for the site, climatic and watering conditions should be selected. The appropriate selection of plants will aid in the effectiveness and maintenance of the bioretention system.

Traffic management measures should be put in place to protect the vegetation and prevent compaction of the bioretention system. If the system is being installed in a developing catchment, then measures such as temporarily covering the inlets to the system with filter cloth are recommended to prevent materials washing into and clogging the system. See Section 2.1.1 'Land development and construction sites' of Chapter 7 for information about site management practices.

## Design guidelines

Hydraulic calculations contained within the following design guidelines consider free discharge hydraulic conditions only, and do not consider any backwater effects of downstream hydraulics.

Use of the design guidelines for assessing hydraulic performance should therefore be applied with caution, and the use of hydraulic models is recommended where design of the proposed system and its hydraulic performance are likely to be impacted by a backwater effect of downstream hydraulic conditions.

### Soil media specification

Between two to three types of soil media are required for the bioretention component of the system (Figure 6). It is important to check that the selected media meets the prescribed hydraulic conductivity and geotechnical requirements, and is free of rubbish and any other deleterious material.

A filter media layer provides the majority of the function through fine filtration, as well as supporting vegetation growth, keeping the filter media porous and providing some uptake of nutrients and other contaminants in stormwater. In order to support vegetation growth, the filter media layer needs to be typically between 300–1000 mm in depth. In construction, the material should be placed and lightly compacted to prevent subsidence or uneven drainage.

A drainage layer is used to convey treated flows into the subsoil pipes (if present). This layer is generally constructed using coarse sand or fine gravel (2 mm to 5 mm particle size). The layer should surround the

subsoil pipe and is typically 150 mm thick.

If fine gravel is used, a transition layer of typically 100-150 mm thick and/or a suitable geotextile fabric should be included between the filter media and the drainage layer to prevent the filtration media from washing into the drainage layer and the subsoil pipes. The material size differential should be an order of magnitude between layers to avoid fine material being washed through the voids of a lower layer. The addition of a transition layer increases the overall depth of the bioretention system. This may be an important consideration for some sites and hence pipes with smaller perforations may be preferable.

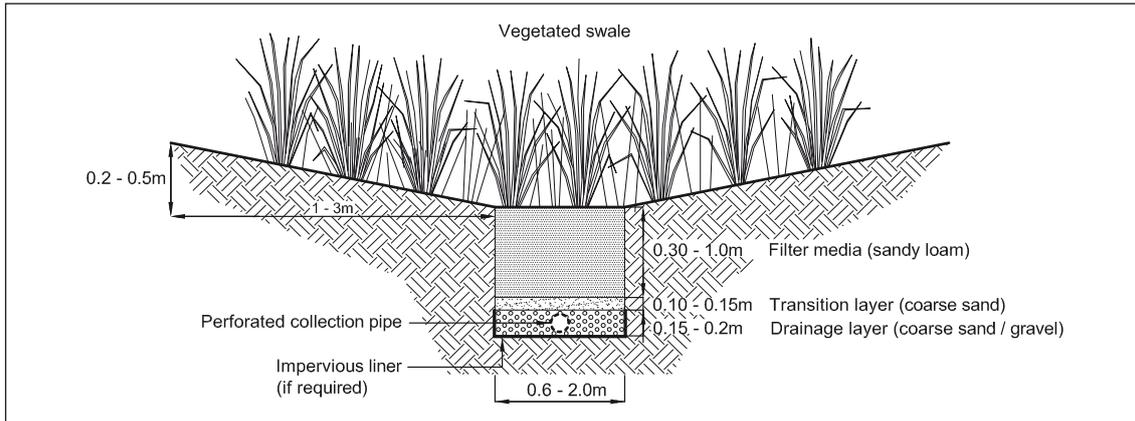


Figure 6. Typical liner arrangement for an impervious bioretention system.

The material for the filter media should be selected to suit infiltration and vegetation requirements. A lower infiltration rate (and higher detention time) may be appropriate where greater ponding above the filtration media is acceptable and can increase the volume of stormwater treated. Table 3, reproduced from Engineers Australia (2006), details typical saturated hydraulic conductivities for various soil types. Typically, filter media consists of a sandy loam with a saturated hydraulic conductivity between 50 and 300 mm/hr (Engineers Australia 2006). The use of a mulch layer or organic material mixed in the filter layer allows for sorption of nutrients (e.g. phosphorus and nitrate).

Table 3. Hydraulic conductivity for a range of media particle sizes (d50)

Soil Type	Particle Size (mm)	Hydraulic Conductivity (mm/hr)	Hydraulic Conductivity (m/s)
Gravel	2.0	36000	$1 \times 10^{-2}$
Coarse Sand	1.0	3600	$1 \times 10^{-3}$
Sand	0.7	360	$1 \times 10^{-4}$
Sandy Loam	0.45	180	$5 \times 10^{-5}$
Sandy Clay	0.01	36	$1 \times 10^{-5}$

Reproduced from Engineers Australia (2006)

Materials such as by-products of industrial processes (e.g. red mud or blast furnace slag) and naturally occurring minerals (e.g. laterite or zeolite) are common media used to effectively adsorb and precipitate phosphorus and other inorganics (Douglas et al. 2004). Treatment media that are commonly used for the nitrogen removal are sawdust (Fahrner 2002; Schipper and Vojvodic-Vukovic 2001, 2000) and woodchips (Jaynes et al. 2004) mixed with sand. While sawdust has been reported to have significantly higher rates of denitrification than woodchips, there are some concerns about durability of finer sawdust media (Horn et al. 2006). Therefore, Horn and others recommended that woodchips should be considered as an alternative

media in the long term due to its durability compared to sawdust. Field trials conducted by Robertson et al. (2000) (seven years), Schipper and Vojvodic Vukovic (2001) (five years) and Fahrner (2002) (16 months) recommended 20-30% volume sawdust/sand to be effective in removing nitrate from groundwater. When using laterite as a filtering media to remove phosphorus however, the recommended amount is 50% volume crushed laterite/sand mix (Douglas et al. 2004).

### Use of impervious liners

For a bioretention system to treat stormwater runoff effectively, water lost to soils adjacent to the bioretention system should be limited.

In the predominantly sandy surface layer of the coastal plains of Western Australia, the saturated hydraulic conductivity is typically more than one order of magnitude higher than that of the filtration media. As soil water flows tend to take the path of least resistance, filtration media can therefore be bypassed. To prevent this water loss from occurring, an impervious liner extending along the sides of the bioretention system (but not the base) is recommended (Figure 7).

Alternatively, where sites have a layer of adjacent lower permeable soil, a drainage layer is to be located at the base to create a head differential to drive flows through the filter layer. If the system is to be an impervious bioretention system, a liner will then typically be installed across the base of the bioretention system (Figure 6).

Impervious liners can have the added benefit of preventing export of water from the bioretention system into sensitive surroundings (e.g. sodic soils, shallow groundwater, or proximity to significant structures). Generally the greatest risk of this occurring is through the base of the bioretention trench. It is therefore recommended that if lining is required, particular attention should be given to the base and sides of the drainage layer. In addition, the base of the bioretention trench can be V-shaped to promote a more defined flow path of treated water towards the subsoil pipes.

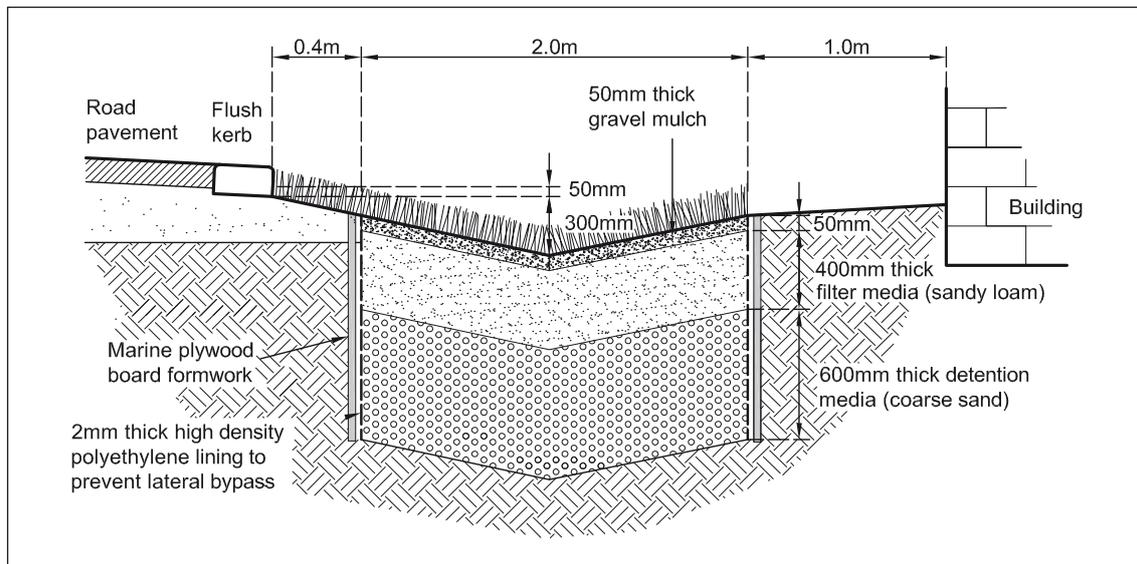


Figure 7. Typical liner arrangement for a pervious bioretention system.

### Bioretention swale design

Design flow estimation, inlet structure details and swale design for a bioretention swale follow the same procedures as the design of a vegetated swale outlined in the Design Guidelines section of the Swales and Buffer Strips BMP, with some minor modifications. Additional guidelines for bioretention swales are described in this section.

The swale's geometrical design is an iterative process that needs to take into consideration site constraints including topography, development layout and density, how flow reaches the swale and the available reserve width.

The maximum infiltration rate through the filtration media must be considered to allow for the subsoil drain (if required) to be sized. The capacity of the subsoil drain, when installed, must exceed the maximum infiltration rate to ensure free draining conditions for the filter media.

The maximum infiltration rate ( $Q_{\max}$  in  $\text{m}^3/\text{s}$ ) through the filtration media can be estimated using Darcy's equation:

$$Q_{\max} = k.L.W_{\text{base}} \frac{h_{\max} + d}{d}$$

Where:

- $k$  = hydraulic conductivity of the soil filter (m/s)
- $W_{\text{base}}$  = width of the infiltration area (m)
- $L$  = length of the bioretention zone (m)
- $h_{\max}$  = depth of ponding above the soil filter (m)
- $d$  = depth of filter media (m)

The suitability for using the above formula for design purposes will need to be assessed for each individual site, considering the influence of both the annual maximum groundwater level and infiltration capacity of surrounding natural soils on bioretention system infiltration, particularly for pervious bioretention systems.

Infiltration modelling software may be required to assess the maximum infiltration rate for design purposes.

### **Sizing of subsoil pipes**

Subsoil pipes are perforated/slotted pipes located at the base of impervious bioretention systems to collect treated water for conveyance downstream.

These collection pipes are sized to allow free draining of the filtration layer and prevent 'choking' of the system. Typically, subsoil pipes should be limited to approximately 150 mm in diameter so that the thickness of the drainage layer does not become excessive. Where the maximum infiltration rate is greater than the capacity of the 150 mm diameter pipe, consideration should be given to using multiple pipes.

To ensure the subsoil pipes are of adequate size:

- perforations must be adequate to pass the maximum infiltration rate into the pipe;
- the pipe itself must have adequate hydraulic capacity to convey the required design flow; and
- the material in the drainage layer must not be washed into the perforated pipes.

These requirements can be assessed using the equations outlined in this section, or alternatively manufacturers' design charts or hydraulic models can be adopted to select appropriately sized pipes.

To estimate the capacity of flows through the perforations, orifice flow conditions are assumed and a sharp edged orifice equation can be used. The number and size of perforations need to be determined (typically from manufacturers' specifications) and used to estimate the total flow rate into the pipe. Secondly, it is conservative but reasonable to use a blockage factor to account for partial blockage of the perforations by the drainage layer media. A factor of two is recommended.

Flow per perforation is therefore defined as:

$$Q_{\text{perf}} = \frac{C.A\sqrt{2gh}}{\Psi}$$

where:

- $Q_{\text{perf}}$  = flow per perforation ( $\text{m}^3/\text{s}$ )
- $A$  = total area of the orifice ( $\text{m}^2$ )
- $h$  = maximum head of water above the pipe (m) (filtration media depth plus ponding depth)
- $C$  = orifice coefficient
- $\Psi$  = blockage factor ( $\Psi = 2$  is recommended)
- $g$  = gravity constant ( $9.81 \text{ m}^2/\text{s}$ )

The Colebrook-White equation can then be applied to estimate the flow rate in the perforated pipe. Note the capacity of this pipe needs to exceed the maximum infiltration rate.

$$Q_{\text{pipe}} = \left[ -2\sqrt{2gDS_1} \cdot \log_{10} \left( \frac{k}{3.7D} + \frac{2.5\nu}{D\sqrt{2gDS_1}} \right) \right] \cdot A$$

where:

- $D$  = pipe diameter (m)
- $A$  = area of the pipe ( $\text{m}^2$ )
- $k$  = wall roughness (m)
- $\nu$  = kinematic viscosity ( $\text{m}^2/\text{s}$ )
- $S_1$  = pipe slope (m/m)
- $g$  = gravity constant ( $9.81 \text{ m}^2/\text{s}$ )

The composition of the drainage layer should be considered when selecting the perforated pipe system, as the slot sizes in the pipes may determine a minimum size of drainage layer particle size. Coarser material (e.g. fine gravel) should be used if the slot sizes are large enough that sand will be washed into the slots.

### Grated overflow pit design

Flows greater than the bioretention swale's design flow are either conveyed by the road reserve and/or by connection to an underground drainage system. To size a grated overflow pit (for discharge/conveyance of larger events above the maximum infiltration rate), two checks should be made for either drowned or free flowing conditions:

1. the broad crested weir equation to determine the length of weir required (assuming free overfall conditions); and
2. the orifice equation to estimate the area of opening required (assuming drowned outlet conditions).

The larger of the two pit configurations should then be adopted for design purposes.

The weir equation for free overfall conditions is:

$$Q_{\text{overflow}} = C.L.H^{3/2}$$

Where:

- $Q_{\text{overflow}}$  = overflow (weir) discharge ( $\text{m}^3/\text{s}$ )
- $C$  = 1.7
- $H$  = head above weir crest (m)
- $L$  = length of weir crest (m)

Once the length of weir is calculated, a standard sized pit can be selected with a perimeter at least the same length of the required weir length. It is considered likely that standard pit sizes will accommodate flows for most situations.

The orifice equation for drowned outlet conditions is:

$$Q_{\text{overflow}} = C.A\sqrt{2gh}$$

Where:

- $Q_{\text{overflow}}$  = overflow (orifice) discharge ( $\text{m}^3/\text{s}$ )
- $C$  = 0.6
- $h$  = available head above weir crest (m)
- $A$  = orifice area ( $\text{m}^2$ )
- $g$  = gravity constant ( $9.81 \text{ m}^2/\text{s}$ )

## Vegetation

Bioretention systems can use a variety of vegetation types including turf, sedges and tuft grasses. Vegetation is required to cover the whole width of the swale or basin and the bioretention media surface to retard and distribute flows and protect the surface of the system. The vegetation should be able to withstand design flows and be of sufficient density to prevent preferred flow paths and scour of deposited sediments. Sedges and tuft grass are preferred to turf for surfacing bioretention systems due to the potential compaction of the media when mowing turf. Denser and taller vegetation also provides better treatment, especially during extended detention time. The vegetation will provide a surface for biofilm growth in the upper layer of the media, which is particularly useful for the transformation of pollutants such as nitrogen. Densely vegetated swales can provide good sediment trapping, withstand high flows, maintain the porosity of the filtration media and also provide attractive landscaping features. Root barriers may need to be installed around sections of bioretention systems that incorporate perforated/slotted pipes where trees will be planted to prevent roots growing into the pipes (Lloyd et al. 2002).

A description of common rushes, sedges and submergents of the south-west of WA are contained in Chapter 8 of the *River Restoration – a guide to the nature, protection, rehabilitation and long-term management of waterways in Western Australia* (Water and Rivers Commission/Department of Environment 1999–2003). The manual provides details of common species and those available commercially for rehabilitation projects, including details of appearance, location, soil type, water quality, water depth and propagation.

## Maintenance

One of the primary maintenance requirements for bioretention systems is to inspect and repair or replace the treatment system components. Generally this involves periodic maintenance of the landscaped area.

Pesticide and fertiliser application to the plants should be limited during the establishment phase and avoided during the operation phase of the system. Regular watering of the vegetation may be required in the establishment phase. Bioretention system components should blend over time through plant and root

growth, organic decomposition and the development of a natural soil horizon. These biological and physical processes will lengthen the facility's life span and reduce the need for extensive maintenance.

A critical maintenance consideration is the monitoring of sediment accumulation at the inlet points. Depending on the catchment activities, the deposition of sediment can smother plants and reduce the available ponding volume. Should excessive sediment build-up occur, it may impact on plant health and lead to a reduction in their capacity to maintain the infiltration rate of the filter media.

Regular sediment removal and inspection and repair of any scour and erosion areas should be undertaken, including assessment after large storm events. Rubbish and other debris should also be removed from the surface components, including inlet structures, culverts and overflow pits.

Routine maintenance should include health evaluation of the trees and shrubs and the subsequent removal of any dead or diseased vegetation. Diseased vegetation should be removed by hand. Diseased plants imply inappropriate species selection, and the choice of plants should be reconsidered under these circumstances. In addition, bioretention systems can be susceptible to invasion by aggressive weeds, which can reduce infiltration and conveyance capacity if not routinely maintained. Vegetation may need to be pruned to maintain conveyance and the appearance of the system.

Highly organic and often heavily vegetated areas in standing shallow water can create a breeding ground for mosquitoes. Routine inspection for areas of standing water and corrective measures to restore proper infiltration rates are necessary to prevent water ponding for more than four days, to eliminate these breeding environments.

Mulch replacement is recommended when erosion is evident or when the site begins to look unattractive.

## Worked example

A site in Perth WA consists of a collector road and a service road separated by a 7.5 m wide median. The median area offers the opportunity for a local treatment measure. The area available is relatively large in relation to the catchment, however is elongated in shape. The catchment area for the swale and bioretention area includes the road reserve and the adjoining gravel parking area (of approximately 35 m depth and with a fraction impervious of 0.6). The layout of the catchment and bioretention swale is shown in Figure 8.

Three median crossings are required. The raised access crossings separate the bioretention treatment system into a two-cell system (referred to in this example as Cell A and Cell B).

Each bioretention swale cell will treat its individual catchment area. Runoff from the collector road is conveyed by the conventional kerb and gutter system into a stormwater pipe and discharged into the surface of the swale at the upstream end of each cell. Runoff from the kerbless service road can enter the swale as distributed inflow (sheet flow) along the length of the swale.

The proposed system will not be subject to any backwater effects and will freely discharge to the receiving downstream pipe network.

As runoff flows over the surface of the swale, it receives some pre-treatment and coarse to medium sized particles are trapped by vegetation on the swale surface. During runoff events, flow is temporarily impounded in the bioretention zone at the downstream end of each cell. Filtered runoff is collected via a perforated pipe in the base of the bioretention zone. Flows in excess of the capacity of the filtration medium pass through the swale as surface flow and overflow into the piped drainage system at the downstream end of each bioretention cell.

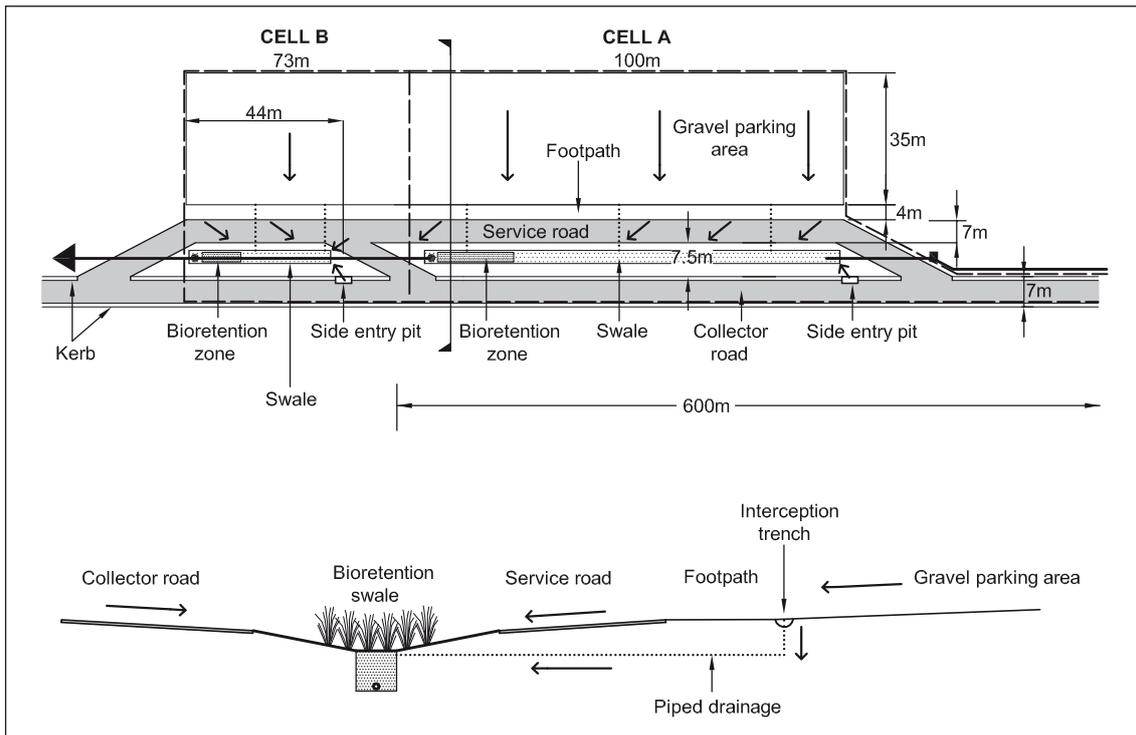


Figure 8. Catchment area layout and section for worked example.

### Design objectives

- Treatment to meet water quality targets established for this site as 80%, 45% and 45% reductions of TSS, TP and TN respectively (compared to development without any water sensitive urban design applied).
- Subsoil drainage pipe to be designed to ensure that the capacity of the pipe exceeds the saturated infiltration capacity of the filtration media (both inlet and flow capacity).
- Design flows up to 5 year ARI range are to be safely conveyed into a piped drainage system without any inundation of the adjacent road.
- The hydraulics for the swale need to be checked to confirm flow capacity for the 5 year ARI peak flow.
- Acceptable safety and scouring behaviour for the 5 year ARI peak flow.

### Design criteria and constraints

- The combined depth of the bioretention filter layer and transition layer to be a maximum of 600 mm.
- Maximum ponding depth allowable is 200 mm.
- Width of median available for siting the system is 6 m of its total 7.5 m width.
- The filtration media available is a sandy loam with a saturated hydraulic conductivity of 4.0 m/day ( $4.6 \times 10^{-5}$  m/s).

### Site characteristics

The site features the following characteristics:

- Overland flow slopes of 1.3% for both Cell A and B
- Clayey soil, with a water table sufficiently below natural surface that it does not impact the design

- Fraction impervious: 0.60 (gravel parking area); 0.90 (roads); 0.50 (footpaths); 0.0 (median)
- Catchment areas as shown in Table 4

**Table 4. Catchment areas**

Catchment	Parking area	Collector road	Service road	Footpath	Median	Catchment area
Cell A	100 m × 35 m	600 m × 7 m	100 m × 7 m	100 m × 4 m	100 m × 7.5 m	9550 m <sup>2</sup> (total)
	3500 m <sup>2</sup> × 0.6	4200 m <sup>2</sup> × 0.9	700 m <sup>2</sup> × 0.9	400 m <sup>2</sup> × 0.5	750 m <sup>2</sup> × 0.0	6710 m <sup>2</sup> (impervious)
Cell B	73 m × 35 m	73 m × 7 m	73 m × 7 m	73 m × 4 m	44 m × 7.5 m	4199 m <sup>2</sup> (total)
	2555 m <sup>2</sup> × 0.6	511 m <sup>2</sup> × 0.9	511 m <sup>2</sup> × 0.9	292 m <sup>2</sup> × 0.5	330 m <sup>2</sup> × 0.0	2599 m <sup>2</sup> (impervious)

### Surface area of bioretention system

Figures 3 to 5 were used with the following parameters to estimate the size of the bioretention system to achieve the required target pollutant reductions specified in the design objectives:

- 200 mm extended detention (ponding)
- Impervious catchment area for Cell A 6710 m<sup>2</sup>
- Impervious catchment area for Cell B 2599 m<sup>2</sup>

Using Figures 3 to 5, the following bioretention system surface areas for each cell are selected:

- Cell A : 61 m<sup>2</sup> = 6 m × 10.2 m (0.89% of impervious catchment area)
- Cell B : 22 m<sup>2</sup> = 6 m × 3.7 m (0.85% of impervious catchment area)

These areas provide expected pollutant reductions of 85%, 68% and 48% for TSS, TP and TN respectively, which exceed the design requirements of 80%, 45% and 45%.

### Estimating design flows

With a small catchment, the Rational Method is considered an appropriate approach to estimate the 6 month and 5 year ARI peak flow rates.

#### *Time of concentration (t<sub>c</sub>)*

Cell A and Cell B are effectively separate elements for the purpose of sizing the swales for flow capacity and inlets to the piped drainage system. Therefore, t<sub>c</sub> is estimated separately for each cell.

- Cell A: t<sub>c</sub> calculations include consideration of runoff from the parking area, as well as from gutter flow from the upstream collector road. Comparison of these travel times concluded that the flow along the collector road was the longest and was adopted for t<sub>c</sub>.
- Cell B: t<sub>c</sub> calculations include overland flow across the parking area and road, as well as the swale/bioretention flow time.

Following procedures in *Australian Rainfall and Runoff* (Institution of Engineers Australia 2001) Book VIII, the following t<sub>c</sub> values are estimated:

- t<sub>c</sub> Cell A : 10 mins
- t<sub>c</sub> Cell B: 8 mins

### Design rainfall intensities

Design rainfall intensities (Table 5) were derived for the example area consistent with Institution of Engineers Australia (2001) Book II.

**Table 5. Design rainfalls for calculated time of concentration (Perth Airport rainfall data)**

Catchment	$t_c$	1 year ARI (mm/hr)	5 year ARI (mm/hr)
Cell A	10 min	34	61
Cell B	8 min	36	66

### Design runoff coefficient

Apply method outlined in *Australian Rainfall and Runoff* (2001), Book VIII:

$$C_{10}^1 = 0.1 + 0.0133 ({}^{10}I_1 - 25)$$

$C_{10}^1$  = pervious runoff coefficient

$$C^{10} = 0.9f + C_{10}^1 (1 - f)$$

$C_{10}$  = 10 year ARI runoff coefficient

$f$  = fraction impervious

${}^{10}I_1$  = 10 year ARI 1 hour rainfall intensity

Overall fraction impervious (based on impervious fractions for individual land use types):

$$\text{For Cell A (area weighted) } f = 6710 / 9550 = 0.70$$

$$\text{For Cell B (area weighted) } f = 2599 / 4199 = 0.62$$

$${}^{10}I_1 = 29.0 \text{ mm/hr}$$

$$C_{10}^1 = 0.15$$

$$C_{10} \text{ for Cell A} = 0.68$$

$$C_{10} \text{ for Cell B} = 0.62$$

Runoff coefficients for various ARI events, as shown in Table 6, are then calculated as  $C_y = F_y C_{10}$ , with the frequency factor  $F_y$  defined in Institution of Engineers Australia (2001) Book VIII, Table 1.6.

**Table 6. Calculated runoff coefficients for various ARI events**

Catchment	$C_1$	$C_5$
Cell A	0.54	0.64
Cell B	0.49	0.58

### Peak design flows

Using the Rational Method, peak design flows ( $\text{m}^3/\text{s}$ ) for the catchment are shown in Table 7, as:

$$Q = 0.00278.C.I.A$$

Where:

$I$  = rainfall intensity (mm/hr)

$C$  = runoff coefficient

A = catchment area (ha)

**Table 7. Calculated peak design flows for various ARI events**

Catchment	Q <sub>1 year</sub> (m <sup>3</sup> /s)	Q <sub>5 year</sub> (m <sup>3</sup> /s)
Cell A	0.051	0.11
Cell B	0.021	0.045

### Maximum infiltration rate

The maximum infiltration rate reaching the perforated pipe at the base of the soil media is estimated by using the hydraulic conductivity of the media, and the available head above the pipe and applying Darcy's equation.

$$Q_{\max} = k.L.W_{\text{base}} \cdot \frac{h_{\max} + d}{d}$$

$$Q_{\max} = 4.6 \times 10^{-5} \times L \times 6.0 \times \frac{0.2 + 0.6}{0.6}$$

Where:

- k = hydraulic conductivity of the soil filter (m/s)
- W<sub>base</sub> = base width of the ponded cross section above the soil filter (m)
- L = length of the bioretention zone (m)
- h<sub>max</sub> = depth of pondage above the soil filter (m)
- d = depth of filter media (m)

Maximum infiltration rate Cell A (L = 10.2 m) = 0.0038 m<sup>3</sup>/s

Maximum infiltration rate Cell B (L = 3.7 m) = 0.0014 m<sup>3</sup>/s

### Swale design

The swales need to be sized to convey 5 year ARI flows to the underground pipe network without water encroaching on the adjacent road. Manning's equation is used with the following parameters.

- base width of 1 m with 1:3 side slopes (max depth of 0.76 m)
- grass vegetation (assume 5 year ARI flows above grass height)
- 1.3% slope

Note the depth of the swale and side slopes are determined by the requirement of discharging the parking area runoff onto the surface of the bioretention system. Given the cover requirements of the parking area drainage pipes as they flow under the service road (550 mm minimum cover), the base of the surface of the bioretention system is set at 0.76 m below road surface.

The design approach taken is to size the swale to accommodate flows in Cell A and then adopt the same dimension for Cell B for aesthetic reasons (Cell B has lower flow rates).

The maximum capacity of the swale is estimated adopting a 150 mm freeboard (i.e. maximum depth 0.76-0.15 = 0.61 m), as shown in Figure 9. Using Figure 5 of the Swales and Buffer Strips BMP, Manning's  $n = 0.038$  for a depth of 0.61 m.

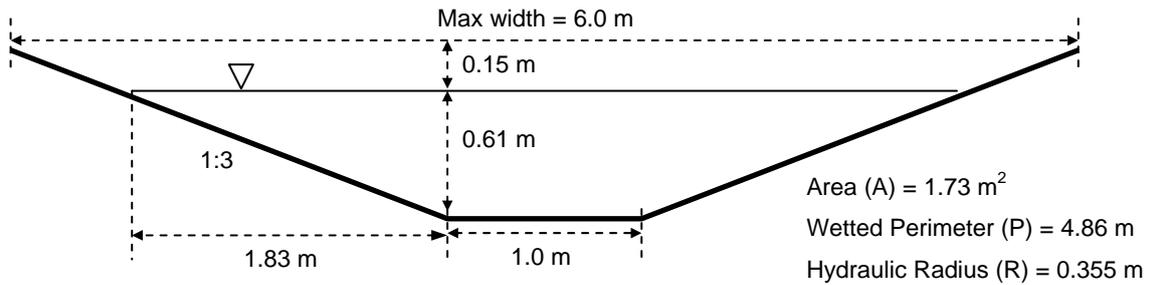


Figure 9. Swale dimensions for the worked example.

Applying Manning's equation, the maximum capacity of the swale is 2.6 m<sup>3</sup>/s. Therefore, there is adequate capacity, given the relatively large dimensions of the swale, to accommodate the catchment runoff connection (Table 7).

### Inlet details

There are two mechanisms for flows to enter the system: firstly underground pipes (either from the upstream collector road into Cell 1 or from the parking area runoff) and secondly direct sheet runoff from the service road and footpath. Flush kerbs with a 50 mm set down are intended to be used to allow for sediment accumulation from the service road and footpath surfaces. Riprap is to be used for scour protection for the pipe outlets into the system. The intention of these is to reduce localised flow velocities to avoid erosion.

### Vegetation scour velocity

To prevent scouring of the vegetation, velocities must be kept below 0.5 m/s during  $Q_{5\text{year}}$ . Using Manning's equation to solve the depth for  $Q_{5\text{year}}$ :

$$Q_{5\text{year}} = 0.11 \text{ m}^3/\text{s}, \text{ depth} = 0.18\text{m (with } n = 0.07 \text{ from Figure 5 of Swales and Buffer Strips BMP)}$$

$$\text{Velocity} = 0.42 \text{ m/s} < 0.5 \text{ m/s, hence OK}$$

Hence, the swale and bioretention system can satisfactorily convey the peak 5 year ARI flood, with minimal risk of vegetation scour.

### Sizing of perforated collection pipes

To estimate the inlet capacity of the subsurface drainage system (perforated pipe), it is assumed that 50% of the holes are blocked. To estimate the flow rate, an orifice equation is applied using the following parameters:

$$\text{Head} = 0.85 \text{ m (0.5 m filter layer depth + 0.1 m transition layer thickness + 0.2 m max pond level + 0.05 half of pipe diameter)}$$

$$\begin{aligned} \text{Pipe opening} &= 2100 \text{ mm}^2/\text{m} \\ &= 1050 \text{ mm}^2/\text{m (allowing for 50\% blockage)} \end{aligned}$$

$$\text{Slot width} = 1.5 \text{ mm}$$

$$\text{Slot length} = 7.5 \text{ mm}$$

$$\text{No. of rows} = 6$$

$$\text{Diameter} = 100 \text{ mm}$$

$$\text{Number of slots per metre} = (1050) / (1.5 \times 7.5) = 93.3$$

Assume orifice flow conditions:

$$Q = CA \sqrt{2gh}$$

$C = 0.6$  (Assume slot width acts as a sharp edged orifice)

$$\begin{aligned} \text{Inlet capacity per m of pipe} &= (0.6 \times (0.0015 \times 0.0075) \times \sqrt{2 \times 9.81 \times 0.85}) \times 93.3 \\ &= 0.0026 \text{ m}^3/\text{s} \end{aligned}$$

Inlet capacity/m  $\times$  total length:

$$\text{Cell A} = 0.0026 \text{ m}^3/\text{s}/\text{m} \times 10.2 \text{ m} = 0.026 \text{ m}^3/\text{s} > 0.0038 \text{ m}^3/\text{s} \text{ (max infiltration rate)}$$

$$\text{Cell B} = 0.0026 \text{ m}^3/\text{s}/\text{m} \times 3.7 \text{ m} = 0.0095 \text{ m}^3/\text{s} > 0.0014 \text{ m}^3/\text{s} \text{ (max infiltration rate)}$$

Hence a single pipe for each cell has sufficient perforation capacity to pass flows into the pipe.

The Colebrook-White equation is applied to estimate the flow rate in the perforated pipe. A slope of 0.5% is assumed and a 100 mm diameter perforated pipe (as above) was used. The capacity of this pipe needs to exceed the maximum infiltration rate.

Estimated flow using the Colebrook-White equation:

$$Q_{\text{pipe}} = \left[ -2 \sqrt{2gDS_1} \cdot \log_{10} \left( \frac{k}{3.7D} + \frac{2.5 \nu}{D \sqrt{2gDS_1}} \right) \right] \cdot A$$

where:

$$\begin{aligned} D &= \text{pipe diameter} &&= 0.10 \text{ m} \\ A &= \text{area of the pipe} &&= 0.0079 \text{ m}^2 \\ k &= \text{wall roughness} &&= 0.007 \text{ m} \\ \nu &= \text{kinematic viscosity} &&= 1.007 \times 10^{-6} \text{ m}^2/\text{s} \\ S_1 &= \text{pipe slope} &&= 0.005 \text{ m/m} \\ g &= \text{gravity constant} &&= 9.81 \text{ m}^2/\text{s} \end{aligned}$$

$$Q_{\text{pipe}} = 0.0027 \text{ m}^3/\text{s} \text{ (for one pipe)}$$

This is less than the maximum infiltration rate for Cell A of 0.0038 m<sup>3</sup>/s, hence the pipe diameter will need to be increased (to a maximum of 150 mm) or two pipes installed to convey the maximum infiltration rate.

### Overflow design

Overflow pits are required to convey flows in excess of the 200 mm maximum ponding depth from above the bioretention system to an underground pipe network. Hence, the inlet of each pit is set at 200 mm above the base of the swale. Grated pits are to be used at the downstream end of each bioretention system.

The maximum head for the pits is equal to the maximum allowable height of flows (i.e. the road surface less the 150 mm freeboard), minus the height of the pits (which is set at the 200 mm maximum ponding depth), i.e.

$$(0.76 - 0.15) - 0.20 = 0.41 \text{ m} \text{ (see Figure 10)}$$

First check using a broad crested weir equation:

$$Q_{5 \text{ year}} = C.L.H^{3/2} \quad \text{with } C = 1.7, H = 0.41 \text{ and } Q_{5 \text{ year}} = 0.11 \text{ m}^3/\text{s}$$

Solving for L results in a required weir length  $L = 0.25$  m (which would be provided by a 62 mm square pit, although standard pits are not available in this size and a larger pit would need to be used).

Now check for drowned outlet conditions:

$$Q = CA \sqrt{2gh} \quad \text{with } C = 0.6$$

$$A = \frac{Q}{C\sqrt{2gh}}$$

$$= \frac{0.11}{0.6\sqrt{2 \times 9.81 \times 0.41}}$$

$$A = 0.065 \text{ m}^2$$

The discharge area required is  $A = 0.065 \text{ m}^2$  (a 300 mm  $\times$  300 mm pit would more than provide this area).

Hence, drowned outlet flow conditions dominate the overflow design. A pit size of 450  $\times$  450 mm for both Cell A and Cell B is adopted as this is the minimum pit size acceptable by the local council to accommodate underground pipe connections.

### Soil media specification

Three layers of soil media are to be used: a sandy loam filtration media (500 mm) to support the vegetation, a coarse transition layer (100 mm) and a fine gravel drainage layer (200 mm).

The design of the system is illustrated in Figure 10.

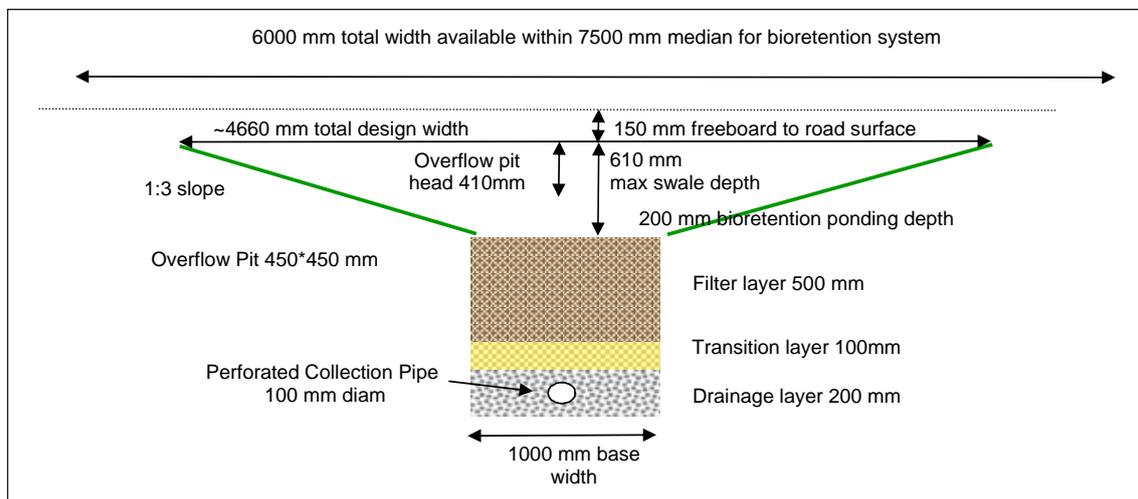


Figure 10. The completed bioretention system design for the worked example.

### Drainage layer hydraulic conductivity

Typically, flexible perforated pipes are installed, surrounded by fine gravel media. In this case study, 5 mm gravel is specified for a 200 mm thick drainage layer. This media is much coarser than the filtration media (sandy loam). Therefore, a 100 mm thick transition layer of coarse sand is used to reduce the risk of washing the filtration layer into the perforated pipe.

## Impervious liner requirement

In this catchment, the surrounding soils are clayey soils with an estimated saturated hydraulic conductivity of approximately 3.6 mm/hr. The sandy loam media that is proposed as the filter media has a hydraulic conductivity of 166 mm/hr (4 m/day).

Therefore, the conductivity of the filter media is > 10 times the conductivity of the surrounding soils and an impervious liner is not required.

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# Conveyance Systems

## 4.3 Living Streams



*Figure 1. Geegelup Brook drain to living stream project, Bridgetown. (Photograph: Cheryl Hamence, Blackwood Valley Landcare 2006.)*



*Figure 2. Paterson Street Drain to Living Stream Project, Bayswater. (Photograph: Bayswater Integrated Catchment Management Group 2004.)*

### Background

A healthy waterway or living stream is a complex ecosystem supporting a wide range of plants and animals (Water and Rivers Commission 1998). Living streams feature stabilised vegetated banks and a more natural morphology (compared to straight drains) that provide diverse habitats for animals such as frogs, fish and waterbirds. The protection of existing waterways and the rehabilitation of degraded waterways into living streams in urban areas are important techniques for improving stormwater management.

Changes to the catchment due to urbanisation can impact the health of waterways in a number of ways:

- increases in flow result in changes to the planform, size and shape of the channel;
- erosion of the channel to accommodate increased flows results in vegetation loss, smothering of habitat, loss of river pools and increased turbidity;
- changes to water quality, due to contaminants delivered by poorly managed stormwater, such as metals that are toxic to aquatic fauna and nutrients that can fuel excessive algal growth that depletes the water column of dissolved oxygen.

Protection and enhancement of existing natural waterways and the design of living streams need to consider the catchment management practices required to establish healthy ecosystems. In spite of the complexity of the physical, chemical and biological interactions, managing the increase in discharge from urbanisation is fundamental to facilitating waterway and ecosystem protection. The management of flood events to protect stream health is also consistent with drainage and flood protection objectives. Minimising changes to the hydrology should be done with application of WSUD measures across the catchment and disconnection of impervious surfaces from streams (Ladson et al. 2006).

Urban waterways are increasingly being recognised for their potential value as multiple use corridors that provide additional benefits to the traditional channel hydraulic objectives. A living stream achieves multiple outcomes, including creating a healthy ecosystem, improving water quality, conveying floodwaters and creating an attractive landscape feature for the residential community (Water and Rivers Commission 1998). The enhanced open space promotes recreational use, and improves environmental and landscape values. Healthy fringing vegetation provides wildlife habitat, ecological corridors, erosion control and

bio-filtering of pollutants. Community understanding through visible linkage of stormwater and environment is also promoted.

This management practice is typically appropriate in areas with degraded natural streams and where there is opportunity to modify existing trapezoidal open drains with significant flows in areas of proposed development. Living streams have also been applied to replace sections of piped drainage, particularly as pre-treatment to a receiving water body. Construction of living streams is suitable for ephemeral, as well as permanent, water regimes.

## Performance efficiency

The major role of living streams in stormwater management is the conveyance of runoff and the provision of stormwater quality improvement, as healthy fringing and aquatic vegetation act as a biological filter.

While primarily providing a conveyancing function, living streams in many instances will also act to retain and detain water at different times of the year, due to the seasonal nature of local rainfall and shallow groundwater levels. The broad floodplain of living streams reduces flow velocities and provides flood storage, reducing the post-development peak flows.

Living streams filter both organic and inorganic material carried in the runoff and will assimilate a portion of the nutrients flushed from the catchment (Pen 1999). The healthier the vegetation and the wider the vegetation buffer, the better the water quality improvement performance of the living stream. Wide buffers allow the interception of overland flow across a greater extent and the trapping of suspended sediment including organic material.

Research on grass strip and other vegetative buffers indicate they can achieve phosphorus and nitrogen filtration rates of the order of 50–100% (Barling et al. 1994; Daniels et al. 1996; Haycock et al. 1996).

Studies in the south-west of WA have demonstrated that total suspended sediment exports can decrease by an order of magnitude from over 100 to less than 10 kg/ha/yr for nitrogen and phosphorus exports, however this may be less in sandy low phosphorus sorption soils due to a change in the form of the nutrients (McKergow et al. 2003).

## Cost

The cost of urban waterways restoration is largely dependent on the extent of improvements required and the site conditions. Existing streams in a natural condition will require minimal costs, often associated with protecting the current conditions (such as using fencing).

More degraded systems may require erosion protection, vegetation management and waterway realignment, which significantly increase costs. River restoration projects are often completed on a voluntary basis by environmental organisations and local community groups, which can reduce costs.

Case studies for river revegetation projects in south-west WA and detailed cost estimates for these projects are contained in Water and Rivers Commission (1999). A summary of costs and indicative works undertaken is shown in Table 1, highlighting the wide range of costs depending on volunteer contributions. Costs for Paterson Street Drain in Bayswater (Figure 2) are considered the most representative in terms of modification of an existing urban drain to a living stream, as costs include (to some extent) professional fees and earthwork costs. Based on this cost, an indicative range of \$20–\$30/m<sup>2</sup> (2006 dollars) is provided as a guide for the conversion of drains to living streams for new development.

Further detailed cost breakdown for individual components of river restoration works, including materials, machinery, equipment, and labour costs are provided in *River Restoration – How much does it cost?* (Department of Environment 2006), available at <<http://waterways.water.wa.gov.au>>.

**Table 1. Indicative costs for waterway restoration projects in WA**

Project	Scope of Work	Total Capital Cost (\$)	Unit Cost (\$/m <sup>2</sup> )
Baigup Reserve, City of Bayswater	Weed control, revegetation, signage and boardwalks for an area of approx 20 ha adjacent to Swan River.	500 000	2.50
Paterson St Drain City of Bayswater	Restoration of 100 m section of Water Corporation steep sided trapezoidal drain. Works included weed control, revegetation and earthworks to lessen bank slope and introduce meanders. Cost includes professional fees of landscape design and survey. Approx total area : 0.15 ha	26 000	17.30
Jane Brook Shire of Mundaring	Weed control and revegetation of Falls Park and Brookside Park Parkerville. Streambed erosion occurring due to flows from upstream urban development. Approx total area of project : 5 ha	106 000	2.12
Avon River Shire of Toodyay	Weed control and revegetation of 1 ha area at Duidgee Park Toodyay. Approx area of project : 0.1 ha	4 600	4.60
Mahogany Creek Shire of Mundaring	Weed control and revegetation of 0.06 ha area of Mahogany Creek in Hovea.	2 400	4.00

Source: Water and Rivers Commission (1999)

## Design considerations

Selecting the location and alignment for living streams is largely dictated by the natural terrain and established flow paths, and in some instances by other planning considerations (e.g. infrastructure requirements).

In considering waterways, priority should be given to maintaining and enhancing natural creeks where possible for their amenity and local significance. Waterway restoration may not be feasible in urbanised areas where space is limited. Where the floodplain has been infilled or developed, it may be difficult to retrofit existing waterways.

Modifications to existing waterways will generally be required where living streams are created from open drains. Channel cross sections, profiles and alignment may need to be modified to manage flow volume and velocity, as well as to provide storage capacity.

Reinforcement of the channel through soft restoration and stabilisation may be required to prevent erosion of the channel banks and bed. Factors such as soil types and stratigraphy and hydrogeological conditions will need to be examined. Highly erodible and deep soils will require careful attention to cross section design and stabilisation of surfaces. Protection measures such as detention areas, grade control structures (e.g. riffles), organic matting, brushing bank protection and use of intensive planting to increase hydraulic roughness can be implemented to manage high velocity zones.

To prevent erosion and improve water quality, vegetation around the stream is required. A vegetative buffer should preferably be of indigenous species, however grass strips are also effective. Deciduous species

should not be planted as they contribute a significant amount of leaf matter to the organic load over one season and also provide less ecological value. The leaves of deciduous species are also softer and degrade faster than the leaves of native plants, releasing nutrients into the waterway.

The invert of living streams should be designed to not intersect the groundwater table. In areas where this is not feasible and the living stream channel intersects the regional groundwater table, groundwater level and water quality investigations should be undertaken to better define the interaction between the waterway (flow, quality) and groundwater, and provide guidance to the design process. The constructed stream should be ephemeral, i.e. the invert of the channel should be dry during the dry season. This is to avoid the creation of warm, stagnant water during periods of little or no flow, as these conditions may result in algal blooms and increased midge and mosquito breeding. See Section 1.7.7 'Public health and safety' of the Introduction section of this chapter for more information on mosquito management. Also see information regarding mosquito management in the Constructed Wetlands, Swales and Buffer Strips and Infiltration Basins and Trenches BMPs.

In the case of retrofitting existing open drains in urban areas, any changes to existing drain inverts, meandering and channel configurations should be hydraulically assessed (modelled) to ensure the existing flood capacity of the drain is maintained and flood levels are not adversely affected by the works.

## Design guidelines

In natural streams, the shape and size of the channel and extent of vegetative growth in the channel are in balance with the discharge characteristics of the catchment. Constructed channels, in the 'living streams' approach, are designed to mimic natural streams with high flows accommodated along the vegetated streamline and its floodway. Infiltration, detention and treatment of the stormwater through contact with vegetation are maximised at base flow and during low intensity rainfall events. During high rainfall events, flood protection is maintained by conveyance in the floodway. Flow velocities can be reduced and flood storage maximised for high flows by providing a broad vegetated floodway. Therefore, designing a living stream requires design of a two-phased system, with a channel for frequent low flows and a floodway for rare larger events.

Guidelines on stream channel analysis, stabilisation and rehabilitation design are provided in *River Restoration – a guide to the nature, protection, rehabilitation and long-term management of waterways in Western Australia* (Water and Rivers Commission/Department of Environment 1999–2003).

### Channel design

Construction or retrofitting of a watercourse should aim to create a natural channel form that replicates the ecological as well as hydrologic functions of a healthy waterway.

Channel variability, including large woody debris, meanders, pools and riffles, is important to create diverse habitat conditions. If available, a reference reach (either a good condition section of the same waterway or a good condition reach of a nearby waterway with similar sized catchment) should be surveyed to determine the natural channel characteristics, including cross-sectional size, channel shape, bed form (bed paving materials, snags, pools, riffles, etc.) and stream alignment, to be used as a reference for channel construction or restoration.

If a reference reach is unavailable, then theoretical equations exist to estimate appropriate channel morphology based on the catchment size and discharge. Oversized channels can lead to problems such as in-stream meandering, sediment deposition, vegetation congestion and subsequent flooding and erosion during large flow events. Undersized channels can lead to flooding, erosion and flows breaking out of the channel. Waterway capacities are sized to provide free flowing conditions that limit the accumulation of sediments and localised ponding. The design of this free flowing condition must not permit supercritical

flow, which may compromise the surface armouring (grass, shrubs, geotextile systems, etc.) or public safety. Typically, flow velocities over vegetated waterways should not exceed 1.2 m/s. Where localised supercritical flow occurs, it should be controlled over hard bed armouring, such as a rock riffle structure.

Manning's equation can be used to estimate the channel capacity and velocity. Hydraulic modelling packages such as HEC-RAS (the US Army Corps of Engineers Hydrologic Engineering Center's River Analysis System) can also be used to design a river channel and analyse parameters such as flow velocities and stage heights.

The stability of a channel can be established by selecting a suitable channel width to accommodate the dominant flow, known as the bankfull discharge. Typically, the bankfull discharge is the average peak flow for a 1.5 year average recurrence interval (ARI) event. The bankfull width is the width of the channel at water level during a bankfull discharge. Flows greater than the bankfull discharge overtop the main channel and flow across the floodway (Figure 3). This two-staged channel approach assists in mimicking natural stream form, increasing storage and controlling flow velocities. Confining flood flows to a deep, narrow channel will increase the potential for erosion and deliver flows faster, increasing the risk of flooding downstream. The floodplain cross section should be evenly sloped on a slight grade towards the low flow channel to avoid waterlogging and water ponding (i.e. to avoid mosquito breeding). Bunds or levees should not be constructed along the banks of the channel as they confine flows to the channel and prevent floodwaters from re-entering the channel from the floodplain as floods recede.

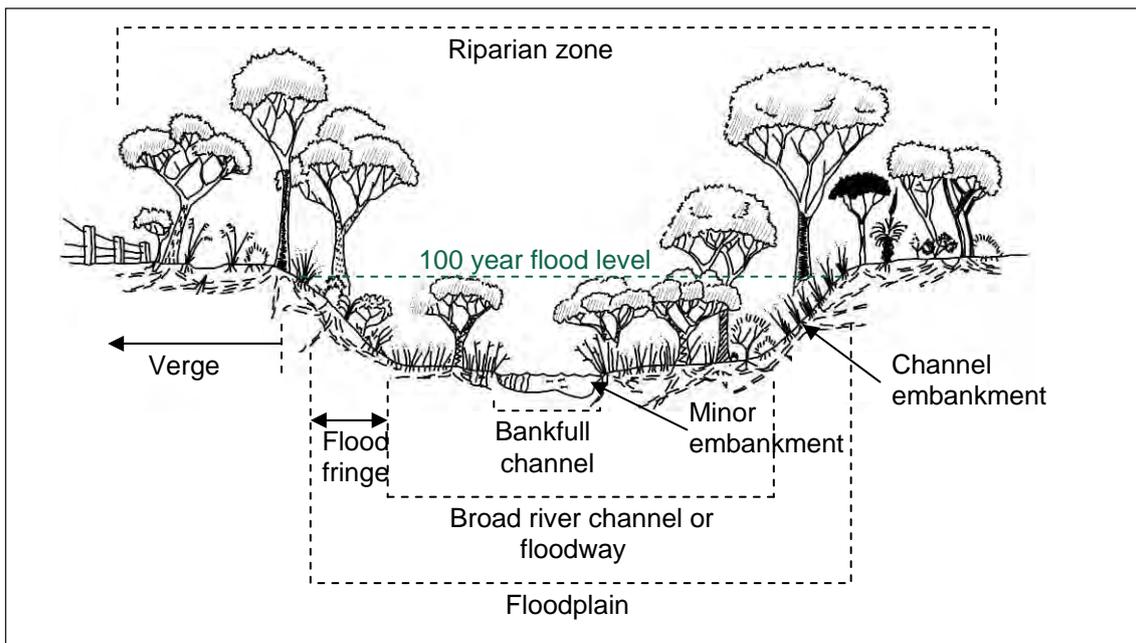


Figure 3. Stages of a natural river channel cross section. (Water and Rivers Commission/Department of Environment 1999–2003.)

Channels should be constructed to give a natural, broad U-shape, rather than a fixed artificial shape such as a trapezoidal or rectangular cross section. Newbury and Gaboury (1993) found the ratio of depth to width for natural channels to fall within the range of 1:10 to 1:15. However, broad, shallow channels are not the most efficient shape for conveying flow and may result in large areas of land being required to meet flood control objectives. If land availability is a constraint, then the conveyance efficiency of the waterway can be increased by designing a narrower, deeper channel, however this will increase the tractive force of flows and may result in additional bed protection being required to prevent erosion (Newbury & Gaboury 1993).

Slope construction must be designed with a consideration of structural stability, free draining conditions, maintenance activities and public safety. For vegetated waterways, slopes should be limited to a maximum

grade of 1:4 to facilitate vegetation establishment and ensure structural stability. A gentler slope of no steeper than 1:6 is required to facilitate ease of maintenance and to provide a safe transition between the bank and the drain invert.

A design aim of constructed waterways is to retain as much of the sinuosity of the natural drainage as possible so that velocities can be minimised, storage capacity can be increased and the ecological and landscape values of the drainage corridor can be enhanced. Studies of watercourse behaviour have shown that this meandering pattern generally provides the greatest stability in channel flow. Straightened drainage lines are often observed attempting to rebuild a natural meander pattern over time and require ongoing maintenance to retain an artificial alignment. Leopold, Wolman and Miller (1964) observed that river patterns consisted of the following characteristics (Figure 4):

- a full meander wavelength is found to occur between 7 to 15 times the bankfull width;
- the average distance between the ends of riffles is half the meander wavelength;
- typically, the radius of the sinusoidal curves ranges between 2.3 to 2.7 times the bankfull width.

The longitudinal slope of the constructed or retrofitted waterway should be the same as the natural (pre-interference) grade of the waterway or reference waterways in the region. Slopes steeper than 1:100 are feasible by using engineered bed armouring or a series of grade controls such as a riffle sequence. Gentler slopes may be required in open earth channels or where vegetation alone armours the bed. Very flat longitudinal slopes may result in waterlogging or stagnant ponds, however this may not be an issue in well-draining soils (e.g. coastal plain sands).

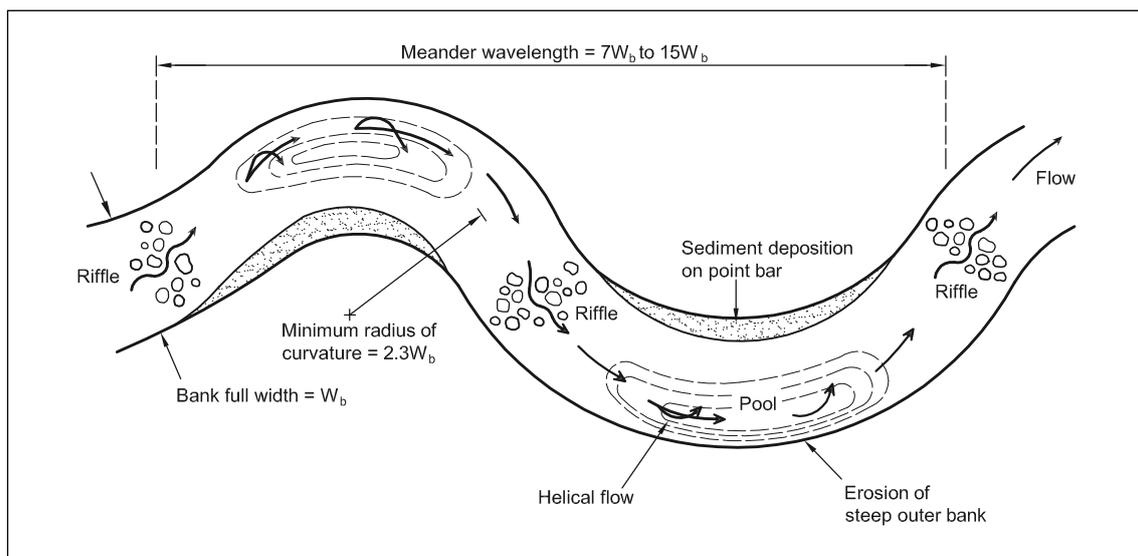


Figure 4. Theoretical meandering stream channel form. (Water and Rivers Commission/Department of Environment 1999–2003.)

### Erosion prevention

Protection against erosion is a key factor that needs to be considered as part of channel design. Materials ranging from stone pitching and gabions to vegetation and geotextiles can be used to bind the soil and reduce velocities. Vegetation is particularly effective in preventing erosion and is discussed in a separate section. Design guidelines for erosion prevention at confluences, discharge points for stormwater and channel crossings, and techniques to prevent channel erosion are outlined in this section.

Erosion often occurs in the vicinity of crossings on waterways. Bridges or culvert crossings should be designed so that they do not obstruct flow or inhibit the migration of aquatic fauna. The design should ensure that the local hydrology and stream characteristics (e.g. meanders) remain essentially unchanged. Open span bridge/arch structures or low level floodway crossings are preferred where feasible to minimise

interference with the natural flows and aquatic habitat of a river channel. If culverts are being used, then multi-celled box culverts that replicate the cross section shape and size of the channel are recommended so that flows are not concentrated or flooding increased and to provide faunal passage. At least one of the box culverts (located nearest to the bank) should be recessed below bed level to allow fish passage. Rocks can be adhered to the base of the culverts to reduce velocity and provide suitable conditions for fish movement (Witheridge 2002). Crossings with pipe culverts are not recommended on waterways due to problems associated with jetting effects, erosion, blocking with debris and creating barriers to faunal movement. Bridge pylons and culverts should be aligned perpendicular to the main flow channel. Crossings should be located along a straight reach of the river or meander inflection point (where the flow crosses from one bend into the next). Crossings should not be located at or near bends due to the potential to cause bank erosion. Erosion protection of the bed and banks in the vicinity of the crossing should be provided.

Channel instability can occur at the confluence of watercourses. The constructed channel should enter the receiving waterway at a gentle angle (rather than at right angles) to direct flows in the same direction as the main waterway and minimise the risk of erosion. The channel should also enter at the same bed level so that head-cutting does not occur.

Direct discharge of piped stormwater to a receiving waterway should be avoided where possible. Ideally, piped flow should cease at the boundary of the riparian area of the receiving living stream and flow made to spread out and filter through buffer vegetation prior to entering the waterway channel. Where piped flow enters waterways, the invert level, size, slope and alignment should be designed to minimise potential impacts on the waterway. Adequate wing and cut-off walls at the exit of the culvert should be provided to control the flow, prevent erosion and avoid failure of the structure. Armouring of the bed and banks around the culvert outlet is often required to prevent erosion of the waterway.

Different bed materials and channel conditions will have different velocity thresholds and resistance to erosion. Recommended maximum design velocities to prevent erosion of various channel materials are detailed in Table 2.

**Table 2. Recommended flow velocities for various bed materials**

Type of waterway bed material	Recommended maximum flow velocity
Rock lined channels (100–150 mm)	2.5–3.0 m/s
Grassed covered surfaces	1.8 m/s
Stiff, sandy clay	1.3–1.5 m/s
Coarse gravel	1.3–1.8 m/s
Coarse sand	0.5–0.7 m/s
Fine sand	0.2–0.5 m/s

Source: Concrete Pipe Association of Australasia (1983)

Log structures can also be used to increase channel roughness, enhance stream habitat and stabilise the streambed. Large woody debris can be placed across the channel or aligned close to the banks to assist stream stability and create habitat (Figure 5). In-stream large woody debris (logs and branches) are a feature of natural waterways and important for providing stable habitats, food sources and shelter for aquatic fauna. Further information on the importance and installation of large woody debris in waterways is provided in Water and Rivers Commission/Department of Environment (1999–2003); Water and Rivers Commission (2000a, 2000b and 2000c).



Figure 5. a) Construction of a log and rock riffle structure in the Canning River, Pioneer Park, Gosnells. (Photograph: Department of Water 2004.) b) Log riffle built on the South Dandalup River, Pinjarra, to stabilise the sandy riverbed, induce a scour pool and enhance habitat diversity. (Photograph: Water and Rivers Commission 1999.)

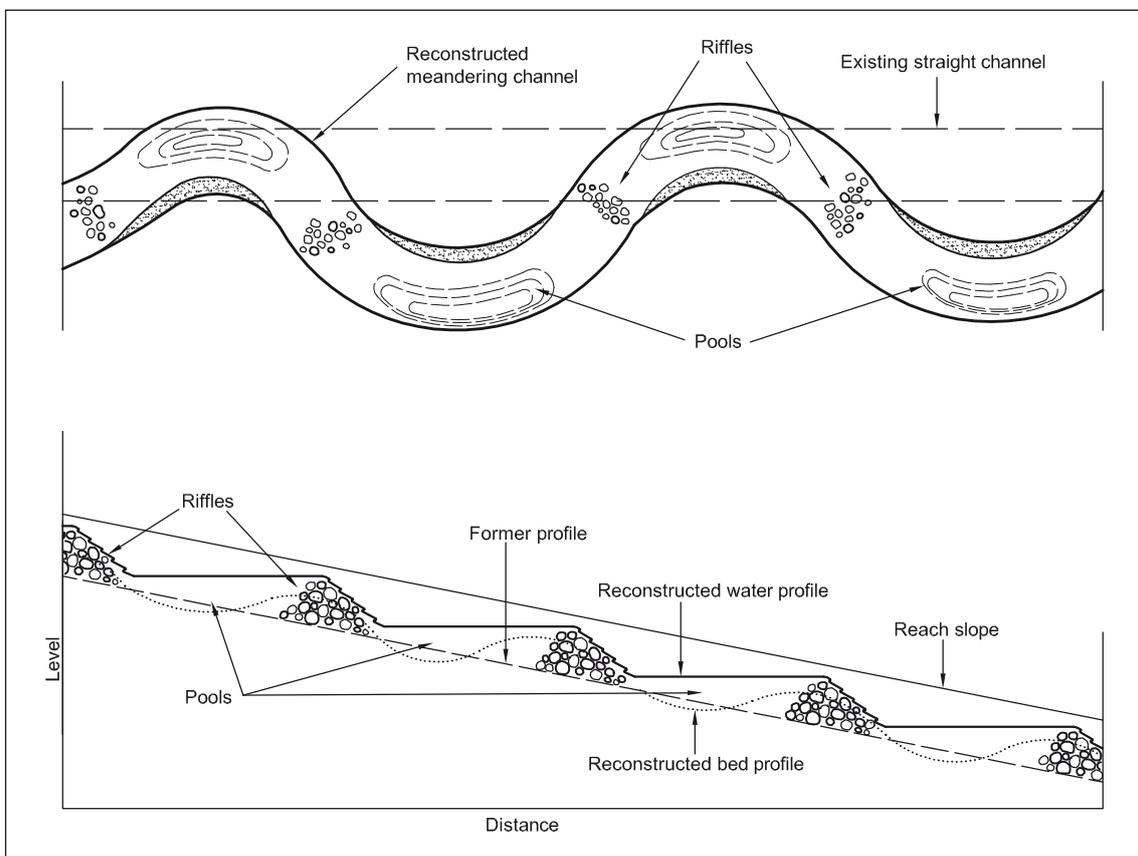


Figure 6. Ideal reconstructed channel alignment and pool-riffle sequence. (Water and Rivers Commission/ Department of Environment 1999–2003.)

The degradation of channels caused by erosion can be managed by rebuilding the pool-riffle sequence for streams in steeper areas. This technique involves using riffles to increase the bed level and control the slope of the reach to achieve stability. Flows over unstable reaches are controlled using a series of step pools (Figure 6). A pool-riffle series was used to control the steep 0.7% slope of Geegelup Brook and restore habitat (Figure 1). The banks of the trapezoidal channel were regraded to a gentler slope and revegetated. Pool-riffle sequences also have the added benefit of promoting favourable habitats by increasing the holding capacity of water within the reach, creating pools that are a focus for fish and are typically a refuge for aquatic fauna during the dry season. Unlike traditional weirs and drop structures, riffles do not block the migration of fish and other aquatic fauna, but do enhance the habitat diversity of the waterway,

encourage the growth of biofilms and aerate flows. If fish are present in the receiving waterway, then the channel should be designed so that there are no barriers to the migration of fish into the constructed channel. Fish require access along waterways and to floodplains and tributaries for breeding and other life cycle processes. Guidelines for riffle design can be found in Water and Rivers Commission/Department of Environment (1999–2003).

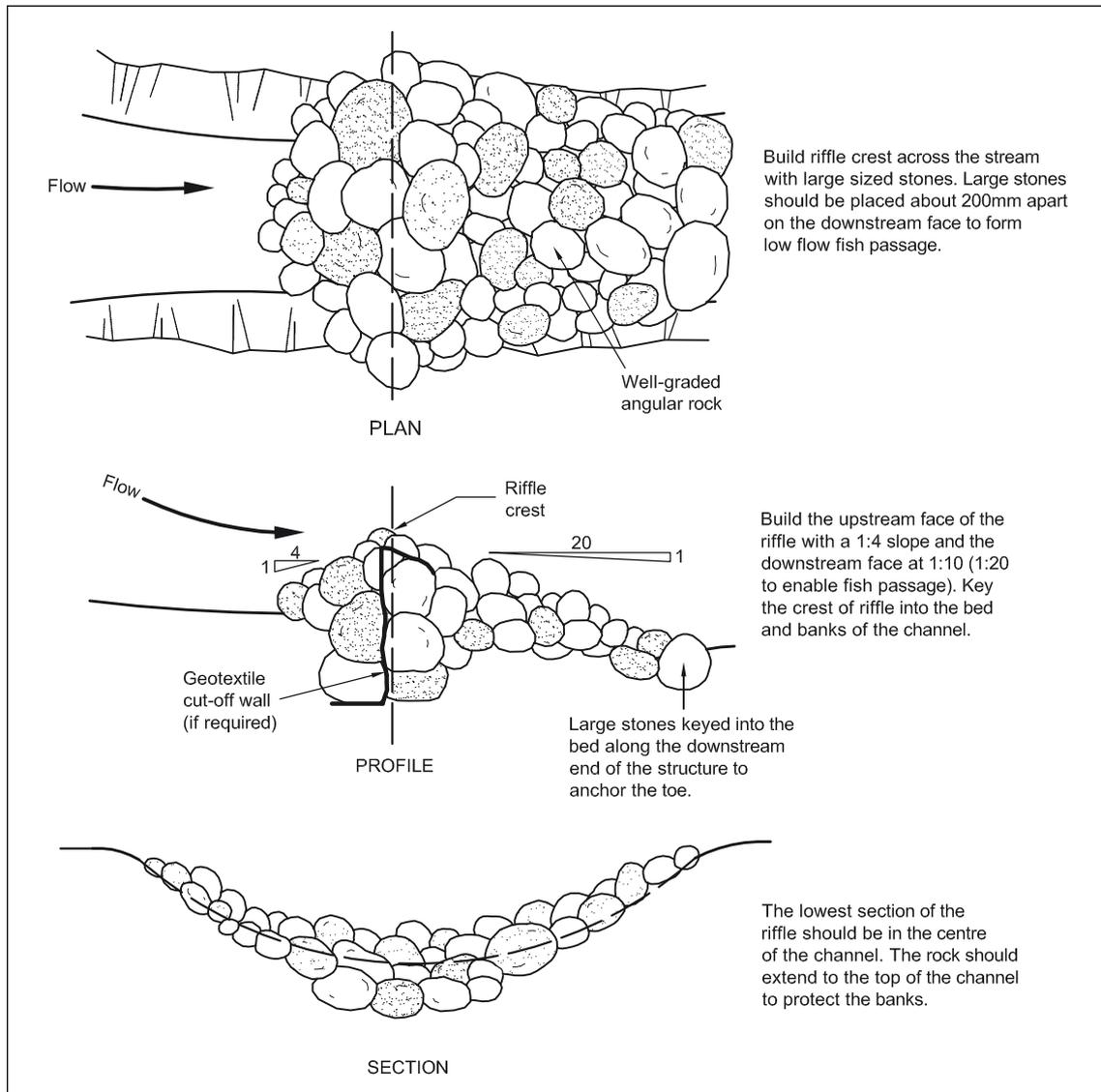


Figure 7. Design details for riffle construction.

The following considerations should be included in the design of riffle sequences:

1. Riffles should be located along straight reaches of the waterway or at meander inflection points (Figure 4). Riffles should not be located on bends as they may direct flows into the downstream bank, causing erosion.
2. The heights of the riffles should be set to follow the average slope of the reach. If using riffles to control erosion, the height of the riffle should backflow to the base of the next riffle upstream (Figure 6).
3. Riffles should typically be designed to block no more than 10% of the channel cross-sectional area and the height be kept under 500 mm to minimise disruption to high flows.
4. The crest of the riffle should be keyed into the bed and banks and the rocks extended to the bankfull level in the batters (Figure 7).

5. Use a range of rock sizes to allow for interlocking and to minimise voids in the structure. The minimum rock sizing can be estimated by determining the maximum tractive force during critical flows. The CHUTE design package can be used to assist analysis of critical flow conditions and guide appropriate rock sizing. CHUTE is available on the eWater Cooperative Research Centre Catchment Modelling Toolkit website: <<http://www.toolkit.net.au>>.
6. The downstream rock apron should typically be constructed with a grade of 1:10. Where fish are present in the waterway, a grade of 1:20 is required to allow for fish passage.
7. In dispersive or non-cohesive soils, filter cloth may be required to line the channel beneath the rock. If using filter cloth on the banks, ensure the bank angle is well below the angle of repose of the rock to minimise the risk of failure caused by the rock slipping on the cloth.
8. To prevent flows piping between the rocks and washing out materials, filter cloth or a clay liner can be used to form a vertical cut-off wall through the crest of the riffle to below bed level.

### **Vegetation management**

Managing vegetation in living streams is primarily aimed at addressing four key issues: stabilising natural surfaces against erosion by providing the necessary armouring; attenuating and treating stormwater flows; improving aesthetic value of multiple use corridors; and improving the ecological value of the catchment. The modification of existing vegetation should only be undertaken if a clear net gain to the overall waterway health can be demonstrated.

Native plants that provide shade and have hard leaves that decompose slowly are essential elements of healthy stream ecosystems. The type of species used in living stream revegetation should reflect those that are native to the botanic region within which the waterway is located, and preferably within the same local provenance. This is because such species are better adapted to local conditions; it avoids contaminating and possibly degrading the gene pool; and avoids the possibility of generating new weedy species. Even when the specific objective of the revegetation is nutrient management, there is often no need to import non-local species.

In choosing appropriate species, the soil limits of the species should be considered. The hydroperiod and flow velocity is also important to plant species selection. Given the cyclical nature of the local rainfall pattern in Western Australia, plant species selection needs to consider the dry seasonal periods that typically extend 5 months each year. The wetland species can be defined as permanent or seasonal inundation tolerant. Their ability to survive inundation and waterlogging will be based on special physiological attributes such as the presence of air cells within the roots and stems. Runner type native grasses (rather than clumping varieties) and sedges and rushes that can bend in high flows and protect the channel from erosion are recommended in frequently flowing areas. A range of species should be selected to increase biodiversity and resilience of the community, allowing for varying success in survival, and should include sedges, submergents, shrubs and trees. Direct seeding, planting, transplanting, application of pre-seeded matting and brushing with branches harvested from plants bearing mature seeds are all techniques available to revegetate the living stream. Revegetated areas may require protection from erosion, grazing and trampling. Tree guards, fencing, organic matting and deflectors can be used to increase the success rate of plant establishment.

A vegetation plan is a useful tool for determining the area to be revegetated and/or the area of vegetation to be retained and enhanced, the range of soil types and riparian zones present, the number of plants/seeds required and timing schedule. A basic plan may include the following requirements:

- define floodplain, embankment and channel bed area (m<sup>2</sup>) requiring revegetation;
- characterise water quality – salinity, nutrients and turbidity;
- identify existing soil, vegetation community species and existing weed characteristics and extent in the waterway;

- map the morphology (plan and cross section) and indicate annual flood line and points of erosion and deposition;
- ongoing review of the success of the plantings and weed management.

Recommended buffer widths for waterways are determined using biophysical criteria, as outlined in Water and Rivers Commission (2001). The minimum recommended buffer of native vegetation adjacent to constructed waterways in urban areas is 10 to 20 m from the top of the bankfull channel. The channel banks and a minimum 10 m wide strip along the top of the banks should be vegetated with native vegetation. For natural waterways, a ‘foreshore reserve’ width of 30 m is recommended (Western Australian Planning Commission 2006). However, a flexible approach for determining a waterway reserve setback is recommended, to account for site conditions such as topography, waterway form, vegetation complexes, soils and extent of the floodway. Consideration of these site conditions when determining the buffer for a constructed waterway is also applicable and might result in a buffer greater than 10 m. It is recommended that the biophysical criteria approach be used, especially where significant ecological, social or economic values are present (Western Australian Planning Commission 2006). This will minimise the potential for loss of valuable habitat and the degradation of foreshore and waterway values. Activities likely to degrade the buffer’s protective function are not considered compatible in foreshore areas.

Rarely inundated floodplain areas are often managed as parkland or floodplain paddocks (in rural/semi-rural areas). Ideally, the channel should be fenced off (if grazing is an issue) to exclude livestock and the area revegetated. Where livestock have restricted access to the floodplain, pasture should not be overgrazed but managed to ensure complete groundcover at all times of the year so that in the event of a large flood, erosion of pasture land is minimised. Livestock should be kept off inundated foreshore/parkland to avoid pocketing the foreshore and creating numerous depressions that may hold standing water and allow mosquito breeding. Where possible, fences should be aligned parallel to the direction of flood flows to minimise the potential for debris accumulation and damage of fences. Materials such as lawn clippings, soil and waste stockpiles should not be stored where they can wash into the channel. Fertiliser use in or near waterways to enhance plant growth is generally not recommended. See Section 2.2.7 of Chapter 7: Non-structural controls for more information.

If possible, sufficient time should be allowed for vegetation establishment to stabilise the reconstructed channel prior to diverting flows down the channel. There is some risk that during the period that the reconstructed channel is stabilising (where full vegetative cover has not been achieved and soil is exposed) flows may cause some erosion of the channel. If the works are likely to mobilise sediment during the early stages of disturbance, then techniques to trap sediment can be implemented, such as filter strips (vegetation planted perpendicular to flow) or temporary settlement ponds to prevent sedimentation of the waterway or receiving water bodies.

Refer to Water and Rivers Commission/Department of Environment 1999-2003, particularly report numbers RR 4: *Revegetation – Revegetating riparian zones in south-west Western Australia*, RR 5: *Revegetation – Case studies from south-west Western Australia* and RR 8: *Using rushes and sedges in revegetation of wetland areas in the south west of WA*. Also refer to the Water Note series of publications. In areas outside of the south-west, refer to local revegetation guidelines. For example, for the Avon catchment, refer to *Riparian Plants of the Avon Catchment – a field guide* (Department of Environment 2004).

## Maintenance

The successful rehabilitation of a healthy, ecologically functioning waterway is a long-term process. The stability of vegetated waterways is largely dependent on the success of plant establishment to protect the channel from erosion.

By designing a stable meander alignment that mimics a natural waterway and is in balance with the catchment hydrology, long-term maintenance of the channel can be reduced. Waterway engineering works should be

inspected at least annually and, if possible, after each heavy rain. If problems develop, maintenance should be performed promptly to prevent additional, costly damage. Abuse and neglect are the most common causes of waterway failure. Common maintenance problems include weeds, eroded or bare areas, sediment deposits, litter accumulation and inadequate plant establishment. Pre-treatment methods, such as filter strips or litter and sediment traps, upstream of the living stream will assist in managing maintenance by providing a designated area to remove these pollutants. This will minimise disturbance of the rehabilitation area for maintenance purposes, which may be difficult to access once vegetation establishes. Maintenance activities may be needed more frequently during the initial establishment phase, or when the waterway conveys large volumes of water or is on a steep slope. Structures such as riffles and large woody debris installations should be inspected after the first major flow event. Some minor settling or movement should be anticipated and may require repair. These types of structures usually stabilise after the first year or high flow period.

It is recommended that a newly revegetated site be checked every two weeks for the first six months to allow early detection of germinating weed species, assessment of the success of plantings and maintenance of tree guards if these are used (Water and Rivers Commission 2002a). Once plantings are well established and good weed control is achieved, the resources needed to maintain the site will decline. Weed control is usually most demanding in the first two to three years when native vegetation is establishing, and if conducted correctly during this period, future maintenance should be minimised. Weed control should be undertaken in an appropriate manner, such as by staging the works and gradually replacing weeds with native plants, so that the beneficial functions that the exotic vegetation may be providing are maintained. Poorly managed removal of exotic vegetation may lead to channel destabilisation, higher velocity flows and the loss of shade and faunal habitat. Common riparian weed species in the south-west of Western Australia are Bridal Creeper (*Asparagus asparagoides*), Watsonia (*Watsonia* spp), Victorian Coast Teatree (*Leptospermum laevigatum*), Willow (*Salix babylonica*), Common Fig (*Ficus carica*) and Castor Oil Plant (*Ricinus communis*) amongst many other species. Isolated plants should be removed before they mature and spread. To find out which plants are weeds in Western Australia, go to the Weed Species section of the Department of Conservation and Environment's Florabase website: <<http://florabase.calm.wa.gov.au/weeds>>. Control options include physical removal, solarisation and herbicides. Due to the sensitivity of water environments, herbicides should be used cautiously. Clearing weeds from around native seedlings during the first two to three years will dramatically improve native plant growth and survival rates. However, there will always be a need to monitor the area and it is recommended this be undertaken once every season. Unexpected events such as fire, flood or increased human use can degrade the site and allow increased weed invasion. Refer to Water and Rivers Commission/Department of Environment (1999-2003) and associated Water Note series for further guidance on weed management in riparian zones.

Some selective thinning of vegetation may be required to restore the hydraulic capacity of the stream if overgrowth in the channel is causing a flooding problem or risk of an avulsion. However, a cautious approach is essential to prevent destabilising the stream. Specialist advice and required approvals to clear native vegetation should be sought. Clearing of significant debris dams and culvert blockages should be undertaken to maintain the capacity of the channel. Information on maintenance of riparian vegetation is provided in Water and Rivers Commission (2002a). Maintenance activities may include weed and feral animal control, infill planting, mulching and watering over the first summer.

Further information on monitoring of waterway works is available in Water Note 28: *Monitoring and Evaluating River Restoration Works* (Water and Rivers Commission 2002b).

## Local examples

There are a number of successful local examples of living stream projects.

Chapter 6: Retrofitting of this manual provides detailed examples of the following projects where drains were converted to living streams: Bayswater Main Drain at Paterson Street in the City of Bayswater; Bannister

Creek Project in the City of Canning; Coolgardie Street Drain in the City of Belmont; and Geegelup Brook project in Bridgetown.

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## 5 Detention Systems

### 5.1 Dry/Ephemeral Detention Areas



Figure 1. Detention basin retrofit, Bridgewater, City of Mandurah. (Photograph: Department of Water 2007.)



Figure 2. Darkan Street Detention Basin with riser outlet, Shire of Mundaring. (Photograph: JDA 1997.)

#### Background

Dry/ephemeral detention areas are landscaped areas formed by simple dam walls, by excavation below ground level or by utilisation or enhancement of natural swales or depressions. These areas primarily serve to capture and store stormwater to prevent excessive runoff and channel erosion in receiving environments, and as areas to remove particulate-based contaminants and sediment.

These areas are termed dry/ephemeral as they have a base level located at or above the regional groundwater level (typically defined as the long-term maximum groundwater level), with inundation of the area occurring as a result of intermittent stormwater inundation, rather than as a result of groundwater exposure.

The Department of Water is currently not including constructed ponds and lakes as a stormwater quality improvement BMP in this manual. This applies to designs that involve artificial exposure of groundwater (e.g. through excavation, or lined lakes that require groundwater to maintain water levels in dry seasons) or the modification of a wetland type (e.g. converting a dampland into a lake) due to water conservation, environmental and health concerns.

For information regarding the Department of Water's current position on the construction of ponds and lakes, the reader is referred to the *Interim Drainage and Water Management Position Statement: Constructed Lakes* (Department of Water 2007).

In order for detention areas to perform their design function of detaining flows, the storage volume needs to be available for the next storm event, therefore maintaining a permanent pool is not considered best practice.

#### Performance efficiency

Dry/ephemeral detention areas are effective at removing particulate-based contaminants and sediment but less effective for treatment of soluble pollutants where biological uptake of nutrients is required. Pollutant removal through sedimentation relies on strong affinity for sorption of metals, nutrients and hydrocarbon contaminants with particulates. Pollutant removal efficiency increases with increasing hydraulic residence times.

There is little local data to assess the performance efficiency of dry/ephemeral detention areas. These systems however operate with a similar principle to sedimentation basins, which have been assessed. Fletcher et al. (2003) examined the performance of sedimentation basins in removing pollutants, such as total suspended solids, total phosphorus, total nitrogen and heavy metals, and the results are presented in Table 1.

Due to the infiltration capacity of sandy coastal plain soils, it would be expected that the performance efficiency of dry/ephemeral detention areas for many parts of WA would be at the higher end (or in excess) of the expected removal percentages shown in Table 1.

**Table 1. Typical annual pollutant load removal efficiencies for sedimentation basins**

<b>Pollutant</b>	<b>Expected removal</b>	<b>Comments</b>
Litter	>95%	Subject to appropriate hydrologic control. Litter and coarse organic matter should ideally be removed in an aerobic environment prior to a basin, to reduce potential impacts on biological oxygen demand.
Total suspended solids	50–80%	Depends on particle size distribution.
Total nitrogen	20–60%	Depends on speciation and detention time.
Total phosphorus	50–75%	Depends on speciation and particle size distribution. Will be greater where a high proportion of phosphorus is particulate.
Coarse sediment	>95%	Subject to appropriate hydrologic control.
Heavy metals	40–70%	Quite variable, dependent on particle size distribution, ionic charge, attachment to sediment (vs % soluble), detention time, etc.

Source: Fletcher et al. (2003)

## Cost

Construction costs associated with these facilities can vary considerably.

The variability can be attributed to whether the existing topography will support the function of a dry ephemeral detention area, the complexity of the outlet structure, and whether it is installed as part of new construction or implemented as a retrofit of an existing drainage system. Varying subsurface conditions and labour rates can also contribute to the inconsistent costs.

Local cost data for dry/ephemeral detention systems is limited. An alternative method of costing these systems is to examine the costs of similar systems, such as ponds and swales. Center for Watershed Protection (1998) cited in United States Environmental Protection Agency (2001); Fletcher et al. (2003) cited in Taylor (2005) and Walsh (2001); Weber (2001) cited in Taylor and Wong (2002) reported costs for ponds (sourced from limited data in Australia) ranging from \$2 000/ha of catchment to \$30 000/ML of pond volume, and \$60 000/ha of pond area.

Taylor (2005) also reported costs for vegetated swales of approximately \$4.50/m<sup>2</sup>, which included earthworks, labour and hydro-mulching. For swales with rolled turf the cost was approximately \$9.50/m<sup>2</sup> and for a vegetated swale with indigenous species the cost was approximately \$15–20/m<sup>2</sup>.

It would be expected that the above costs for both these systems would be comparable to the components of a landscaped dry/ephemeral detention area.

Center for Watershed Protection (1998), cited in United States Environmental Protection Agency (2001), estimated the annual cost of routine maintenance for ponds at typically about 3-6% of the construction costs. However, there is almost no actual maintenance cost data available in published literature and studies carried out have yet to experience the full maintenance cycle.

Maintenance costs may vary considerably depending on the aggressiveness of the vegetation management required at the site and the frequency of litter removal.

## Design considerations

The design approach should be selected based on the target pollutants as well as site and economic constraints.

As with other BMPs, pre-treatment can extend the functional life and increase the pollutant removal capability of ephemeral detention areas. Pre-treatment can reduce incoming velocities and capture coarser sediments, which will reduce the maintenance requirements and extend the life of the detention system. This is usually accomplished through means such as buffer strips and/or gross pollutant traps.

Forebays (or inlet zones) at the inflow points to the detention area can capture coarse sediment, litter and debris, which will simplify and reduce the frequency of maintenance. Forebays can be sized to hold either the expected sediment volume between clean-outs, and/or designed to have sufficient capacity to detain or infiltrate (where possible) frequently occurring storm events (typically < 1 year ARI) without discharge to the main ephemeral detention area.

Construction of dry/ephemeral detention areas has lower acid sulphate soil (ASS) risks compared to risks associated with construction of ponds and lakes, as dry/ephemeral detention areas should be designed to not alter groundwater levels, which could result in flooding or exposing ASS. ASS however must still be considered when designing in areas that have a high risk of forming ASS, or where dewatering during construction in medium and low risk areas could affect soils in high risk areas. These areas are defined in ASS risk mapping available from the Department of Environment and Conservation and in Planning Bulletin 64: *Acid Sulphate Soils* (Western Australian Planning Commission 2003). Land development proposals within these areas will typically be required to undertake site specific soil investigations and prepare ASS management plans and, where relevant, dewatering management plans.

Dry/ephemeral detention areas must be designed to minimise the risk of mosquito breeding. See Section 1.7.7 'Public health and safety' of the Introduction section of this chapter for more information on mosquito management. Some of the mosquito management guidelines in the Constructed Wetlands BMP may also be applicable for dry/ephemeral detention areas.

## Design guidelines

### Design flows

The *Decision Process for Stormwater Management in WA* (Department of Environment & Swan River Trust 2005) provides general design flow criteria guidance for the use of landscaped dry/ephemeral detention areas in public open space areas or linear multiple use corridors.

To protect receiving environments from flooding and erosion and to maintain ecological water requirements, the generally adopted approach for design is to maintain pre-development discharge rates for storm events up to the 100 year ARI, with events up to the 1 year ARI retained or detained on-site or as high in the catchment as possible. As discussed in the Design Considerations section of this BMP, this may result in the use of forebay/inlet zone areas to maintain frequently occurring storms separate from the main dry/ephemeral detention area.

A range of hydrologic methods can be applied to estimate design flows. If the catchment is relatively small, the Rational Design Method (Institution of Engineers Australia 2001) may be used for sizing of inlet hydraulic structures.

It is recommended however that the detention area sizing, design configuration and design of outlet structures (pipes, spillways, etc.) be undertaken using a comprehensive flood routing method. If required, the Department of Water can provide advice on suitable hydrologic/hydraulic models to undertake this design.

The typical approach to estimate the design flow is to establish a pre-development model of the catchment area. The model is used to estimate the pre-development flow rates from the contributing catchment under its current land use. Where possible, modelled pre-development flow rate estimates should be verified against any existing historical data or anecdotal information.

Note that in some areas the pre-development flow rate may exceed the capacity of the downstream receiving environment, and the design flow estimate may need to be reduced accordingly to protect the receiving environment.

### Basin layout

To optimise hydraulic efficiencies and thereby reduce the potential for short-circuiting and dead zones, it is desirable to adopt a high length to width ratio. The ratio of length to width varies depending on the size of the system and the site characteristics. To minimise earthworks, smaller systems have typically been built with low length to width ratios, which has often led to poor hydrodynamic conditions.

The term ‘hydraulic efficiency’ was used by Persson et al. (1999) to define the expected hydrodynamic conditions of stormwater detention systems. Engineers Australia (2006) presented a range of expected hydraulic efficiencies for detention systems for a series of notional shapes, aspect ratios and inlet/outlet placements. It was recommended that such systems should achieve a minimum hydraulic efficiency of 0.5, but ideally should be designed to promote values greater than 0.7 (Figure 3).

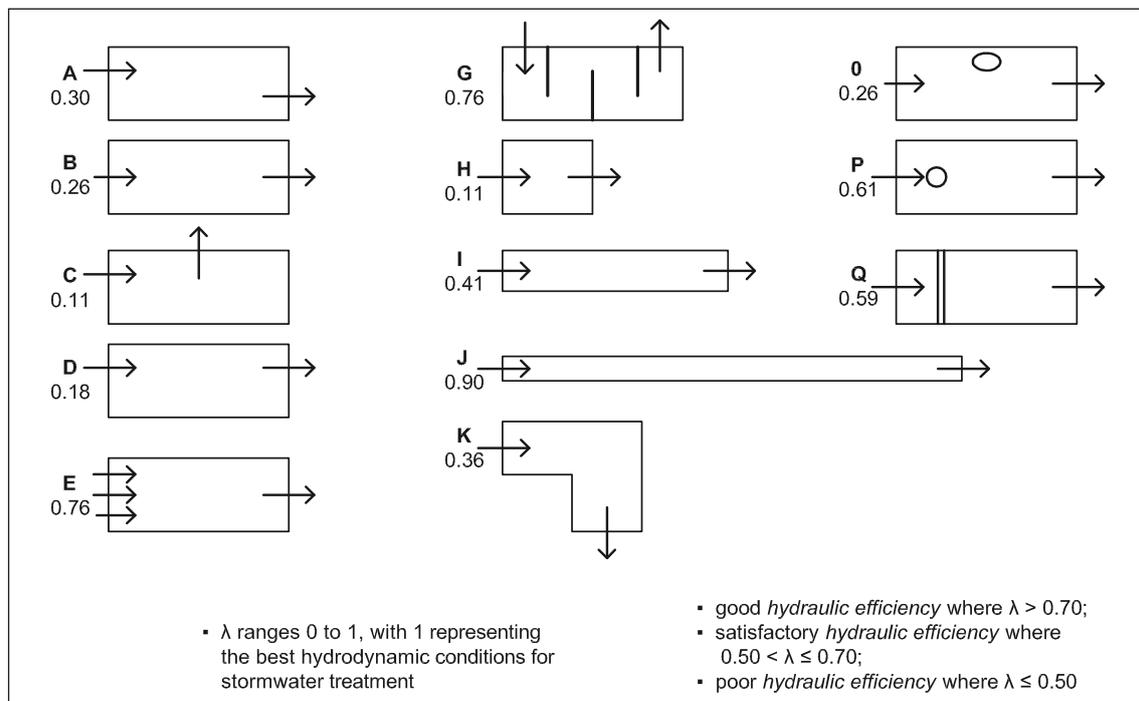


Figure 3. Hydraulic Efficiency ( $\lambda$ ) is a quantitative measure of flow hydrodynamic conditions in constructed wetlands and basins.  $\lambda$  ranges from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment. (Source: Engineers Australia 2006.)

Note that in Figure 3, the circles in diagrams O and P represent islands in a basin and the double line in diagram Q represents a structure to distribute flows evenly.

There can often be multiple inlets to the basin and the locations of these inlets relative to the outlet structure can influence the hydraulic efficiency of the system. Inlet structure designs should aim to reduce localised water eddies and promote good mixing of water within the immediate vicinity of the inlet.

### Forebay/inlet zone

The forebay/inlet zone is a transitional zone between the stormwater outfall and the main ephemeral detention area. The function of the inlet forebay ranges from providing a sedimentation area to providing a small ephemeral wetland area that stores frequently occurring storm events.

A notional required forebay/inlet zone area can be computed by the use of sedimentation theory, targeting the 125 µm sediment (settling velocity of 11 mm/s) operating at the 1 year ARI peak discharge. The specification of the required area (A) for sedimentation is detailed in Engineers Australia (2006) (based on Fair and Geyer 1954) for systems with no permanent water pool:

$$R = 1 - \left( 1 + \frac{v_s A}{nQ} \right)^{-n}$$

Where:

- R = fraction of target sediment removed
- $V_s$  = settling velocity of target sediment
- Q = rate of applied flow
- A = basin surface area
- n = turbulence or short-circuiting parameter

Typical settling velocities of sediments can be estimated using the values listed in Table 2. The above expression for sedimentation is applied with ‘n’ being a turbulence parameter. Figure 3 provides guidance on selecting an appropriate ‘n’ value (according to the configuration of the basin). ‘n’ is selected using the following relationship:

$$n = \frac{1}{1 - \lambda}$$

Where:

- n = turbulence or short-circuiting parameter
- $\lambda$  = hydraulic efficiency, ranging from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment.

**Table 2. Settling velocities for various particle sizes under ideal conditions**

Classification of particle size	Particle diameter (µm)	Settling velocities (mm/s)
Very coarse sand	2 000	200
Coarse sand	1 000	100
Medium sand	500	53
Fine sand	250	26
Very fine sand	125	11
Coarse silt	62	2.3
Medium silt	31	0.66
Fine silt	16	0.18
Very fine silt	8	0.04
Clay	4	0.011

(Source: Engineers Australia 2006.)

## Hydraulic structures

Hydraulic structures are required at the inlet and outlet of the detention area. Their function is essentially one of conveyance of flow, with provisions for energy dissipation at the inlet structure and extended detention at the outlet.

Discharge of stormwater into the dry/ephemeral detention area may be via a forebay/inlet zone or direct input. It is essential that inflow energy is adequately dissipated to prevent localised scour in the vicinity of pipe outfalls. Design of stormwater pipe outfall structures is common hydraulic engineering practice. Litter control is normally required at the inlet structure. It is generally recommended that some form of gross pollutant trap be installed as part of the inlet structure. Conveyance of flow to the detention area may be via an overland flow system, such as a swale or living stream, which will provide some pre-treatment.

Configuration of the outlet structure is largely dependent on the required operation of the system during periods of high inflows. The outlet structure typically consists of two components: the outlet pit and outlet culvert. In areas of low topographic relief, the outlet structure may consist of a single outlet culvert without an outlet pit.

The computation of the required outlet culvert is an essential element of the retarding basin design and will be based on flood routing computations, as outlined in *Australian Rainfall and Runoff* (Institution of Engineers Australia 2001).

The main function of the outlet pit is to connect the detention area to the outlet culvert. Design considerations of the outlet pit include the following:

- ensure that the crest of the pit is set at the invert of the detention area to allow the area to drain completely following a storm event;
- ensure that the dimension of the pit provides a discharge capacity that is greater than the discharge capacity of the outlet culvert;
- provide protection against clogging by flood debris.

In computing the dimension of the pit, two flow conditions need to be considered. Firstly, the weir flow condition when free outfall conditions occur over the pit (usually when the extended detention storage of the retarding basin is only partially used):

$$P = \frac{Q_d}{C_w H^{1.5}}$$

Where:

P = Perimeter of the outlet pit (m)

H = Depth of water above the crest of the outlet pit (m)

Q<sub>d</sub> = Design discharge (m<sup>3</sup>/s)

The second flow condition for consideration is the orifice flow condition, when the outlet pit is completely submerged (corresponding to conditions associated with larger flood events):

$$A_o = \frac{Q_d}{C_d \sqrt{2gH}}$$

Where:

C<sub>d</sub> = Orifice Discharge Coefficient (0.6)

H = Depth of water above the centroid of the orifice (m)

$$A_o = \text{Orifice area (m}^2\text{)}$$
$$Q_d = \text{Design discharge (m}^3\text{/s)}$$

The orifice flow condition provides the critical condition in terms of design capacity.

Note the above equations assume the outlet pit is freely discharging and operating under inlet control. Should outlet control conditions (i.e. backwater effects) be likely for the proposed outlet structure design, then flood routing computations are recommended.

The additional provision of an overflow route for extreme events is standard design practice to ensure that overflow from the detention area can be safely conveyed either by the use of a spillway or ensuring that any embankments are designed to withstand overtopping. This issue requires specialist design input on a case by case basis and is therefore not discussed further in this document.

### **Vegetation specification**

Plant species for the forebay/inlet zone area will typically be predominantly ephemeral wetland species. Suitable indigenous plant species will vary depending on the location of the site. Local revegetation expertise should be sought. Suggested plant species suitable for the forebay area of detention systems on the Swan Coastal Plain and their recommended planting density are detailed in the Constructed Wetland BMP.

Vegetation within the main dry/ephemeral basin area will vary and may range from existing remnant vegetation, to grassed public open space, to ephemeral wetland species (or a combination).

### **Maintenance**

The maintenance plan should include removal of accumulated litter and debris in the detention area at the middle and end of the wet season. The frequency of this activity may be altered to meet specific site conditions and aesthetic considerations.

Biannual inspections for sediment accumulation, pest burrows, structural integrity of the outlet, and litter accumulation are typical. In parkland settings, maintenance plans should also address irrigation, nutrient and pest management issues. Accumulated sediment in the forebay should be removed about every 5-7 years or when the accumulated sediment volume exceeds 10% of the basin volume. Sediment removal may not be required in the main detention area for as long as 20 years. Refer to BMP 2.2.2 'Maintenance of the stormwater network' in Chapter 7 for further guidance on managing sediments removed from the stormwater system.

Vegetation harvesting should be timed so that it has minimal impact on factors such as bird breeding and there is time for re-growth for runoff treatment purposes before the wet season.

### **References and further reading**

- Center for Watershed Protection 1998, *Costs and Benefits of Storm Water BMPs: Final Report 9/14/98*. Center for Watershed Protection, Elliot City, Maryland; not seen, cited in United States Environmental Protection Agency (2001).
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- Walsh, G. 2001, Gary Walsh, Senior Engineer, Melbourne Water, Victoria, personal communication; not seen, cited in Taylor (2005).
- Weber, T. 2001 and 2002, Tony Weber, Senior Waterways Program Officer (Water Quality), Brisbane City Council, Queensland, personal communication; not seen, cited in Taylor and Wong (2002).
- Western Australian Planning Commission 2003, Planning Bulletin No. 64: *Acid Sulfate Soils*, Western Australian Planning Commission, Perth, Western Australia.

# Detention Systems

## 5.2 Constructed Wetlands



Figure 1. Liege Street Wetland, Cannington, intercepts and treats stormwater prior to it reaching the Canning River. (Photograph: City of Canning 2006.)



Figure 2. Tom Bateman constructed wetland in the City of Gosnells. (Photograph: South East Regional Centre for Urban Landcare 2006.)

### Background

Constructed wetlands are vegetated detention areas that are designed and built specifically to remove pollutants from stormwater runoff. Constructed wetlands differ from constructed lakes, which are defined as constructed, permanently inundated basins of open water, formed by simple dam walls or by excavation below ground level. For information on constructed lakes, refer to the Department of Water's *Interim Drainage and Water Management Position Statement: Constructed Lakes* (2007).

Constructed wetlands are particularly useful where stormwater contains high concentrations of soluble material that is difficult to remove with other treatment methods. Depending on their design, constructed wetlands can also serve to attenuate larger storm events and reduce peak flows, offsetting the changes to flow frequency relationships caused by increased catchment imperviousness, and protecting downstream environments from erosion and flooding. Constructed wetlands also increase flora and fauna habitat in already urbanised catchments where many natural wetlands have been cleared, drained or filled. They also provide passive recreation opportunities and can provide opportunities for educational and scientific studies.

New constructed wetlands should be designed specifically for local conditions. Deep permeable sands and a high groundwater table are common on the Swan Coastal Plain, and have typically made traditional wetland designs unsuitable. However, well-designed and well-vegetated constructed wetlands that mimic the ephemeral character of natural wetlands on the Swan Coastal Plain will provide effective water pollution filters. The more traditional constructed wetlands designs may be suitable in other parts of WA, for example, on the clay soils of the south coast region.

Constructed wetlands that expose contaminated or nutrient-rich groundwater or surface water can result in water quality problems in the wetland, reduce the treatment effectiveness of the system and result in the net export of pollutants. Poorly designed wetlands can create ideal habitats for algal blooms and midge and mosquito breeding.

Wetland vegetation provides an ideal structure for the growth of biofilms, which assimilate dissolved nutrients. Wetland plants can improve water quality by encouraging sedimentation, filtering nutrients and

pollutants (through roots, stems and leaves), oxygenating their root zone, providing shade and, to some extent, by using nutrients when in the growth phase.

For more detailed information on constructed wetlands on the Swan Coastal Plain, see Department of Water and Swan River Trust (in preparation).

## Performance efficiency

Changes in environmental conditions can greatly influence wetland processes. These include diurnal changes in water temperature and dissolved oxygen, and seasonal changes in daylight hours, water temperature, water depth, wetland vegetation growth, microbiological activity and chemical reactions. In areas with significant seasonal variation in water temperature, the treatment efficiency for a particular contaminant may vary markedly at different times of the year.

Alternating deep and shallow zones in the wetland, perpendicular to the water flow, can promote various chemical reactions to transform and remove nitrogen from the system. Shallow and ephemeral zones are generally well oxygenated, promoting mineralisation (breakdown of organic nitrogen to ammonium) and nitrification (breakdown of ammonium to nitrate). The deeper zones promote denitrification, a process occurring in the absence of oxygen, converting nitrate to gaseous nitrogen, which is then released to the atmosphere (Department of Water & Swan River Trust, in preparation). However, the deeper zones should not cut into the groundwater table to remain wet year-round because this can create stagnant ponds and result in water quality problems, as discussed in the Background section of this BMP.

Phosphorus can be removed through sedimentation, filtration, biological uptake and sorption. Suspended material can be removed from the water column by sedimentation and filtration. Organic matter can be removed through sedimentation/filtration and degradation and microbial uptake. Pathogens can be destroyed by exposure to ultra violet light in open waters, adsorption and predation. Even some heavy metals can be removed from the water column through sedimentation, adsorption and plant uptake, however high levels can be toxic to plants and animals and may have an adverse impact on the wetland (Department of Water & Swan River Trust, in preparation).

It is also clear that treatment efficiency for some contaminants is influenced by the maturity of the wetland, with new wetland soils sometimes having a higher assimilation capacity for phosphorus and nitrogen than older wetland soils. The accumulation of organic matter from dead plant material also influences the soil pollutant interactions. Higher wetland vegetation density is likely to achieve greater treatment efficiency than lower density because of the increased contact between contaminants and plant surfaces that support micro-organisms, which mediate most removal processes. Fringing wetland vegetation supports the growth of epiphytic biofilms, which are a matrix of bacteria, fungi and algae that assimilate dissolved nutrients. However, high density vegetation may create suitable mosquito and midge breeding conditions if not designed appropriately. The Midge Research Group's (2006) *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies* provides guidance on how to plant vegetation to reduce the risk of mosquitoes and midges.

Indicative estimates of treatment efficiency for constructed wetlands based on Fletcher et al. (2003) are shown in Table 1. Actual treatment efficiencies will depend on the hydraulic efficiency and the design of the wetland.

The hydraulic effectiveness of a wetland reflects the interaction of three factors: detention period, inflow characteristics and storage volume. It defines the overall percentage of catchment runoff introduced to the wetland for treatment. As a general rule of thumb, the area of a constructed wetland should typically be approximately 1–2% of the total catchment area in order to be effective, otherwise excessive hydraulic loading and short-circuiting is likely to reduce its biofiltration effectiveness. However, this approximate figure should only be used for preliminary wetland sizing. Catchment characteristics (e.g. land use and water quality) will determine the wetland size.

**Table 1. Typical annual pollutant load removal efficiencies for constructed wetlands**

<b>Pollutant</b>	<b>Expected removal</b>	<b>Comments</b>
Litter	>95%	Subject to appropriate hydrologic control. Litter and coarse organic matter should ideally be removed in an aerobic environment prior to the wetland, to reduce potential impacts on biological oxygen demand.
Total suspended solids	65–95%	Depends on particle size distribution.
Total nitrogen	40–80%	Depends on speciation and detention time.
Total phosphorus	60–85%	Depends on speciation and particle size distribution. Will be greater where a high proportion of phosphorus is particulate.
Coarse sediment	>95%	Subject to appropriate hydrologic control.
Heavy metals	55–95%	Quite variable, dependent on particle size distribution, ionic charge, attachment to sediment (vs % soluble), detention time, etc.

Source: Fletcher et al. (2003)

## Cost

Costs for constructing wetlands can vary greatly depending on the configuration, location, site specific condition (including hydrogeology, temporal patterns and seasonal temperature variations), volumes, flow rate and pollutant removal targets.

There is little available cost data for constructed wetlands in WA. Typical construction costs presented in Weber (2002), cited in Taylor and Wong (2002) and based on eastern states examples, range from approximately \$500 000 to \$750 000 per wetland hectare. The two key variables underpinning the construction costs are the extent of earthworks required and the types and extent of vegetation.

The Center for Watershed Protection (1998), Webber (2001) and United States Environmental Protection Agency (2001), cited in Taylor (2005), reported annual maintenance costs of approximately 2% of construction costs.

## Design considerations

Before the commencement of site investigations or the design process, the objectives for the constructed wetland must be established. Objectives include environmental benefits (such as water quality improvement, detention and erosion control), habitat value (enhancing biodiversity and conservation) or aesthetic and recreational values (Department of Water & Swan River Trust, in preparation).

Constraints for the wetland must be identified and considered. On the Swan Coastal Plain, these constraints are likely to include (Department of Water & Swan River Trust, in preparation):

- land availability, including future land use plans
- types and form of pollutants (e.g. dissolved nutrients, gross pollutants, toxicants and sediment)
- pollutant delivery (e.g. mostly diffuse; baseflows; first flush events; and timing of pollutant arrival)
- geology (e.g. very sandy soils or presence of bedrock)
- hydrology (e.g. frequently high groundwater table)
- topography (e.g. very flat or steep site)
- site specific constraints (e.g. environmental, conservation and heritage issues, neighbouring land uses)

- location of service infrastructure (e.g. roads, sewerage, scheme water and gas pipelines, and telephone and power lines)
- end use of the treated water (e.g. delivery into downstream waterways or reuse as irrigation water)

Subject to the outcomes of constraints analysis, a site investigation will be required to determine whether a constructed wetland is the appropriate technique for the site. A site investigation typically includes the following (summarised from Department of Water & Swan River Trust, in preparation):

- **Topographical Survey:** Preliminary information on site topography can be extrapolated from aerial photographs and topography maps, however a detailed topography survey is required at intervals of 0.1 m to 0.5 m. The aim of this survey is to identify any constraints that may impact the wetland design.
- **Groundwater Monitoring:** Regular monitoring of shallow groundwater bores (less than 5 m below ground surface) provides a good indication of groundwater levels and quality where shallow groundwater is present. The bores should be monitored at least quarterly for physical parameters (dissolved oxygen, redox potential, conductivity, pH and temperature), nutrients and groundwater elevation for at least one year. This will help to establish water table fluctuations and seasonal changes in groundwater quality. Groundwater elevation data can then be collated to determine groundwater contours across the site and general groundwater flow direction, which may not follow topography. Analysis of groundwater quality will identify any hot spots caused by a contaminated groundwater plume or historical land use activities. See the Water Quality Protection Note: *Groundwater Monitoring Bores* (Department of Water 2006) for more information on bore installation.
- **Geotechnical Survey:** Drilling of bores can provide further information on soil horizons. Physical properties of the soil impact the success of plant establishment.
- **Acid Sulphate Soils:** Areas that have a high risk of forming ASS, or where dewatering in medium and low risk areas could affect soils in high risk areas, must be considered in designing constructed wetlands. These areas are defined in ASS Risk Maps available from the Department of Environment and Conservation and Planning Bulletin 64: *Acid Sulphate Soils* (WA Planning Commission 2003). Land development proposals within these areas should undertake site specific soil investigations and prepare acid sulphate soil management plans and, where relevant, dewatering management plans.
- **Surface Water Hydrology Monitoring:** If existing surface water flows enter the wetland, then monitoring of these flows and water quality is recommended.
- **Vegetation Survey:** The existing native vegetation species on-site and in similar wetland types in the surrounding region should be identified and incorporated into the wetland design.

Typically, constructed wetlands are most appropriate on sites that meet or exceed the following criteria:

- impervious catchment area should be greater than 1 hectare;
- soils are relatively impermeable or have sufficient base flow passing through them to sustain vegetation (unless selected vegetation can sustain long dry periods);
- must be situated on mild slopes or where slope stability is not an issue;
- land availability is not significantly restricted to accommodate the detention volume.

The most important criterion for determining the success of a constructed wetland system is the local hydrology (Figure 3). It is therefore imperative that these systems be located in areas that have suitable hydrologic characteristics to ensure the long-term viability of wetland processes.

The hydrologic regime of the constructed wetland has a significant impact on its ability to assimilate nutrients. Ideally, the wet and dry season flows and when the pollutants are delivered to the wetland and their concentrations should be known. In addition, it is important that the water quality of the inflow (surface and groundwater) is known, as this determines the size of the wetland and influences the design. Large wetlands are more successful at removing sediment and the nutrients attached to sediment, while wetlands with alternating bed depths are more suitable for removing dissolved nutrients by the nitrification/denitrification process and biofilm growth.

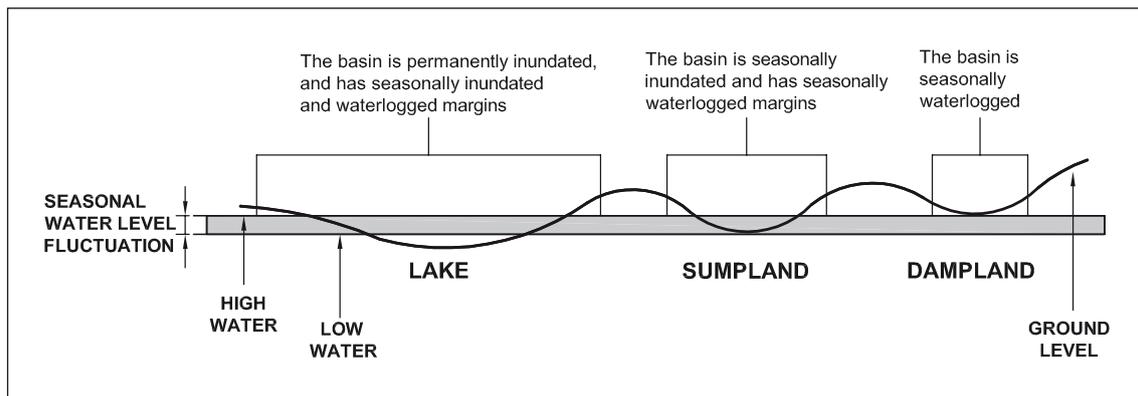


Figure 3. Natural wetlands are classified according to their landform and water permanence (Semeniuk & Semeniuk 1995). Constructed wetlands should mimic the natural hydrology and landforms suitable for the catchment.

Soils at the proposed site for a constructed wetland must have sufficient water retention characteristics and be able to promote wetland plant growth, particularly during the dry season. Wetland vegetation requires a suitable soil profile from the ground surface to below the static water level. It may be necessary to stockpile topsoil during construction and re-spread this soil along the base and side slopes of the wetland.

The utilisation of the existing site contours can reduce potentially costly earthworks involved in construction.

The proximity of the wetland to residential areas needs to be considered in the selection and design of this BMP. Neighbouring communities will need to be consulted on the appearance, functionality and role of the constructed wetland. There are also safety concerns where the wetland is built in a publicly accessible area.

Mosquito and midge breeding can be a problem if the wetland is poorly designed. According to the Midge Research Group of Western Australia's (2006) *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies*, ephemeral water bodies (i.e. where the water level fluctuates and the water body dries out) generally present the lowest risk for mosquitoes and midges. Refer to the Mosquito and Midge Management guidelines section of this BMP for more information.

## Design guidelines

The following design guidelines are based on Department of Water and Swan River Trust (in preparation). Unless constructed wetlands are appropriately located, designed and managed, they can produce significant populations of mosquitoes and chironomid midges, with subsequent impacts on surrounding residents. Therefore, where possible, the water body characteristics with a lower risk rating detailed in the Midge Research Group Western Australia's (2006) *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies* should also be incorporated.

### Key design principles

For wetlands to be a successful part of the treatment train, the following key design principles are recommended (adapted from Department of Water and Swan River Trust, in preparation):

- **Locate the wetland to achieve the maximum possible buffer to residential areas.** For example, the *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies* (Midge Research Group of Western Australia 2006) states that a buffer of more than 200 m provides the lowest risk from mosquitoes and midges.

- **Integrate the wetland with local conditions and design for the inputs.** It is beneficial for the wetland to be incorporated into the hydrology, natural surface contours, existing vegetation and drainage lines of the site. The size of the wetland and its design is determined from the inflow water quality and it is essential that the types and loads of pollutants are identified.
- **Wetland sizing.** The sizing of wetlands must be done correctly to account for the volumes of water entering the system, whilst reducing the risk of stagnant water. The hydroperiod (time of inundation) should determine the dimensions of the system.
- **Ensure that flow velocities remain low.** High flows entering a wetland can re-suspend the accumulated sediment and nutrients, resulting in detrimental impacts downstream. The system should be designed to include controls to reduce the inflow velocity or to bypass high flows.
- **Incorporate deep inlet zones.** A deep inlet zone providing a settling area can reduce large amounts of sediment from entering the wetland, which prevents clogging of vegetation and reduction of water depth.
- **Design wetland bathymetry and vegetation layout for variations in hydrology, including promoting shallow water areas and wetting and drying cycles.** Alternating deep and shallow zones perpendicular to the flow in the wetland can promote various chemical reactions, such as nitrogen removal (Figure 4). Seasonally dry zones promote aeration of the sediments and reduce mosquito breeding risks.

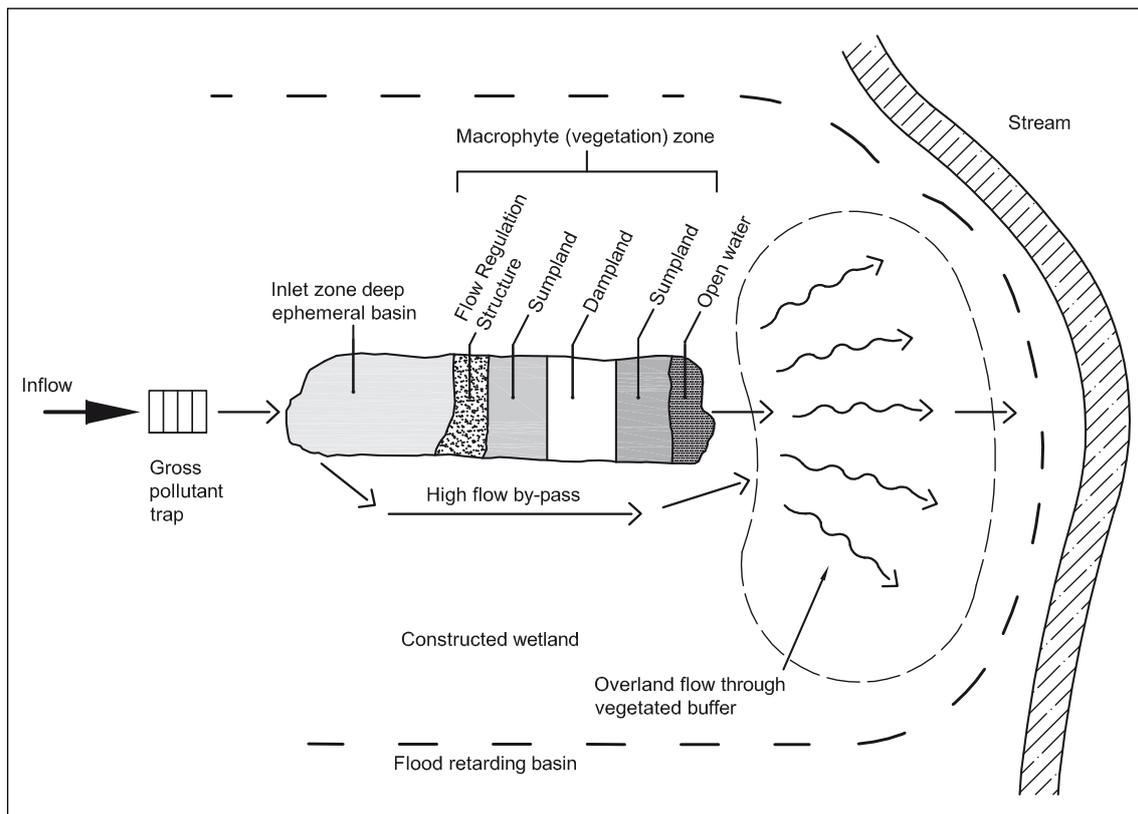


Figure 4. Bathymetry of a constructed wetland.

- **Create gentle sloping shorelines.** Banks should be designed with slopes of 1:6 to 1:8 to allow for public safety and create wider ranges of zones for plant growth. The banks should not be flat or contain depressions that can inhibit drainage, creating stagnant water and mosquito breeding areas.
- **Maximise vegetation-water contact by creating dense vegetation stands within the wetland.** Wetlands should be designed to incorporate large sections of densely vegetated zones, as vegetation aids water treatment by slowing flows and promoting sedimentation. Maximising water contact with biofilm growth on plant surfaces aids the removal of nutrients and other pollutants. Specialist advice on selecting suitable in-stream species is recommended.

- **Vegetate around the wetland's edge.** Fringing vegetation serves as a buffer for the wetland, capturing nutrients and pollutants in overland flow, preventing erosion and limiting weed and algal growth. Fringing vegetation provides shade and water temperatures more conducive to nutrient processing.
- **Limit the use of or avoid using fertilisers and pesticides.** It is essential that wetlands are not surrounded by highly fertilised lawns, as this may result in the direct application or runoff of nutrients to the wetland. Native plants are a more suitable alternative because they can be cost effective, require little or no fertiliser, little watering (except in establishment phases) and provide habitat for fauna.
- **Design as part of a treatment train and use source controls.** Constructed wetlands should form part of a treatment train for water quality improvement. Gross pollutants can clog wetlands, and heavy metals and other chemicals can impact on the growth of wetland plants and their associated biofilms. Pre-treatment systems and implementation of non-structural controls throughout the wetland's catchment are required to prevent these pollutants entering the wetland.

### Key components

The key components of the constructed wetland system include the Inlet, Channel, Basin, Floodplain and Outlet, as shown in Figure 5.

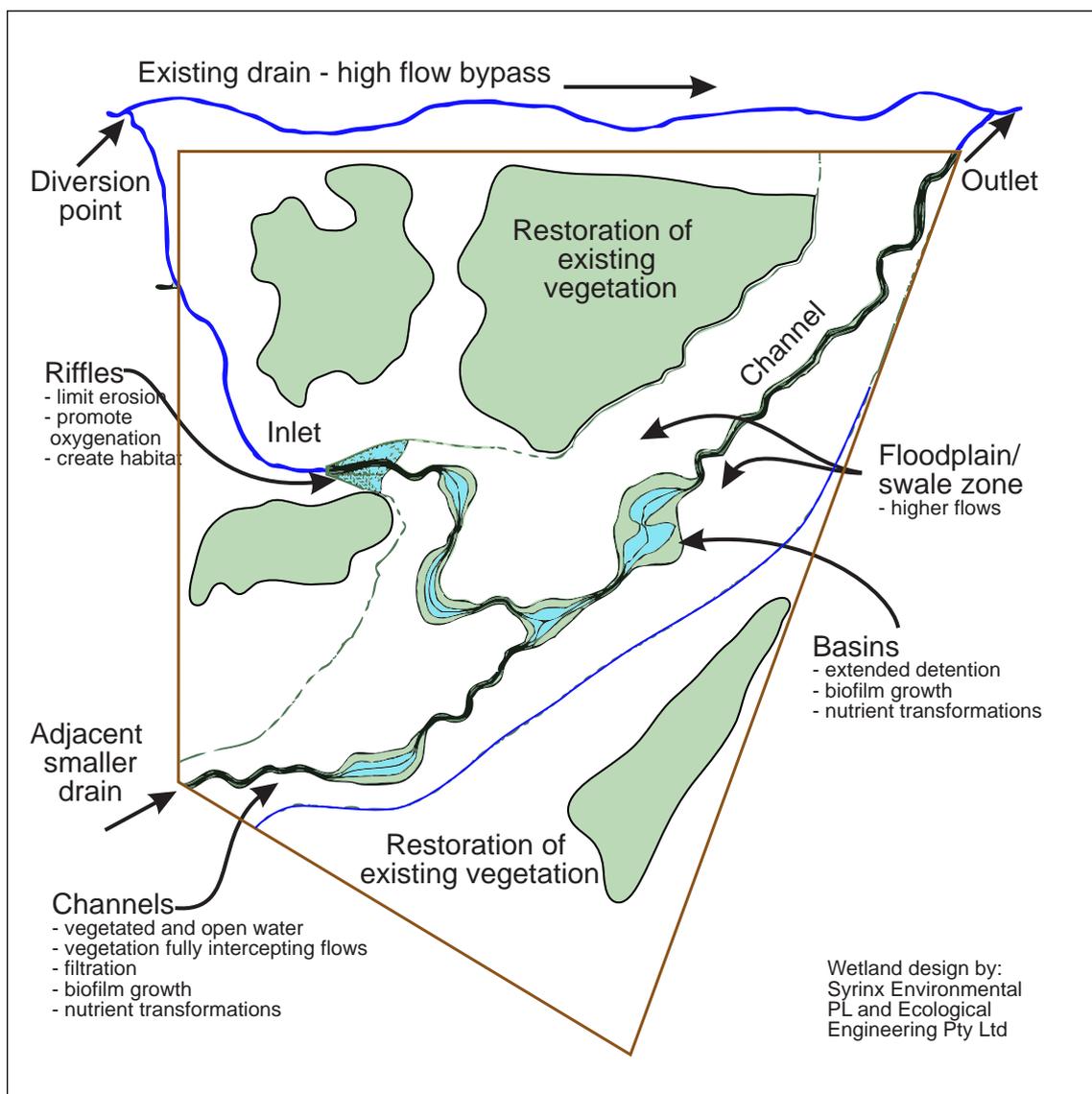


Figure 5. Example of a constructed wetland design, showing key components of an ephemeral wetland. (Department of Water & Swan River Trust, in preparation.)

## **INLET**

Flow velocities in the wetland need to be managed by careful consideration of all stage heights and flows when designing the geometry. A deep inlet or similar system should be used to attenuate high flows. A diversion structure may be required to ensure that potentially damaging above-design high flows bypass the wetland. However, it is important that this structure is designed to allow normal storms and first flush events to enter the wetland for treatment.

## **CHANNELS/CREEKLINES and BASINS (Low Flow Areas)**

Creeklines (channels) and basins form the main treatment area for low flows. Channel widths should vary in an effort to move away from a linear type drainage line. Shallow, wide, meandering streams with a series of basins (both vegetated and open water) are often very effective constructed wetlands as they increase detention times and create a more diverse range of habitats, both of which can promote nutrient removal processes. Average channel cross-sectional areas should be designed to provide sufficient volume to account for increases in hydraulic roughness (or surface friction) over time due to the establishment and growth of in-stream vegetation.

Channels and basins may need to be lined with a less permeable (e.g. clay) layer to reduce groundwater interactions and to achieve the water quality treatment objectives. The invert or base of the channel or basin should be above maximum groundwater levels, however capillary action will allow soils to stay wet almost year round in shallow groundwater areas and thus maintain vegetation during dry seasons.

Channels can incorporate three main components:

- open sections are best located in flat areas of the wetland;
- vegetated sections – about 70% of total channel area should be vegetated in-stream (i.e. less than 30% of the channel should be open water), fully intercepting flows to maximise settling, biofilm and plant uptake and microbial assisted nutrient transformations;
- riffles (loose rock structures built in-stream) – can be constructed in sections of the channel that are steeper to reduce the risk of erosion. Riffles promote oxygenation of water (necessary in the breakdown of ammonium) and create additional macroinvertebrate habitat (such as habitat for filter feeders).

## **FLOODPLAIN (High Flow Areas)**

The floodplain area attenuates higher flows (i.e. less frequent, large storm events), controlling flow velocities. Swales and floodplains can treat both overflow from baseflow channels and rising groundwater. Water inundating the floodplain area can either infiltrate into the groundwater or flow back into the channel as flows recede. A slope and/or soil permeability that allows for the high flow waters to either recede back into the channel or infiltrate into the groundwater is necessary. To reduce the risk of mosquito breeding, there should be no surface water within floodplain areas within four days of being inundated (within high risk areas or mosquito breeding risk times of the year).

See the Swales and Buffer Strips BMP for more design guidelines on swales.

The function and structure of the wetland components are outlined in Table 2.

## **OUTLET STRUCTURE**

The outlet structure acts to control discharges from extended detention areas to ensure that sufficient detention time for biological processes has been achieved.

Outlet structures will typically consist of weir and/or riser type arrangements, designed to provide uniform detention time over the full range of the extended detention depth. The placement of riser outlet orifices and their diameters is designed using an iterative process by varying outlet orifice diameters and levels at discrete depths over the length of the riser up to the maximum detention depth.

**Table 2. Components of a constructed wetland (Department of Water & Swan River Trust, in preparation)**

<b>Zone</b>	<b>Functions</b>	<b>Structure</b>
<b>Inlet</b>	<ul style="list-style-type: none"> <li>• Buffer the wetland from high flows</li> <li>• Encourage sedimentation</li> </ul>	<ul style="list-style-type: none"> <li>• Piped inlets</li> <li>• Diversion channel into wetland</li> </ul>
<b>Channel</b>	<ul style="list-style-type: none"> <li>• Encourage filtration and sedimentation</li> <li>• Evenly distribute flow and reduce flow velocity to promote further filtration and sedimentation</li> <li>• Promote biological transformations and uptake</li> <li>• Provide habitat for invertebrates</li> </ul>	<ul style="list-style-type: none"> <li>• &gt;100 mm clay layer (if required)</li> <li>• 200 mm topsoil over clay layer</li> <li>• Gently sloping embankments to reduce erosion</li> <li>• Emergent plants with extensive shallow roots, planted perpendicular to flow path in low flow section</li> <li>• Riffles in high flow/steep sections</li> </ul>
<b>Basin</b>	<ul style="list-style-type: none"> <li>• Provide additional detention volume</li> <li>• Promote pollutant transformation</li> <li>• Promote biofilm growth</li> <li>• Reduce flow velocity</li> <li>• Treat localised groundwater, if groundwater interception already occurs, however constructed wetlands at new sites should not artificially expose groundwater</li> <li>• Provide habitat and refuge for fauna, especially invertebrates</li> <li>• Provide diverse habitat for flora</li> </ul>	<ul style="list-style-type: none"> <li>• &gt;100 mm clay layer (if required)</li> <li>• 200 mm topsoil</li> <li>• Gently sloped embankments</li> <li>• Offset inputs and outputs of flow path to avoid short-circuiting and increase hydraulic retention time</li> <li>• Various depths between and within basins to create habitat</li> </ul>
<b>Swale/Floodplain</b>	<ul style="list-style-type: none"> <li>• Detain wet season flows</li> <li>• Optimise water treatment using dense vegetation with dense shallow root systems for biofilm creation</li> <li>• Increase adsorption, sedimentation and permeability and infiltration to groundwater through use of clay-sand semi-permeable topsoil cover and dense vegetation</li> <li>• Promote biofilm growth for bacterial transformations</li> <li>• Create habitat for bacteria, fungi and fauna</li> </ul>	<ul style="list-style-type: none"> <li>• 200 mm topsoil</li> <li>• Dense vegetation cover to encourage sedimentation and reduce erosion</li> <li>• Gentle swale gradients to reduce scouring and increase vegetation diversity</li> </ul>
<b>Outlet</b>	<ul style="list-style-type: none"> <li>• Control stormwater detention time/water levels</li> <li>• Can allow for effective gauging</li> </ul>	<ul style="list-style-type: none"> <li>• Riser pit or V-notched weir</li> </ul>

The target maximum discharge is computed as the ratio of the volume of the extended detention to the required detention time:

$$\text{Target Max Discharge (m}^3/\text{s)} = \text{Extended Storage Volume (m}^3\text{)}/\text{Detention Time (s)}$$

The orifice areas and placement required to achieve the target maximum discharge rate can then be calculated using the orifice discharge equation as follows (if the outlet system will operate under inlet control conditions):

$$A_o = \frac{Q}{C_d \sqrt{2gh}}$$

Where:

- $C_d$  = Orifice discharge coefficient (0.6)
- $h$  = Depth of water above the centroid of the orifice (m)
- $A_o$  = Orifice area (m<sup>2</sup>)
- $Q$  = Flow rate to drain out the extended detention area

The weir equation can then be used to define the required perimeter (and thus dimension) of the riser outlet for discharge of larger events in excess of the riser orifice capacity:

$$P = \frac{Q_d}{C_w H^{1.5}}$$

Where:

- $P$  = Perimeter of the riser outlet pit (m)
- $H$  = Maximum required design depth of water above the crest of the outlet pit (m)
- $Q_d$  = Design discharge (m<sup>3</sup>/s)
- $C_w$  = Sharp crested weir coefficient (1.7)

In order to ensure the riser outlet will operate efficiently, it is important that the orifices are prevented from clogging up. Debris guard examples are shown in Figure 6.

Any areas of the wetland requiring regular drainage for maintenance should contain a manually operated drain or bypass structure, allowing water to temporarily bypass the area of the wetland being maintained. Depending on maintenance requirements, this may require a separate outlet of different capacity to the outlet structure described above.



Figure 6. Debris guard examples for riser outlets. (Source: Morton Bay Waterways & Catchments Partnership 2006.)

## Vegetation design

Remnant vegetation areas should be retained and/or restored in keeping with the objectives of the constructed wetland. Choice of vegetation species for each zone depends on the expected hydroperiod and the substrate. The recommended vegetation types for each hydrologic zone for wetlands on the Swan Coastal Plain are outlined in Table 3. For some more specific information on vegetation types, the Perth Biodiversity Project has established reference sites for different vegetation communities, including wetland types, on the Swan Coastal Plain (go to <<http://www.councils.wa.gov.au/directory/walga/index.html/pbp>>). In accordance with the *Decision Process for Stormwater Management in WA* (Department of Environment & Swan River Trust 2005), constructed wetlands should not artificially expose groundwater. Therefore if necessary, ephemeral plants should be chosen over species that require permanent inundation. Plant structures should be fairly open to allow passage of water and optimise sunlight penetration and biofilm growth, yet have dense surface roots.

Planting densities depend on lead time before stormwater enters the system, planting season and weed risk. However, a general density of 4 plants/m<sup>2</sup> is recommended for channel and basin areas. Planting densities need to be high to reduce weed competition and minimise ongoing maintenance costs. Planting densities can be lower for floodplain areas, where an average 3 plants/m<sup>2</sup> is recommended. Plants should be planted in rows perpendicular to the flow path, with each row offset from the previous to minimise short-circuiting and the creation of preferential flow paths.

In WA's south-west, the ideal time to plant low flow channel and basin areas is in early to mid spring when plant growth is at its optimum. Floodplain areas should be planted in winter unless the area will be irrigated. The success of planting is critical for the establishment phase. Water levels in the wetland may need to be manipulated to ensure that soils are saturated for at least eight weeks after planting or until seedlings exceed 200 mm in height. It is critical to allow time for plants to establish themselves before the wetland becomes fully operational.

**Table 3. Vegetation types for wetlands on the Swan Coastal Plain (adapted from Department of Water & Swan River Trust, in preparation)**

Vegetation Zone	Vegetation Types	Examples
Channel and shallow permanent basins	Closed sedgeland and rushes	<i>Eleocharis acuta</i> , <i>Baumea juncea</i> , <i>Baumea articulata</i> , <i>Juncus kraussii</i>
Near-permanent basins	Scattered sedgeland with submergents	<i>Triglochin huegelii</i> , <i>Villarsia</i> spp, <i>Schoenoplectus validus</i>
Lower swale/floodplain	Melaleuca woodlands	<i>Melaleuca raphiophylla</i> , <i>Melaleuca preissiana</i>
Upper swale (dryland)	Closed rushland, sedgeland and heathland	<i>Melaleuca preissiana</i> , <i>Kunzea ericifolia</i> , <i>Baumea juncea</i>

## Mosquito and midge management

If a constructed wetland scores a 'low risk' according to the *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies* (Midge Research Group of Western Australia 2006), then it is likely that minimal monitoring and maintenance for chironomid midges and mosquitoes would be required. In other types of constructed wetlands, regular monitoring, including larval and adult trapping, should be undertaken to determine if control/treatment options are necessary.

Mosquito and midge control are achieved by adopting a composite methodology, known as integrated control, involving various complementary techniques that are designed to reduce the mosquito habitat or

make it unsuitable, as well as encourage biological regulation of the mosquitoes, and thus limit or even eliminate the use of pesticides.

Water levels within the constructed wetland will vary through the natural fluctuation of the groundwater level and surface inflow. Drying out the constructed wetland will achieve mosquito control by interrupting the breeding cycle of mosquito larvae in the sedge bed zone.

Deep-water zones within the constructed wetland will generally be free from surface vegetation. Such areas do not support large populations of mosquitoes, at least in the long term; mosquito populations that colonise the deep-water areas are eventually controlled (but not necessarily eliminated) by predation, physical disturbance, or depletion of food resources.

The long axis of the wetland should be parallel to the prevailing wind direction, which is the direction most common during spring/summer (Midge Research Group of Western Australia 2006). The construction of smooth rather than irregular edges and surfaces to the constructed wetland will help prevent the formation of stagnant pools. Stagnant pools may form within the marsh and ephemeral zones of the wetland that will create an environment conducive to mosquito breeding. Creation of these pools is minimised by creating a slope or installing permeable soil that prevents water ponding. For these areas, monitoring of mosquito populations should be undertaken and other management measures, such as chemical treatments, may need to be considered.

Mosquito control at breeding sites may be achieved by applying chemical larvicides and by introducing biological agents into the habitat. Some control agents can be toxic to other species, in particular, frogs, turtles, fish, birds and invertebrates. Prolonged use can also lead to the development of resistance in the mosquito population. Chemical control should therefore not be viewed as a long-term strategy, but rather as a short-term response to episodes of heavy breeding. See the Department of Health (2006) *Mosquito Management Manual* for more guidance.

The constructed wetland should be regularly monitored to assess mosquito production and to assess the action to be taken if monitoring indicates an increase in mosquito populations. Both adult and larval mosquitoes should be monitored.

For detailed advice on how to reduce the risk of mosquitoes, see the Department of Health (2006) *Mosquito Management Manual* and the Midge Research Group of Western Australia (2006) *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies*.

## Maintenance

To determine whether the wetland is performing as expected, a monitoring program detailing hydrology and the water quality of inflow and outflow is recommended. At a minimum, the following monitoring should be undertaken (Department of Water & Swan River Trust, in preparation):

- monitoring of surface water levels and flow pathways and groundwater levels in the wetland is necessary to ascertain whether the actual wetland hydrology matches that of the design intent; and
- monitoring of the inflow and outflows for total suspended solids and nutrients should be undertaken in low flow and high flow periods.

A detailed maintenance plan must be developed that specifies short and long-term maintenance of the wetland. For simple wetlands, the plan may only need to specify how often to maintain and inspect the banks, when to inspect inlet and outlet structures for signs of clogging and when to remove sediment. More complex wetland designs with mechanical devices, such as valves or pumps, may require much more detailed maintenance plans, including manufacturers' maintenance recommendations.

The maintenance plan should include the following:

- Schedule biannual inspections and conduct inspections after major storm events. Initially, determine if the constructed wetland is working according to design by looking for signs of bank erosion, excessive sediment deposits or plant deterioration. Routine inspection should include checking for clogged or damaged structures and inspecting and testing any mechanical structures such as gates, valves or pumps. Inspections should also include looking for the formation of any isolated pools on the wetland profile. These inspections should also include monitoring for mosquito larvae and undertaking mosquito control if and when required.
- Clear overgrown vegetation from access roads to ensure accessibility to the constructed wetlands for maintenance purposes.
- Remove environmental weeds, particularly those that are invasive.
- Remove accumulated sediment in the inlet zone and regrade approximately every 5–7 years or when the accumulated sediment volume exceeds 10% of the available volume. Sediment removal may not be required in the main pool area for as long as 20 years. Accumulated sediment removed from constructed wetlands should be assessed to determine the risk associated with contamination (e.g. from heavy metals, nutrients and hydrocarbons) so that appropriate steps can be undertaken to treat and dispose of the contaminated materials. Refer to BMP 2.2.2 ‘Maintenance of the stormwater network’ in Chapter 7 for further guidance on managing sediments removed from the stormwater system.
- Remove accumulated litter and debris at the middle and end of the wet season. The frequency of this activity may be altered to meet specific site condition and aesthetic considerations.
- Harvesting (periodic annual or semi-annual cutting and removal of wetland vegetation) may be necessary to maintain the wetland’s soluble nutrients and pollutants removal capacity. Annual vegetation harvesting best occurs in the dry season, as it is generally after the bird breeding season, and there is time for re-growth for runoff treatment purposes before the wet season.
- Revegetation to keep density as prescribed in the vegetation plan, including replacement of dead wetland plants with plants of equivalent size and species.
- Monitoring of the surface water hydrology, groundwater levels, and total suspended solids and nutrients of inflow and outflow is recommended to determine whether the wetland is performing as it was designed.
- Records should be kept of monitoring and maintenance activities.

## Case studies

There are a number of successful local examples of constructed wetland projects. Chapter 6: Retrofitting of this manual provides a detailed example of a constructed wetland project where existing linear drains were recreated as a wetland. The Liege Street Wetland in Cannington (Section 7.6, Chapter 6) aims to treat nutrient-enriched stormwater and groundwater from three drains prior to discharging to the Canning River (Figures 1 and 2).



*Figure 7. Black Creek trapezoidal drain converted to a constructed wetland, City of Cannington. (Photographs: (left) JDA 1999, (right) Water and Rivers Commission 2003.)*

Another retrofitting example is the Black Creek Wetland, which replaced an existing trapezoidal drain in Cannington (Figure 7). The aim of the constructed wetland is to provide an area for sedimentation of particulate material from the industrial Black Creek catchment, as well as provide improved habitat to cater for the needs of various waterbirds.

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## 6 Pollutant Control

### 6.1 Litter and Sediment Management



*Figure 1. Gross pollutant trap upstream of Liege Street Wetland, Cannington. (Photograph: Department of Water 2004.)*



*Figure 2. Maintenance of a litter and sediment trap, upstream of Lake Goollelal, Kingsley. (Photograph: Department of Water 2006.)*

#### Background

Litter and sediment management (LSM) systems are primary treatment measures that retain gross pollutants by physical screening or rapid sedimentation techniques. Gross pollutants generally consist of litter, debris and coarse sediments.

Litter includes human derived rubbish, such as paper, plastic, styrofoam, metal and glass. Debris consists of organic material including leaves, branches, seeds, twigs and grass clippings. Coarse sediments are typically inorganic breakdown products from sources such as soils, pavement or building materials. Gross pollutants are defined as debris items larger than 5 mm (Allison et al. 1997) and coarse sediments are defined as grain sizes greater than 0.5 mm diameter. Some of these pollutants are a threat to wildlife, degrade aquatic habitats, reduce aesthetic qualities, leach harmful pollutants and attract vermin.

Through the implementation of water sensitive urban design (WSUD) in stormwater management, the requirement for LSM devices has been significantly reduced, particularly due to the focus on retention of stormwater at-source and ‘disconnecting’ pollutant transport pathways. Non-structural control methods, such as litter collection programs, strategic bin design and placement, sediment controls on construction sites, street sweeping and minimising the use of deciduous plants in streetscape landscaping, also have significant potential to reduce litter and sediment inputs to the stormwater system. Refer to Chapter 7 for guidelines on these non-structural management measures.

Sediment can also be trapped using filtration techniques, such as buffer strips and swales, and infiltration and detention systems, such as infiltration basins and constructed wetlands, as described in BMPs 4.1, 3.1 and 5.2 in this chapter (refer to Table 2 in the Chapter 9 Introduction). These methods can also retain fine particles. Where implemented at-source, filtration and infiltration methods have the advantage of separating pollutants prior to being carried by flows into the stormwater system, thereby avoiding the difficulties associated with separating pollutants entrained in the flow.

Nevertheless, LSM systems still have a role to play in stormwater management to complement non-structural controls and as pre-treatment to other measures, such as constructed wetlands and bioretention systems, where upstream characteristics warrant their use.

LSM systems can be aesthetically unobtrusive as they require a relatively small footprint and can be situated

below ground. They are suited for retrofitting to an existing piped drainage system, particularly in highly urbanised areas, and targeting specific problem areas with high loads of gross pollutants. Use of these systems assists in preventing blockages of drains and other conveyance based systems.

There are six commonly used LSM systems in Australia. These range from at-source treatment for the upper reaches of the catchment (e.g. side entry pit traps) to those intended for slow-moving waterways (e.g. litter booms) further down the catchment (Allison et al. 1997):

- **Side entry pit traps** are baskets fitted below the entrances to stormwater systems from road and carpark gutters. When stormwater passes through the basket into the side entry pit, material larger than the basket mesh (typically 5–20 mm) is retained. This material remains in the basket until it is cleaned out during required regular maintenance.
- **Litter control devices** are baskets sitting below the entry point of the inlet pipe. Water entering the baskets flows out through the openings, while debris larger than the pore size is retained. As debris builds up, it reduces the pore sizes, allowing smaller material to be caught.
- **Trash racks** consist of vertical or horizontal steel bars, typically 40–100 mm apart, fitted across stormwater channels or inlet and outlet pipes to receiving water bodies. When water passes through the trash rack, it retains material larger than the bar spacing. As material builds up behind the rack, finer material may also be collected.
- **Gross pollutant traps (GPTs)** typically consist of a sediment trap with a weir and trash rack at the downstream end. Flows enter a large typically concrete lined basin and are detained in the basin by a weir, decreasing flow velocities and encouraging sedimentation. The trash rack collects debris from flows overtopping the weir. GPTs servicing small catchments can be located below ground. These devices typically use a series of underground chambers, weirs, screens or baffles to control flows and trap sediments. An alternative below-ground system is a continuous deflective separation (CDS) device, which operates by diverting the incoming flow of stormwater and pollutants into a chamber that has a circular screen that induces a vortex to keep pollutants in continuous motion, preventing solids from ‘blocking’ the screen. The secondary flows induced by the vortex concentrate sediment in the bottom of the unit. Water passes through the screen and flows downstream.
- **Floating debris traps**, or litter booms, are made by placing partly submerged floating booms across waterways to trap highly buoyant and visible pollutants such as plastic bottles. The booms collect floating objects as they collide with it. Newer designs use floating polyethylene boom arms with fitted skirts to deflect floating debris through a flap gate into a storage compartment. Floating booms are not suited to fast moving waters. Additionally, the traps miss most of the gross pollutant load because only a small fraction of gross pollution remains buoyant for a significant length of time.
- **Sediment basins** may be concrete lined, or built as more natural ponds excavated from the site soils and stabilised with fringing vegetation. The basins consist of a widening and/or deepening of the channel so that flow velocities are reduced and sediment particles settle out of the water column. Macrophytes planted in and around the basin will assist in minimising the risk of sediment re-suspension. A pervious rock riffle or weir at the outlet may also assist filtering the water and preventing the conveyance of sediment downstream. Sediment basins are often used as pre-treatment to remove coarse sediment prior to flow entering a constructed wetland system.

Other types of litter and sediment traps include (Victoria Stormwater Committee 1999):

- **Grate and side entrance screens**, which consist of metal screens that cover the inlet to the drainage network and prevent large litter items from entering and blocking the drain.
- **Baffled pits**, where a series of baffles are installed in a stormwater pit to trap floating debris and encourage sediments to settle.
- **Circular settling tanks**, consisting of a cylindrical concrete tank installed below ground that is divided into an upper diversion chamber and a lower retention chamber. A diversion weir at the inlet directs stormwater into the lower retention chamber where sediment settles to the base of the chamber. Flow

exits the chamber through a riser pipe. The inlet and outlet pipes are set at the same level, trapping some oil in the retention chamber.

- **Boom diversion systems**, where a floating boom diverts all low to medium flows into a screened off-line pollutant collection chamber, such as a baffled unit. Under high flow conditions, the boom floats and only deflects floating debris into the chamber, while the majority of flow passes under the boom and bypasses the trap.
- **Release nets** consist of a cylindrical sock made of netting that is secured over the outlet of a drainage pipe and captures all material larger than the pore size of the net. If the net becomes blocked or full, a mechanism is triggered to release the net from the pipe. The net moves downstream until it reaches the end of a short tether attached to the side of the drain that constricts the net opening and prevents the trapped pollutants from being released.

## Performance efficiency

Manufacturers have developed a range of proprietary products designed to trap and separate litter and sediment from stormwater runoff. Most of these products have not been extensively independently tested in the field.

Removal efficiencies are often based on tests of scaled models in the laboratory or limited field testing. In addition, most gross pollutants cannot be sampled by traditional automatic samplers and have not been included in studies evaluating the impact of stormwater runoff on receiving waters.

Fletcher et al. (2003) reports the performance of litter and sediment management systems along with the rationale for these estimates and considerations for their application. Performance estimates for a range of pollutants are shown in Table 1.

While there is a lack of information regarding performance efficiencies locally, the failure to remove nitrogen and phosphorus, as shown in Table 1, is consistent with local studies reported in Martens et al. (2005), based on monitoring in Perth's western suburbs.

**Table 1. Pollutant removal effectiveness (Fletcher et al. 2003)**

Pollutant	Expected removal	Comments
Litter	10–30%	Depends on effective maintenance and specific design. 10% where trap width is equal to channel width, 30% where width is 3 or more times channel width.
Total suspended solids	0–10%	Depends on hydraulic characteristics; will be higher during low flow.
Total nitrogen	0%	Transformation processes make prediction difficult.
Total phosphorus	0%	Total phosphorus trapped during storm flows may be re-released during inter-event periods due to anoxic conditions.
Coarse sediment	10–25%	Depends on hydraulic characteristics; will be higher during low flow.
Heavy metals	0%	

Stormwater designers are recommended to check the claimed performance efficiency results of specific devices, examine the conditions the results were obtained under, ensure testing is independent and refer to guidelines, such as the Victoria Stormwater Committee (1999), for removal rate estimates in the absence of available data. For example, monitoring of a GPT capturing runoff from a 50 ha catchment in Coburg,

Melbourne, over a period of 3 months found the unit trapped practically all gross pollutants (Allison et al. 1997). The device was also found to have minimal impact on flows in the drain. However, it should be noted that for the purposes of the study, the trap was cleaned after every storm, and the CDS unit was used as a downstream control in combination with side entry pit traps installed at all road drain entrances in the catchment.

## Cost

A life cycle cost method is recommended in assessing the true costs of LSM systems. This approach takes into consideration the capital costs as well as maintenance, servicing and spoil disposal costs over the life of the system.

Taylor (2005) details a range of costs for various LSM systems, but notes a very high degree of variability in most cost elements and urges caution in the use of the information provided.

Due to the high variability and lack of standardisation of available cost data, it is recommended that capital costs for individual LSM systems be assessed on a case by case basis. Annual maintenance costs presented in Taylor (2005) (cited as Weber 2001 and 2002) typically range in the order of 7 to 30% of the capital cost.

## Design considerations

The principal design objective of LSM systems is to achieve a balance between the impact on the discharge capacity of the drainage system, the trapping efficiency of the unit and the capital and maintenance costs. The expected gross pollutant loading and trapping efficiency have a significant impact on the dimensions of the LSM system and its maintenance requirements.

The selection and positioning of LSM systems need to be strategic as these devices can be expensive to install and maintain. LSM systems should be used to target high litter generation areas, such as commercial areas. In areas with low litter generation rates, such as typically found in low density residential areas, source controls and non-structural methods are likely to be more cost effective. The recommended four steps to optimise the location of LSM systems are (adapted from Victoria Stormwater Committee 1999):

- Identify high litter generation areas from field inspections, examination of land use maps and consultation with council officers and community catchment groups.
- Determine the drainage pathways for each of the high litter generation areas from examination of drainage plans and field verification.
- Determine whether an at-source, in-transit or end-of-pipe LSM system would be most suitable for each area.
- Identify the most suitable and optimal locations for installing the LSM systems in order to achieve the maximum load of gross pollutants trapped per dollar spent on the project.

A guide to determining whether an at-source, in-transit or end-of-pipe LSM system is most suitable is provided below:

- **At-source LSM systems**, such as entrance litter baskets, are likely to be most suited to treat runoff from small sized high litter generation areas, for example a local commercial strip with up to ten shops. At-source systems should also be considered in medium sized high litter generation areas if runoff from the pollutant source areas flows to different drainage networks, or if the runoff combines with significant volumes of runoff from low litter generation areas downstream. In-transit LSM systems may not be cost effective in these cases as numerous units or a very large unit to treat high volumes of flow that carries low concentrations of litter may be required. The advantage of at-source systems is that the inlets that receive the most litter can be targeted. The disadvantage of distributed at-source systems is that the number of sites requiring maintenance is increased.

- **In-transit LSM systems** are generally most suitable to capture flows from medium to large sized high litter generation catchment areas (e.g. large shopping centres and light industrial areas with fast food outlets). In-line systems are most effective where the majority of the source area flows through one outlet and that outlet does not receive significant runoff from other low litter generation areas.
- **End-of-pipe LSM systems** are suited to medium to major high litter generation areas or where a number of smaller source areas are connected along the same drainage pathway.

The design of LSM systems must also consider that previously trapped material may be remobilised when high inflows causing turbulence or overflows occur.

There are also potential health risks to maintenance workers when handling litter and rubbish, particularly if contaminants have been left in an oxygen limiting environment (i.e. enclosed underground system) for an extended period. Retained water can become anaerobic due to decomposition of settled organics, possibly causing attached nutrients and heavy metals to become dissolved. Safety precautions in handling litter also need to consider potential needles and other sharp objects that may be in the trapped material. Due to the various potential health risks associated with handling litter, appropriate personal protective equipment should be used. Nuisance problems such as odour and mosquito breeding can also occur, particularly if the system is not operating correctly or if maintenance is required (e.g. removing accumulated litter). See Section 1.7.7 'Public health and safety' of the Introduction section of this chapter for more information on mosquito management.

Floating debris traps can also be visually unattractive.

Safety barriers may be required around LSM systems if they have steep sides or deep pools (children can drown in only 4 cm of water). To enable access and for public safety purposes, the bank slope of the trap or basin should typically be between 1:6 and 1:8 (refer to requirements of individual local authorities). Where the banks are too steep, railings, signage or vegetation can be used to discourage public access. If located within the floodway, railings should be aligned parallel to the main direction of flow so that they do not trap debris and contribute to flooding.

Vegetation can be used to disguise the LSM system, as well as prevent easy access to the structure. The appearance of a trap can be greatly improved by landscaping and the selection of construction materials. The use of local rock or coloured concrete in construction may also assist in minimising the visual impact.

## Design guidelines

This section outlines important considerations when choosing a LSM system for site specific purposes. The guidelines are based on *Bringing Order to the Pollution Control Industry – issues in assessing the performance of gross pollutant traps* (Wong et al. 1999).

### Location and layout

The factors to consider when assessing the suitability of a location for installing a LSM system are (adapted from Victoria Stormwater Committee 1999):

- the location of the LSM system in the treatment train and the presence of any other existing or proposed stormwater controls;
- the location in the drainage network relative to the identified high litter generation areas;
- stormwater system details (e.g. pipe sizes and gradients);
- space constraints such as the presence of underground services;
- vehicle access to the site for maintenance; and
- potential impacts on the community (e.g. disturbance during construction and maintenance, visual impacts, odours, or breeding of nuisance and disease vector insects).

The dimensions of a LSM system, the flow paths of stormwater through the system and the mechanisms used to intercept and retain gross pollutants are factors that determine its suitability for installation at a chosen site. Systems designed to capture both gross pollutants and sediment invariably require a larger area than systems designed to trap gross pollutants alone. This is due to the fact that sediment loads are often significantly higher than gross pollutant loads and the trapping mechanism involves flow retardation (i.e. expansion of the waterway to reduce flow velocity) to facilitate settlement of sediment.

The layout of the LSM system and the overflow path are important design considerations in ensuring adequate hydraulic performance of the trap under above-design and non-ideal flow conditions. The available space on-site will need to be compatible with the selected design discharge and the provisions for above-design and non-ideal flow operation.

### Design flow

The appropriate design flow for a LSM system varies from one application to another.

The selection of the design discharge is primarily used to define the minimum height of the flow diversion or flow by-pass mechanism such that all flow at or below this design discharge will pass through the solids separation section of the LSM system. Flows in excess of the design discharge will either over pass or be diverted around the solid separation mechanism.

In LSM systems involving capture of sediment, principally by sedimentation, the minimum dimension of the sediment basin/chamber is set by matching the settling velocity of the targeted sediment size to the ratio of the design flow rate to the surface area of the basin. Remobilisation of settled sediments is an issue that may be addressed by setting the maximum flow velocity below that which is likely to cause re-entrainment.

The majority of storm events with the potential to mobilise and transport urban pollutants to receiving waters are events of relatively low rainfall intensity. This is demonstrated in Figure 3 which presents the overall percentage of the expected volume of the annual stormwater runoff treated by a LSM system, against the design standard of the system for urban catchments using a time of concentration of 1 hour (Wong et al. 1999).

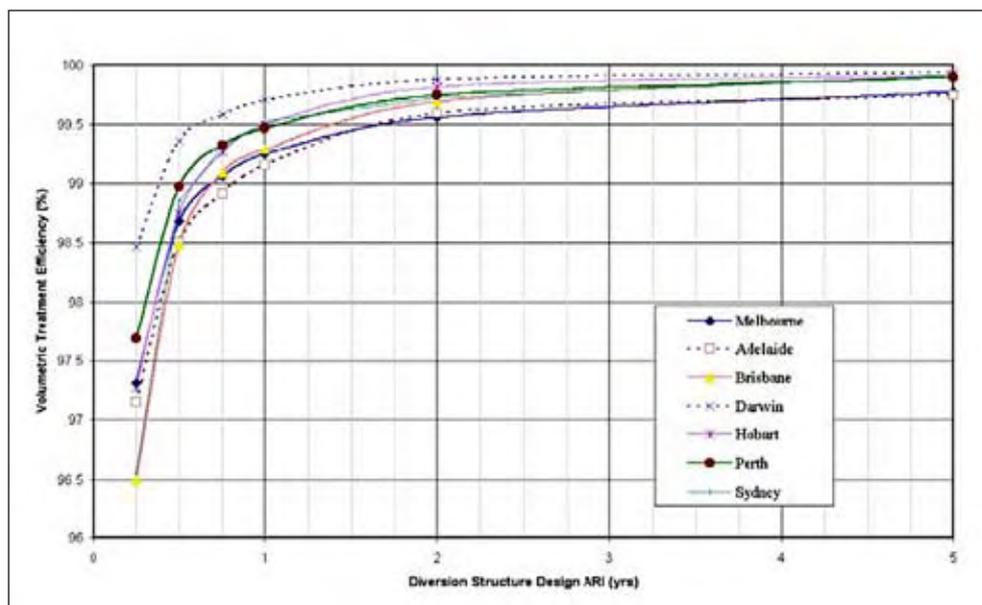


Figure 3. Treatment efficiency for various design ARIs. (Source: Wong et al. 1999.)

The volumetric treatment efficiency listed on the vertical axis of Figure 3 defines the percentage of the expected annual volume of runoff which can be expected to flow through the LSM system at a rate which

is lower than the design discharge of the system. Analyses were carried out for catchments of different sizes with critical storm durations of 0.5, 1, 3 and 6 hours. The results for each of these cases were found to be similar in that most devices can be expected to treat over 95% of the expected annual runoff volume when designed for a 0.25 year average recurrence interval (ARI) peak discharge. The corresponding volumetric treatment efficiency for a device designed for a 1 year ARI peak discharge is approximately 99%.

These results are applicable to any type of hydraulic structure and clearly demonstrate that the design standard of structures need not be set excessively high to gain significant benefits in the overall proportion of stormwater treated.

All LSM systems are required to operate satisfactorily for larger events up to the discharge capacity of the stormwater drainage system in which the LSM systems are placed. The same operating criterion applies in the event of non-ideal conditions associated with situations when excessive inflow of gross pollutants has resulted in the trapping mechanisms being compromised or blocked. Above-design and non-ideal operation criteria include provision of the following:

- a controlled and predictable flow path for stormwater in excess of the design discharge (with predictable energy loss associated with these flow conditions);
- minimum reduction in the discharge capacity of the stormwater drainage system under above-design flow or non-ideal flow conditions; and
- protection of trapped material from being entrained with the flow and consequently transported out of the structure to the receiving waters.

### **Trapping efficiency**

The trapping efficiency is defined as the proportion of the total mass of gross pollutants transported by stormwater that is retained by the LSM system. Common presentations of trapping efficiency data include reports of the weight or volume of gross pollutant removed. These reports are often provided without accompanying information that will enable computation of a mass balance between gross pollutant captured and that which has passed through the LSM system, making comparisons of different systems difficult.

While it is difficult to monitor field installations to satisfy a mass balance criterion, other data related to catchment area, rainfall, stormwater flow, and frequency and duration of above-design conditions, in association with the clean-out data, are helpful in developing a common basis for comparing performance.

Performance data for most LSM systems are confined to hydraulic behaviour under ideal conditions and without the interaction of the flow with urban derived litter and gross solids. This is considered inadequate for assessing the suitability and reliability of LSM systems in field conditions.

Continuous recording of water levels can often be used to assess the performance of a LSM system by identifying periods of non-ideal operating conditions. For example, observing the rate at which the water level in a GPT recedes at the conclusion of a storm event allows an assessment of the degree of blockage in the separation screen of the trap. Similarly, comparison of water levels on the upstream and downstream sides of a screen can often be used to estimate deterioration of the performance of the unit.

### **Gross pollutant characteristics and loading**

Estimates of the gross pollutant loads are required when designing litter and sediment traps.

The composition by mass of gross pollutants and litter for Coburg, a suburb of Melbourne, is presented in Figures 4 and 5. Coburg is considered a typical example of inner city suburbs in Australian capital cities. The study found that in all land use types, a major proportion of the total gross pollutant load is made up of organic material such as leaves, twigs and grass clippings. When the gross pollutant data were sorted to examine the composition of litter, paper and plastics were found to be the dominant types.

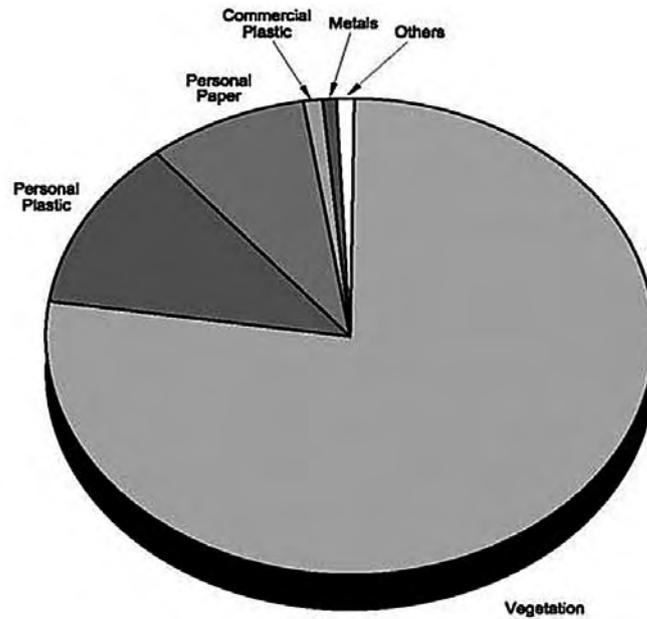


Figure 4. Composition of urban gross pollutants by mass. (Source: Allison et al. 1997.)

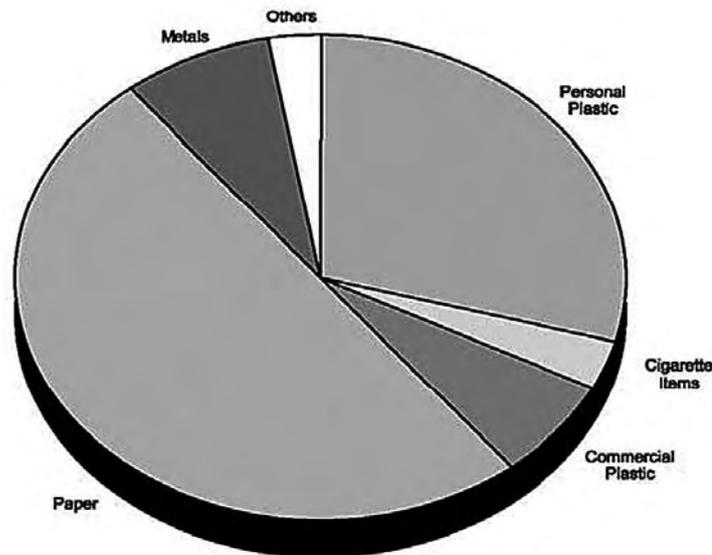


Figure 5. Composition of urban litter by mass. (Source: Allison et al. 1997.)

Studies by Allison et al. (1997, 1998a, 1998b) for the Coburg catchment provided nominal annual gross pollutant (i.e. material greater than 5 mm in size) load estimates of approximately 90 kg/ha/yr (wet weight). In their analysis, it was found that the typical pollutant density (wet) is approximately 250 kg/m<sup>3</sup> and the wet to dry mass ratio is approximately 3.3 to 1. This gives the expected volume of total gross pollutant load as approximately 0.4 m<sup>3</sup>/ha/yr. The results of these studies can be applied to estimate gross pollutant loads in cities with similar rainfall and runoff patterns.

Stormwater runoff in suburbs on the Western Australian coastal plain are likely to have lower loads of gross pollutants due to the higher infiltration rate and lower direct connectivity of the runoff pathways compared to Melbourne. The higher infiltration rate reduces surface water discharge and hence the potential for gross pollutant transport.

The studies also found that a high proportion of the total gross pollutant load consists of vegetation (i.e. leaves) and that urban derived litter, food and drink refuse (from fast food consumers) and cigarette refuse, constitutes approximately 30% of the total gross pollutant load. These items entered the drainage network mainly from commercial areas. Data have indicated that approximately 10% of gross pollution remains buoyant for a significant length of time.

The study by Allison et al. (1997) found that gross pollutant concentrations are highest during the early stages of runoff; however most of the load is transported during periods of high discharge. Similar loads and concentrations of gross pollutants were found in runoff from different storms that occurred on the same day. Therefore, LSM systems should aim to treat the maximum possible discharge and be able to accommodate multiple storms in one day.

### **Minimum dimensions**

The minimum dimensions of the LSM system are dependent on the expected rate of sediment and gross pollutant exported from the catchment and the capture efficiency.

Efficient traps with small capacity for containment of trapped material require a high frequency of clean-out if the integrity of their trapping mechanism is not to be compromised.

## **Maintenance**

Regular inspection and cleaning of LSM systems is essential to maintain their performance and prevent the devices from blockages or releasing pollutants. Poorly maintained devices can increase the risk of upstream flooding (Engineers Australia 2006).

The device should have a site specific maintenance plan, providing guidance on a suitable inspection regime, maintenance practices (including guidelines on the equipment to be used, health and safety procedures, waste disposal arrangements, etc.) and responsibilities. These plans should be prepared in consultation with relevant maintenance personnel. Health and safety procedures need to address handling trapped litter that may contain needles and other sharp objects.

Frequent inspection is initially necessary following installation of the device to develop an appropriate inspection and cleaning regime. Maintenance schedules should not be fixed, but reviewed regularly to reflect the performance outcome from ongoing monitoring and optimise the maintenance regime. Flexibility of the maintenance regime is required given the seasonality and uncertainty of rainfall patterns and pollutant accumulation rates. Inspection and cleaning (if required) immediately prior to the wet season is essential.

Opinions on the frequency and timing of cleaning vary. However, experience suggests that fixed interval cleaning by contract cleaners, combined with regular council audits may be the best combination in most instances. It means that the LSM systems are being cleaned and the costs are budgeted for. A notable exception is where the systems are situated above ground and pollutant build-up can be easily sighted, in which case cleaning on 'demand' may be more effective. Where wet sumps are installed, trapped pollutants may break down and release contaminants and nutrients back into the stormwater system. Under these circumstances, cleaning may need to be undertaken much more frequently. Stormwater managers are required to critically assess the adequacy of manufacturers' recommended maintenance schedules.

The type of land use and industries upstream of the LSM system should be considered in predicting what types of pollutants are likely to be trapped in the device or sediments. Sediments in open basins may contain iron monosulphide black oozes and will require special removal techniques to prevent oxygenation and subsequent acid release and deoxygenation of the water body. In regions like Perth, there is evidence to suggest that accumulated sediments in urban areas are enriched with nutrients, heavy metals and hydrocarbons (Swan River Trust 2003). Management of handling, drying and final disposal of materials

removed during desilting operations needs to be considered. Spoil excavated from sediment basins should be placed where it can not wash back into the basin or release contaminants back into the stormwater system. Areas disturbed by maintenance activities should be stabilised upon completion of the sediment removal works. Refer to BMP 2.2.2 'Maintenance of the stormwater network' in Chapter 7 for further guidance on managing sediments removed from the stormwater system.

Suitable equipment to extract the waste from the stormwater system needs to be used (e.g. for enclosed drains and pits, machinery that operates via suction rather than flushing). If the trap requires dewatering in order to remove solids settled at the base, then discharge of the liquid contents to the sewerage system or a wastewater tanker will need to be arranged. Depending on whether pollutants are collected on a solid surface or in a basket or sump, traps can be cleaned by hand or loader, by removing baskets by a crane truck, or by removing the contents of a sump with a vacuum truck.

An important factor is that there must be ready access to the device for the required type and size of vehicle. This service must be available in the area where the device is installed, otherwise transport costs become significant and there is the temptation to clean traps less frequently than required. The filter medium of some types of traps may need to be occasionally replaced if degraded or clogged.

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# Pollutant Control

## 6.2 Hydrocarbon Management



*Figure 1. Service stations are a common source of hydrocarbon pollutants. (Photograph: Department of Water 2007.)*

### Background

The Unauthorised Discharge Regulations 2004 of the *Environmental Protection Act 1986* make it illegal to discharge substances, such as hydrocarbons, to groundwater or the stormwater system.

The primary aim of hydrocarbon pollution management is to provide at-source containment through the implementation of appropriate structural measures. Non-structural techniques, such as raising the awareness of operators or imposing heavy fines for illegal discharges, are also useful preventive measures. Compliance with control requirements incorporated into building approvals and industry operating licences, as well as pollution discharge inspection and monitoring, help to better regulate the principal sources of contamination.

On any site there may be one or more levels of containment. Primary containment deals with the tank or vessel in which the material is stored. It is therefore the first line of defence and must be fit for purpose. Secondary containment uses devices or structures that capture spills for treatment. These can either be 'local' containment, such as oil-water separators, or 'remote' containment such as floating booms installed on the inlets to ponds or wetlands. Remote containment can be an effective temporary measure for emergency spill response, but should not be considered in preference to local containment measures.

A risk assessment is useful in deciding the appropriate level of containment. The operator should consider the hazardous materials on-site, the risks posed by accidents, the likely failure mode of the primary containment, the sensitivity of receiving environments and the potential pathways for any resultant discharge to enter the stormwater system or be transported to receiving environments.

Commonly applied non-structural practices for hydrocarbon management include:

- Preventing the mixing of stormwater and wastewater (for example from industrial processes or wash-down of vehicles or floors) and treating these water streams separately.
- Servicing, repairs and other activities that may result in contaminants such as oils, grease, solvents, acids, fuels, coolants and surfactants accumulating on hardstand areas should be undertaken in weatherproof and contained areas to prevent these contaminants entering the stormwater system.
- Activities should be undertaken on sealed concrete floors that prevent contaminants entering groundwater and enable comparatively easy clean-up of any spilt servicing fluids.
- Floors should be designed to drain to an internal collection sump and/or surrounded with an impervious perimeter bund. Any stormwater be diverted away from the workshop floor and chemical or parts storage areas.

- Wastes and wastewater should be disposed of in an approved manner, such as by removal off-site by a waste recycling and disposal contractor, or treatment and disposal to sewer where permitted.
- Chemicals and waste products should be stored in weatherproof and contained areas to prevent weathering of storage containers and to minimise the risk of contaminants from accidental spillage or ruptured containers entering the stormwater system or the environment. Storage tanks, such as underground fuel tanks, should be inspected and tested for leakages. All loading and unloading should also be undertaken in contained areas.

Oil-water separators are used to remove remnant pollutants that cannot be controlled using the practices outlined above.

Oil-water separators are often used in retrofit situations to provide some water quality treatment at a lot scale, particularly for small industrial or commercial lots where larger BMPs are not feasible due to site constraints. There is a variety of both proprietary and non-proprietary oil-water separators available, ranging from chambered designs to man-hole types. Many of these systems are 'drop in' systems and incorporate some combination of filtration media, hydrodynamic sediment removal, oil and grease removal, or screening to remove pollutants from stormwater. The standardised designs allow for relatively easy installation.

These separators are best used in commercial, industrial and transportation type land uses (i.e. impervious areas that are expected to receive high sediment and hydrocarbon loadings, such as carparks and service stations). However, oil-water separators cannot be used for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols and alcohols.

For non-structural control information, refer to Sections 2.2.6. 'Maintenance of premises typically operated by local government', 2.2.8. 'Maintenance of vehicles, plant and equipment (including washing)', 2.2.10. 'Stormwater management on industrial and commercial sites', 2.3.4. 'Education and participation campaigns for commercial and industrial premises', 2.4.2 'Point source regulation of stormwater discharge and enforcement activities' and 2.5.1 'Risk assessments and environmental management systems' of Chapter 7: Non-structural controls. For further information on managing stormwater and preventing pollution from industrial sites, see the following Water Quality Protection Notes: *Industrial Sites near Sensitive Environments – establishment and operation* (Department of Environment 2004a), *Mechanical Servicing and Workshops* (Department of Environment 2005a), *Stormwater Management at Industrial Sites* (Department of Water 2006a), *Mechanical Equipment Washdown* (Department of Water 2006b), *Radiator Repair and Reconditioning* (Department of Water 2006c), *Service Stations* (Department of Water 2006d), and *Toxic and Hazardous Substances- storage and use* (Department of Water 2006e), available on the Department of Water website: <<http://drinkingwater.water.wa.gov.au>>.

Further information about spills and emergency response is available at <<http://emergency.environment.wa.gov.au>>.

## Performance efficiency

Selection of an appropriate oil-water separator is largely governed by the level of hydrocarbon interception that is required and the likely oil droplet size. Performance efficiencies for various types of oil-water separators are described below, based on information detailed in Engineers Australia (2006).

- **Flow density-based separators:** use a series of simple flow baffles to trap sediment and floating oil (Figure 2). The collected oil is removed by an oil skimmer to a separate storage tank or periodically removed by a suction tanker. The application of these separators is limited to medium (100-140  $\mu\text{m}$ ) size oil droplets (i.e. runoff conditions close to the source, with limited emulsification of the oil). The maximum treatable catchment area is typically less than 0.2 ha.
- **Coalescence plate-based separators:** use closely packed plates coated with a material that repels water and attracts oil, causing oil droplets to coalesce (i.e. join together). The accumulated oil on the plate then

floats to the surface of the separation chamber. The close spacing of the plates reduces the distance that an oil droplet must travel before it reaches a collection surface. Therefore, to achieve the same degree of treatment as a flow density-based separator, a smaller device can be used. These separators are capable of high interception rates (>90%) for small (50–60 µm) oil droplets that are typical of oil that has been highly emulsified by stormwater. The maximum treatable catchment area is typically less than 0.5 ha.

- **Vortex-based separators:** use the energy of the vortex to promote the density separation of oil and water. Vortex-based separators are capable of intercepting very fine (20–30 µm) oil droplets.

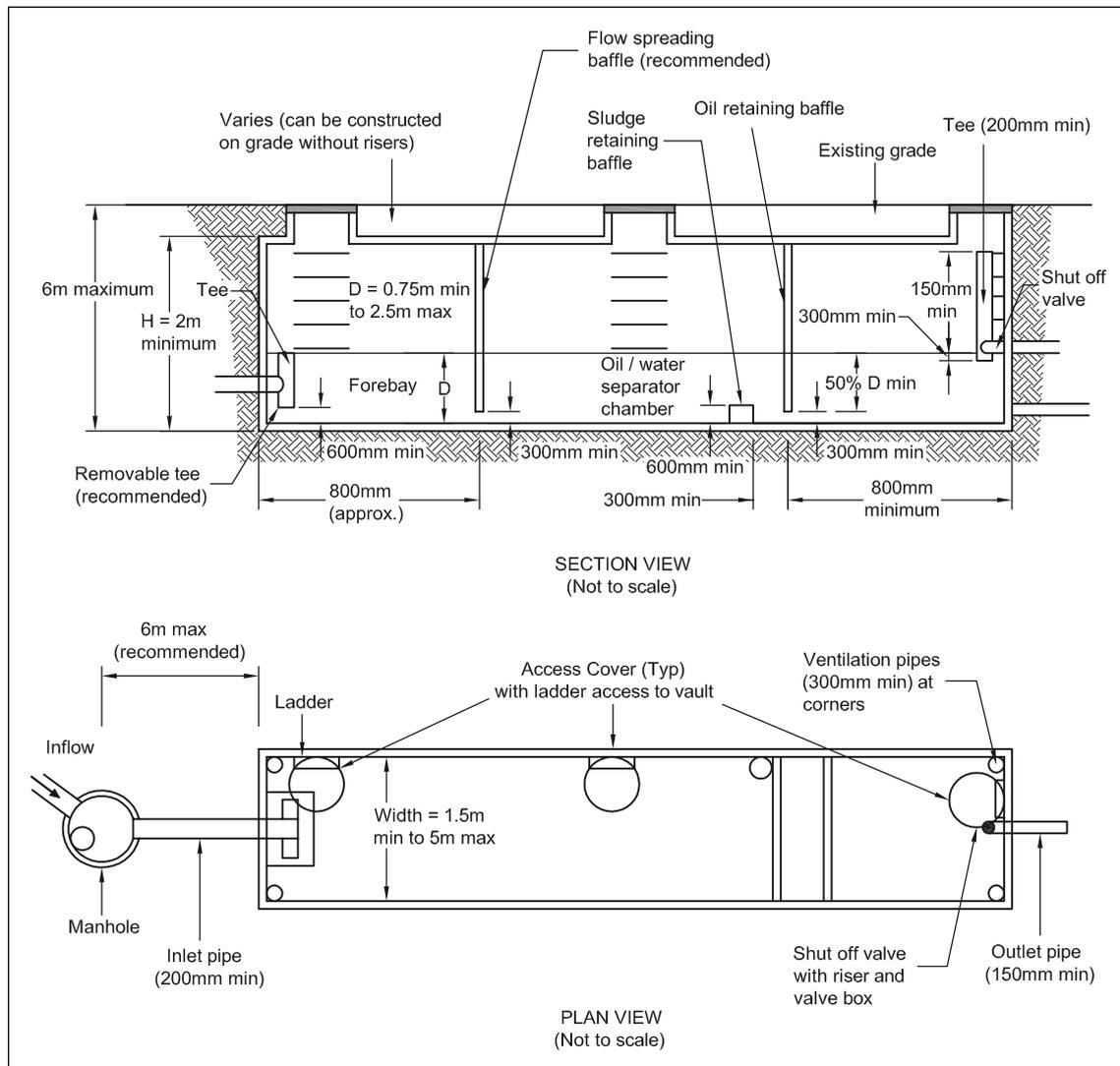


Figure 2. Typical Flow Density-Based Separator Layout. (Source: Auckland Regional Council 2003.)

## Cost

The construction costs for oil-water separators will vary greatly, depending on their size and depth.

A life cycle cost method is recommended in assessing the true costs of oil-water separator systems. This approach takes into consideration the capital costs as well as maintenance, servicing and disposal costs over the life of the system.

Due to the high variability and lack of standardisation of available cost data, it is recommended that capital costs for individual systems be assessed on a case by case basis.

Maintenance costs will also vary significantly depending on the size of the drainage area, the amount of residual collected and the clean-out and disposal methods available (Schueler & Shepp 1993). The cost of

residual removal, analysis and disposal can be a major maintenance expense, particularly if the residuals are toxic and are not suitable for disposal in a conventional landfill.

## Design considerations

Only rainfall runoff that may contain hydrocarbons (e.g. runoff from carpark areas or areas adjacent to fuel pumps) should enter the oil-water separator that is part of the stormwater treatment system. Runoff that is relatively clean (e.g. roof runoff) should be managed separately to minimise the volume of stormwater that requires a high level of treatment. Oil-water separators installed to treat stormwater runoff at industrial or commercial sites should not be used to collect and treat wastewater or fluids from chemical or petroleum spills.

Careful evaluation of the maintenance and disposal issues is highly recommended. Higher residual hydrocarbon concentrations in trapped sediments cause maintenance and residual disposal costs associated with oil-water separators to be higher than other BMPs. Proper disposal of trapped sediment, oil and grease is required as trapped material is likely to have high concentrations of pollutants and might be toxic.

Ease of access for maintenance and inspection is required. In particular, lids should be kept as lightweight as practical.

Oil-water separators should be designed and constructed as offline systems only. In addition, it is recommended that the contributing area to any individual inlet be limited to approximately half a hectare or less of impervious surface.

## Design guidelines

The following design guidelines for an oil-water separator are based on Auckland Regional Council (2003). Auckland Regional Council (2003) is provided as a design reference for oil-water separators in Engineers Australia (2006).

### Rise velocity

The rise velocity for an oil droplet within a separator can be calculated, given the water temperature (which affects the viscosity of the water) and the density of the oil. This rise velocity is then used in the sizing calculation for the device.

$$V_r = \frac{g \cdot D^2 (1 - s)}{18\nu}$$

Where:

$V_r$  = rise velocity of an oil droplet (m/s)

$s$  = specific gravity (e.g. oil 0.9, diesel 0.85, kerosene 0.79 and gasoline 0.75)

$D$  = droplet diameter (m)

$\nu$  = kinematic viscosity of water (m<sup>2</sup>/s)

$g$  = gravitational acceleration (m/s<sup>2</sup>)

### Design flow

The required design (treatment) flow rate can be calculated using the Rational Method equation:

$$Q_d = \frac{C \cdot i \cdot A}{1000}$$

Where:

$Q_d$  = required design (treatment) flow rate (m<sup>3</sup>/hr)

C = coefficient of runoff

i = rainfall intensity for selected design rainfall event (mm/hr)

A = catchment area (m<sup>2</sup>)

In WA, a design rainfall recurrence period of 1 in 6 months can be expected to achieve water quality treatment of at least 95% of the expected annual runoff volume. For small catchments, a critical storm of minimum 10 minute duration should be used.

### Tank sizing for flow density-based separator

The base area of the tank ( $A_b$ ) is a function of the rise velocity ( $V_r$ ), expressed in m/hr, and design flow rate ( $Q_d$ ), expressed in m<sup>3</sup>/hr:

$$A_b = \frac{F \cdot Q_d}{V_r}$$

The factor F is dimensionless and accounts for short circuiting and turbulence effects, which can degrade the performance of the tank. The factor depends on the ratio of horizontal velocity (U) to the rise velocity ( $V_r$ ), as shown in Table 1 based on Auckland Regional Council (2003).

**Table 1. Factor F for calculation of tank sizing**

$U/V_r$	Factor (F)
3	1.28
6	1.37
10	1.52
15	1.64

The volume and area calculated by this method refer to the main compartment of the tank. Additional volume should be allowed for inlet and outlet sections of the tank.

Other key sizing requirements detailed in Auckland Regional Council (2003) for sizing the main compartment of the tank are:

- Length to be at least twice the width
- Depth to be at least 0.75 m
- $U \leq 15V_r$

Additionally, it is recommended that the width is typically between 1.5 m to 5 m, and depth is less than 2.5 m (and between 0.3 to 0.5 times the width). Some of these additional recommendations will not be appropriate for smaller catchments.

To avoid re-entrainment of oil and degradation of performance, it is recommended that the maximum horizontal flow velocity in the main part of the tank be less than 25 m/hr.

### Tank sizing for coalescence plate-based separator

Plate separator suppliers can provide an approximate size to achieve the required oil droplet diameter separation at the chosen design flow rate. The plan area ( $A_{plan}$  in m<sup>2</sup>) of each plate can be approximated from the following equation:

$$A_{plan} = \frac{Q_d}{V_r \cdot N}$$

Where  $N$  = the number of coalescing plates and the rise velocity ( $V_r$ ) and design flow rate ( $Q_d$ ) are expressed in m/hr and  $m^3/hr$  respectively.

### Other considerations

A high flow bypass may be required in certain situations so that flows above the design flow do not enter the oil-water separator and cause re-suspension of debris or entrainment of oils.

A bypass system may not be required where the catchment draining to the oil-water separator is small and therefore the volumetric increase in runoff can be accommodated by the tank size. An adequately sized tank is generally preferable to a bypass system, which will result in contaminants potentially reaching the main drainage system and receiving water bodies.

Where a bypass system is installed, an inlet baffle should be included. The inlet baffle prevents the collected oil from recirculating back into the bypass system and subsequently into the drainage system.

To achieve an even flow distribution across the tank at the inlet, a baffled inlet port or other device is used. The sizing of the inlet port or baffle should be such that some head loss is provided to spread the flow. It is recommended that velocities of the maximum separator flow should be less than 0.5 m/s to avoid oil emulsification.

## Maintenance

The effectiveness of oil-water separators is highly dependent on regular maintenance. Regular inspection and maintenance is required to reduce the risk of re-suspension of debris or entrainment of oils. Failure of hydrocarbon management systems is usually caused by a lack of maintenance.

Recommended maintenance practices are outlined below:

- The device should have a site specific maintenance plan, providing guidance on a suitable inspection regime, maintenance practices (including guidelines on the equipment to be used, health and safety procedures, waste disposal arrangements, etc.) and responsibilities. These plans should be prepared in consultation with relevant maintenance personnel.
- In the case of proprietary systems, use the manufacturers' recommended maintenance specification as a basis. However, stormwater managers are required to critically assess the adequacy of manufacturers' recommended maintenance schedules on a case by case basis. Where necessary, the maintenance requirements or cleaning frequency may need to be increased, particularly for high risk catchments (see Engineers Australia (2006) for further information on catchment risk assessment for hydrocarbon management). Frequent inspection is initially necessary following installation of the device to develop an appropriate inspection and cleaning regime. Maintenance schedules should not be fixed, but reviewed regularly to reflect the performance outcome from ongoing monitoring and optimise the maintenance regime.
- Periodic removal of sediment is required to maintain the capacity of oil compartments, prevent blockages of inlets and maintain the functioning of coalescence plates. As a general guide, in areas of high sediment loading, inlets should be inspected and cleaned after every major storm event, and inspected at least monthly. Typically, oil separators need to be maintained every 1 to 6 months.
- Suitable equipment to extract the waste from the drainage system needs to be used (e.g. machinery that operates via suction rather than flushing).

- Nuisance problems such as odours and mosquito breeding can occur with the use of wet chambers. Therefore, regular visual inspection of chambers is required during the mosquito risk breeding months and pollutants removed and mosquito control undertaken when necessary.
- The amount of material removed from each chamber should be documented so that the frequency of maintenance can be adjusted if required.
- A representative sample of the sediment should be analysed before disposal. If the sediment requires disposal in a landfill, refer to the *Landfill Waste Classification and Waste Definitions 1996* (As amended) (Department of Environment 2005b) to determine the appropriate landfill type and the waste acceptance criteria. The Department of Environment and Conservation regulates the transportation of wastes that may cause environmental or health risks. It does this through the application of the Environmental Protection (Controlled Waste) Regulations 2004. Controlled waste is generally defined as any waste that does not meet the acceptance criteria for a Class I, II or III landfill site. The *Guideline for Controlled Waste Generators* (Department of Environment 2004b) specifies that a generator is a person whose activities produce or apparatus results in the production of controlled waste. Generators are required to use a Department of Environment and Conservation controlled waste licensed carrier to transport the material off-site and be in possession of a controlled waste tracking form.

### Worked example

The following worked example has been adopted from Auckland Regional Council (2003) and amended to represent local hydrologic conditions.

A service station in Perth is to be fitted with an oil-water flow density-based separator to treat runoff that is potentially contaminated with hydrocarbons. Runoff from the roof should be separated from runoff that is likely to be contaminated with hydrocarbons (e.g. pavement runoff). The wastewater from the car wash area is to be directed to a water reuse system, which is connected to the sewer. The flow density-based oil-water separator installed to treat pavement runoff will have a catchment area of 300 m<sup>2</sup> draining to the device.

The rainfall intensity for a 10 minute critical storm duration with a return period of 0.5 years (i.e.  $i_{10m}^{0.5}$ ) in Perth is 34 mm/hr. The separator design flow, using the Rational Method equation is:

$$\begin{aligned}
 Q_d &= \frac{C.i.A}{1000} \\
 &= \frac{1.0 \times 34 \times 300}{1000} \\
 &= 10.2 \text{ m}^3/\text{hr}
 \end{aligned}$$

The separator is to be designed for this example to capture a 60 µm droplet of oil ( $s = 0.9$ ) rising through water at 15°C (which has a kinematic viscosity  $\nu = 1.139 \times 10^{-6} \text{ m}^2/\text{s}$ )

To calculate the rise velocity:

$$\begin{aligned}
 V_r &= \frac{g \cdot D^2 (1-s)}{18\nu} \\
 &= \frac{9.81 \cdot (60 \times 10^{-6})^2 (1-0.9)}{18 \cdot (1.139 \times 10^{-6})} \\
 &= 1.72 \times 10^{-4} \text{ m/s}
 \end{aligned}$$

The rise velocity is  $1.72 \times 10^{-4} \text{ m/s}$  (or 0.62 m/hr).

The maximum design flow horizontal velocity (U) at the separator is  $15 V_r = 15 (0.62 \text{ m/hr}) = 9.3 \text{ m/hr}$ . Therefore the flow cross section (depth times the width) is  $Q_d/U = (10.2 \text{ m}^3/\text{hr}) / (9.3 \text{ m/hr}) = 1.1 \text{ m}^2$ . The minimum required depth is 0.75 m, which gives a width of 1.5 m. These dimensions are within the recommended guidelines of the depth being typically half the width.

For  $U = 15 V_r$ , an F of 1.64 is then used (from Table 1) to calculate the base area  $A_b$ :

$$\begin{aligned} A_b &= \frac{F \cdot Q_d}{V_r} \\ &= \frac{1.64 \times 10.2}{0.62} \\ &= 27 \text{ m}^2 \end{aligned}$$

With this plan area and a width of 1.5 m, the length is 18.0 m. The volume of the main chamber of the tank will be  $20.2 \text{ m}^3$  (excluding inlets and outlets). The tank will actually be longer to allow for an inlet chamber and an outlet section, which, as an approximate guide, could add an additional 20% to the total tank volume.

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Stormwater  
Management  
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10  
Performance  
Monitoring and  
Evaluation



Department of Water  
Government of Western Australia





# Stormwater Management Manual for Western Australia

## 10 Performance Monitoring and Evaluation

Prepared by Lisa Chalmers and Emma Molloy, Department of Water  
Consultation and guidance from the Stormwater Working Team



Department of Water  
Government of Western Australia



SWAN  
RIVER  
TRUST

May 2007

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## Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the State Water Strategy (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Drainage and Waterways Branch of the Department of Water.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

Effective stormwater management requires a good process to track the progress of activities; an understanding of why the activities have succeeded or failed; and what can be done to improve their success in the future.

This chapter outlines a generic process for developing stormwater monitoring and evaluation programs that can be applied at all levels of stormwater management. It is important that a monitoring and evaluation program is prepared at the beginning of the project and this chapter should be read as a project preparation document. The generic process has the following stages:

- A. Purpose**
- B. Objectives**
- C. Evaluation questions and indicators**
- D. Planning**
- E. Implementation**
- F. Analysis and interpretation**
- G. Report and recommendations**

Specific details relevant to determine the success of non-structural and structural best management practices have been discussed in separate sections. Structural BMPs act to alter water quality through physical, chemical and biological processes. Monitoring structural BMPs requires water quality to be assessed prior to the treatment and after the treatment measures have been implemented. Summaries of parameters regarding water flow, quality and quantity have been included to assist stormwater managers in their efforts to select suitable monitoring techniques and analysis to effectively evaluate the performance of BMPs. Non-structural BMPs are institutional and pollution prevention practices designed to prevent or minimise pollutants from entering stormwater or to reduce the volume of stormwater requiring management. The success of non-structural BMPs is heavily dependent on human behaviour and a number of recommended approaches to evaluate these stormwater management projects are outlined.

When a new stormwater management technique or methodology has been implemented it is critical to build knowledge of its functionality and performance. The performance monitoring and evaluation process is useful for determining the success of these BMPs as well as communicating the outcomes to stakeholders. It is useful to have documented the performance of monitoring and evaluation style and process in a report to enable future reference and to share with other stormwater managers the lessons learnt from the stormwater management project.

Examples have been provided to demonstrate the monitoring and evaluation methodologies promoted in this chapter.

# 1 Introduction

## 1.1 Aims of the performance monitoring and evaluation chapter

The aims of the performance monitoring and evaluation chapter are to:

- explain how to develop a stormwater monitoring and evaluation program, and ensure that the plan is integrated into the larger program of works;
- describe the performance monitoring and evaluation process for structural and non-structural best management practice (BMP) performance monitoring;
- provide an overview of performance monitoring and evaluation techniques, their selection, benefits and limitations, and provide links to key literature and resources for the details of the techniques.

## 1.2 Scope of the chapter

This chapter outlines a generic process for developing monitoring and evaluation programs. Performance monitoring and evaluation of structural and non-structural BMPs are discussed generally. References are provided for more detailed information.

Auditing of best management practices is usually undertaken by the organisation responsible for its implementation, such as a developer, local government or a catchment management group. Monitoring of the success of structural and non-structural BMPs is normally undertaken by expert consultants employed by stormwater managers such as local government authorities.

Maintaining or improving the condition of the receiving environment including waterways, wetlands and coastal waters is normally the ultimate objective of implementing a stormwater management project, whether it is a large program or an individual BMP. Regardless of the scale of the stormwater management project stakeholders expect to see evidence of the success of the project and environmental change to the receiving environment as a result. Few organisations have the resources to do large scale monitoring over a large geographical area or for a long period of time. Resources have to be targeted to meet specific regional needs (ARMCANZ & ANZECC 2000).

There are often specific monitoring requirements placed on developers and landholders as part of the condition of development or licences to operate which are reported back and audited to the local government or State government.

## 1.3 Terminology and key definitions

**Best Management Practices (BMP):** Devices, practices or methods for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters (Taylor & Wong 2002).

**Contaminant:** A substance that is not naturally present in the environment or is present in unnatural concentrations that can, in sufficient concentration, adversely alter an environment.

**Effectiveness:** The extent to which program outcomes are achieving project objectives (Bullen undated).

**Efficiency:** The extent to which project outputs are maximised for the given level of inputs. Efficiency is concerned with the processes (activities/strategies/operations) by which the project is delivered and which produce the outputs of the programs. **BMP Efficiency:** Measures of how well a BMP or BMP system removes or controls pollutants. Although 'percent removal' is the most common form of expressing BMP efficiency (when used alone) it is a poor measure compared with alternatives such as the 'effluent probability method' (e.g. US EPA 2002; Taylor & Wong 2003).

**Evaluation:** A periodic but comprehensive assessment of the overall progress and worth of a ‘project’ (Woodhill & Robins 1998). The term used for final assessment of whether the BMP has achieved its pre-defined objectives.

**Goals or Aims:** General descriptions of what a project will achieve (Woodhill & Robins 1998).

**Indicators:** The specific characteristics or phenomena that tell you about the project and what impact it is having on the problem or issue it was set up to tackle (Woodhill & Robins 1998).

**Monitoring:** The collection of data by various methods for the purpose of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures.

**Nutrient:** Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus in water, but is also applied to other essential and trace elements.

**Objectives:** Specific statements about what a project intends to achieve. Or concise, realistic, outcomes orientated statements of what a project aims to achieve.

**Outcomes:** The results of the activities or products of a project, i.e. the ultimate impact of a project (Woodhill & Robins 1998). All the impacts or consequences of the project beyond its outputs. Outcomes are often delayed or long term and they may be intended or unanticipated (Bullen undated).

**Outputs:** The activities completed or products made during a project (Woodhill & Robins 1998). Outputs are within the direct control of the project.

**Program:** Development of monitoring and evaluation activities to determine the success or otherwise of measures put in place as part of stormwater management projects.

**Project:** The term is used to describe the development and implementation of stormwater management plans, BMPs and other catchment management initiatives.

**Performance Indicator:** A specific type of indicator that looks at outcomes to see if they are meeting the project’s objectives.

**Performance Monitoring:** Gathering of information to measure the success of strategies implemented when compared to objectives.

**Receiving environment:** Areas that receive stormwater runoff, including: wetlands, waterways, coastal waters/dunes, groundwater and bushland areas.

**Target:** A numerical concentration limit or descriptive statement relating to an aspect of water management aspired to as part of a stormwater management project.

## 1.4 The target audiences

The target audience for this chapter is stormwater practitioners, mainly local government officers and industry consultants. It also provides information for the land development industry to a lesser extent; however, specific development condition monitoring requirements are outlined in the urban water management plan (UWMP) guidelines. Other practitioners that will find this chapter of use are Department of Water, Department of Environment and Conservation, Water Corporation, Swan River Trust, Main Roads Western Australia, catchment councils and other catchment managers or service providers.

## 1.5 How to use this chapter

This chapter provides a generic process for performance monitoring and evaluation which can be applied at all levels of stormwater management. As outlined in Section 2, it is important that a monitoring and evaluation program is prepared at the beginning of a stormwater management project and therefore this chapter should be read as a stormwater management project preparation document.

Specific details relevant to determining the success of non-structural and structural best management practices are discussed in Sections 4 and 5. It is, however, important to note that most stormwater management projects have a combination of techniques and therefore both non-structural and structural monitoring and evaluation techniques will be employed.

The monitoring and evaluation of combined impacts of stormwater BMPs within a catchment by monitoring the condition of the receiving environment is discussed in the following section of this chapter. Monitoring of urban developments as part of the compliance requirements for a development is a separate land use planning process. However, there are parallels in the monitoring process and this document can be used as a reference.

## 2 What is stormwater performance monitoring and evaluation?

Effective stormwater management requires a good process to track the progress of activities; an understanding of why the activities implemented have succeeded or failed; and what can be done to improve their success in the future. The two tools of performance monitoring and evaluation are ways to measure the success of individual tasks to overall outcomes of a program. The two tools are simply defined below as:

- Performance monitoring is the gathering of information to measure the success of implemented strategies against their objectives;
- Evaluation refers to the process of determining the merit, worth or value of the stormwater management project. It can be a periodic but comprehensive assessment of the program's overall progress and worth (Woodhill & Robins 1998) or a final assessment of whether it achieved its pre-defined objectives.

Some reasons to undertake performance monitoring and evaluation are listed below:

- to determine the success of meeting the stormwater management project goals and objectives;
- to improve actions and procedures of a stormwater management project as it proceeds;
- to find the best ways to add to a stormwater management project's strengths (adaptive management) and correct its weaknesses (risk management);
- to develop the skills and understanding of people involved in a stormwater management project;
- to find new ways to understand the issues by engaging with your stakeholders;
- to provide information for planning a new stormwater management project;
- to demonstrate the worth of the group and organisation;
- to be accountable to stakeholders including funding sources;
- to contribute information to broader scale monitoring and evaluation;
- to detect non-compliance with regulatory requirements;
- to facilitate corporate performance monitoring.

(Falding et al. 2001; Woodhill & Robins 1998; DEC NSW 2004).

The performance monitoring and evaluation program should contribute to the improvement and effectiveness of particular aspects of the stormwater management project, whether it is the process, implementation, or the actual construction or functioning of specific BMPs.

It is important to design the performance monitoring and evaluation program at the beginning of the stormwater management project. Performance monitoring and evaluation is most effective when it is an integral part of the whole stormwater management project, and where there is a constant cycle of planning, acting and reviewing; utilised in this manner data and outcomes can contribute to addressing shortfalls in the stormwater management project (Woodhill & Robins 1998; DEC NSW 2004). Further advice on

stormwater management planning and where performance monitoring and evaluation should fit in this cycle is discussed in Chapter 5.

Time and resources are required to develop and undertake performance monitoring and evaluation, however this investment will assist stormwater managers achieve better results. Preparing a monitoring and evaluation program beforehand will enable the appropriate data to be collected and evaluation opportunities to be identified.

### 3 Performance monitoring and evaluation - a generic process

This section provides a generic process for performance monitoring and evaluation of stormwater management projects. The monitoring and evaluation of stormwater management projects and individual BMPs is intrinsically linked to the objectives of the stormwater management project or BMP itself. This section details how to determine clear program objectives.

Regardless of the scale of the stormwater management project, a generic process can be followed to prepare the performance monitoring and evaluation program (see Figure 1).

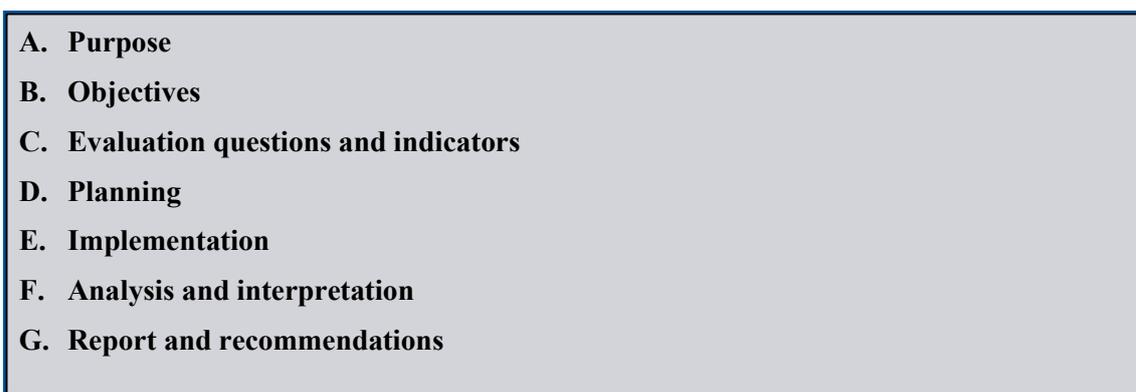


Figure 1. Generic process for the development of performance monitoring and evaluation plans.

#### A) Purpose

The purpose of the monitoring and evaluation program should reflect that of the overall stormwater management project, but be specific enough to determine whether it was successful or not according to the desired objectives and outcomes. This step is the time to consider:

- why the stormwater management project is being monitored and evaluated;
- available resources including financial resources and time availability;
- who to involve and in what way;
- how objective based, open ended and comprehensive the evaluation will be;
- identification of external or specialist help that might be needed;
- timing and deadlines.

Stakeholders should agree on the purpose and scope of the monitoring and evaluation program through negotiation and consultative processes. Terms of reference and memorandums of understanding can be developed for larger multi-stakeholder stormwater management projects.

## **B) Objectives**

The objectives for the performance monitoring and evaluation program relate directly back to the objectives for the stormwater management project. Vague objectives will be difficult to manage, to monitor, and to evaluate. One way of checking whether stormwater management project objectives will be suitable to base a monitoring and evaluation program on is to see if they are SMART.

### **SMART objectives**

**Specific** – what will be achieved is clearly defined.

**Measurable** – there is some way of measuring what will be achieved.

**Achievable** – the objective is realistic given the resources available.

**Relevant** – the objective is essential to the program vision and goals.

**Time-framed** - there is a time by which the objective will be met.

Examples of SMART stormwater management project objectives are:

- within four years of project commencement, 75% of local governments use a stormwater management plan to guide management decisions;
- by June 2007, fence off and revegetate 10 km of Gully Brook;
- by 2010 reduce Gully Brook stream total nitrogen (TN) nutrient status from high (2.0-3.0 mg/L) to moderate (1.0-2.0 mg/L) classification;
- by December 2008, all households of Springfield have received training as part of the ‘this drain is just for rain’ Springfield Council stormwater management project.

Producing stormwater management project objectives such as the examples above may not be easy. A tool that may be used to clarify performance monitoring and evaluation program objectives is an outcomes hierarchy.

The outcomes hierarchy is one process of evaluation planning that describes what a stormwater management project is intended to do or achieve. The outcomes hierarchy can be used at any stage of a program’s lifespan. If the program objectives are listed, they vary from the general to the quite specific. By identifying the outcomes that should result from the stormwater management project objectives and placing them in order from the most general to the most specific this will help set performance and monitoring objectives that are realistic. An objective may have several outcomes at various levels of the hierarchy. As an example, below is an outcomes hierarchy table prepared for evaluating environmental education stormwater management projects.

**Table 1. Outcome Hierarchy Process (Modified from DEC NSW 2004)**

Outcome Hierarchy	Definitions and Examples
Ultimate outcomes ↑	Describe the impact of the overall program and the ultimate program goals in biophysical, social, economic, organisational or communications terms. Often the ultimate outcome has several programs, possibly from different organisations contributing to them.  <i>E.g. reduced stormwater pollutants at the source, and improved water quality of creek.</i>
Intermediate outcomes ↑	Describe changes in individual and group knowledge, skills, attitudes, aspirations, intentions, practices and behaviours.  <i>E.g. positive change in knowledge and behaviour of community members.</i>
Immediate outcomes ↑	Describe levels and nature of participation and reactions to the activities to engage participants.  <i>E.g. a community workshop held to raise awareness of daily activities that can impact on stormwater quality.</i>

The ‘outcomes’ include changes in awareness, knowledge, attitudes, skills behaviour, activities and decisions that result from the actions delivered. Outcomes from a stormwater management project can occur over any range of time, from weeks to months to years, and therefore they can be expressed as immediate, intermediate or ultimate outcomes.

‘Immediate outcomes’ describe the levels and the nature of participation, and the reactions to the activities used to engage participants in non-structural BMPs. For structural BMPs you may have immediate changes such as 3 kg of litter trapped in one gross pollutant trap (GPT). For non-structural BMPs outcomes might be a stakeholder workshop held on the value of source control in preventing stormwater runoff generation.

‘Intermediate outcomes’ describe the changes in individual or group knowledge, skills, attitudes, practices and behaviours for an education based stormwater management project. For structural BMPs, an intermediate outcome could be that 70% of all seedlings planted along a ‘living stream’ survived the first two summers. A non-structural outcome may be that participants have improved skills and understanding in river restoration techniques.

‘Ultimate outcomes’ describe the impact of the overall stormwater management project. When ultimate outcomes are reached, they result in change in environmental, social and/or economic conditions. They could be outcomes such as: the pre-development hydrograph is the same as the post-development hydrograph; or the total nitrogen and total phosphorus levels in Melaleuca Brook was reduced by 0.07 mg/L and 0.15 mg/L in two years. A non-structural outcome may be that residents behave in a way that protects the receiving waters due to improved education, skills and resources available to them.

### C) Evaluation questions and indicators

It is important to devise evaluation questions or indicators that are suitable for the program. You may wish to determine your evaluation questions for the various outcomes according to the following template.

**Table 2. Outcomes Hierarchy Framework Template (modified from Catherine Baudains, pers. comm. 2006 and DEC NSW 2004)**

Outcomes hierarchy	Evaluation questions	Indicators	Instruments for collecting data/ information sources
Ultimate outcomes			
Intermediate outcomes			
Immediate outcomes			

#### Evaluation questions

Depending on purpose, evaluation relates to a variety of issues concerning appropriateness, effectiveness, efficiency and process. The evaluation questions could be considered under the following headings.

**Table 3. Evaluation aspects and evaluation questions (Woodhill & Robins 1998)**

Aspect	Evaluation questions
Appropriateness (Was the program a good idea?)	<p>Did the stormwater management project address the right issues?</p> <p>Was there a need for it?</p> <p>Did the objectives address the need?</p> <p>Were the goals and objectives appropriate given the needs of the stakeholders, the funding and the circumstances in which the program was carried out?</p>
Effectiveness (Did it work?)	<p>Did the stormwater management project achieve the desired objectives/outcomes?</p> <p>What were the barriers?</p> <p>Was the stormwater management project effective in achieving its stated goals and objectives?</p> <p>Were all the planned actions carried out?</p> <p>Did these actions lead to the expected outcomes?</p> <p>Were there unexpected outcomes such as unintended social costs or benefits to the stormwater management project?</p> <p>What was the effect of unanticipated external forces on the stormwater management project – how might a period of drought or economic downturn have affected the progress?</p>

Aspect	Evaluation questions
	<p>Flow on effects from the stormwater management project – did other stormwater managers learn from your experiences?</p> <p>People’s perception of the stormwater management project – how did external stakeholders feel about the program?</p> <p>Ideas about how to make improvements – for the future.</p>
Efficiency (Was it cost effective?)	<p>Could there have been better use of the resources?</p> <p>Was the stormwater management project carried out in the best possible way?</p>

### Indicators

An important part of evaluation is deciding what criteria will be used to judge success and what will be monitored. This requires establishing indicators which show whether outcomes of a stormwater management project satisfy the project objectives.

While indicators are very important, they are not the only information that will be required for an evaluation. For example, discussions, interviews and workshops with people involved with or affected by the stormwater management project will often provide an improved understanding about the workings of the stormwater management project. This qualitative information can help explain why an indicator is giving a particular result (Woodhill & Robins 1998).

Indicators should be practical, and should relate to the appropriate geographical scale for the issue being considered. Indicators for site management will differ from local and regional scale indicators (Falding et al. 2001). It is also important to note that indicators for a project may be relatively simple or limited to a small number of important measures.

Ideally indicators are measurable; however, when dealing with social phenomena, e.g. when assessing the outcomes from education and awareness-raising projects, quantitative measurement may be difficult or meaningless. More valuable information will be the nature of people’s perceptions and attitudes that cannot be reduced to a number. Indicators for social phenomena are often unsatisfactory due to the complex nature of human behaviour. This could be overcome by appropriate evaluation questions that provide a description of who, what and why behind the numbers are required.

Criteria to consider when deciding on indicators for a performance monitoring and evaluation program could:

- relate directly to stormwater management project objectives;
- focus on outcomes, not inputs or outputs;
- provide a measurable assessment of the stormwater management project outcomes;
- be directly attributable to the impact of the stormwater management project and not overly influenced by external factors;
- be quickly, easily and cheaply assessed;

- have a reproducible methodology (e.g. regular monitoring at the same sites, using the same techniques);
- give results that are not prone to misinterpretation;
- be capable of showing trends over time;
- be able to permit assessment of cumulative impacts;
- be capable of reporting outcomes clearly through appropriate technologies, e.g. GIS systems;
- be consistent with accepted scientific concepts;
- be readily understandable by the community or project stakeholders;
- be consistent with an equivalent indicator used in other comparable plans, e.g. local government areas, State or Federal levels.

(Modified from Woodhill & Robins 1998 and Falding et al. 2001.)

#### **D) Planning**

Organising a system to monitor the indicators and record the performance monitoring and evaluation program activities will generate a list of stormwater management tasks up front and give some indication of how much time will be required. It is important to prepare a sampling design which includes the sample size, monitoring frequency and monitoring timeframe. A database of results documentation also needs to be prepared. It may be appropriate to trial the methodology being chosen to see if it is appropriate for answering evaluation questions or indicators (McKenzie-Mohr & Smith 1999). The types of activities may include:

- trial of monitoring and evaluation methodology;
- regular monitoring of indicators;
- summarising and graphing the results of indicators;
- holding regular meetings to review progress;
- undertaking surveys of stakeholders;
- employing consultants to provide specialist information or independent reviews.

#### **E) Implementation**

The implementation stage involves gathering the information and monitoring the indicators. The types of activities may include:

- gathering background information;
- monitoring the indicators;
- undertaking reviews of data and methodology.

#### **F) Analysis and interpretation**

This stage involves analysing the data collected, drawing conclusions and making judgements about the performance, and determining the overall value of the program.

In arriving at conclusions, it is often useful to think in terms of issues, trends and themes as listed below:

- An issue is something that people are concerned about. Issues emerge from people's perceptions or from factual information;
- A trend is an observed change over time. It may be physical, biological, social or economic;
- A theme is a pattern seen by looking at all the issues and trends;
- Themes give rise to discussion of desirable changes and priorities for action.

(Woodhill & Robins 1998).

It is important to review a number of sources of information. Where a number of sources of information have led to the same conclusion then there will be greater confidence in the conclusion. However, if there are contradictions, it may be appropriate to undertake further investigation.

### **G) Report and recommendations**

The report and recommendations should be based on the outcomes of the monitoring and evaluation program and:

- explain intended and unintended results;
- identify the desired and actual outcomes;
- make recommendations to improve activities including appropriateness, effectiveness and efficiency;
- plan a new phase of the current stormwater management project;
- plan a new program if necessary;
- share what you have learnt with others;
- gain publicity and support;
- contribute to larger scale evaluations;
- account for funds to a funding agency.

(Modified from Water and Rivers Commission 2002; Woodhill & Robins 1998; Falding et al. 2001.)

## **4. Structural BMP performance monitoring**

Structural BMPs alter water quality through physical, chemical and biological processes. Structural BMP performance monitoring and evaluation requires water quality to be assessed prior to the treatment and after the treatment measures have been implemented.

Structural BMP monitoring involves measurements of selected parameters before and after the inflowing stormwater has been exposed to/treated by the structural BMP. Due to the varied nature of structural BMPs, it is best to consider monitoring and evaluation in terms of measuring what is going in and what is going out of the structural BMP.

The varied nature of structural BMPs has implications for the style and method of monitoring. Much of this is discussed in the following sections. Another consideration is the receiving environment of the structural BMP, which is where the discharge or outflow from the BMP or drain is received. In many cases the discharge will flow to surface water channels - for this, standard guidelines for monitoring surface water referenced later in the document are appropriate and give a good indication of the parameters and processes involved.

Other structural BMPs work to infiltrate stormwater, making it more challenging to capture the post-treatment stormwater to assess the effectiveness of the structural BMP. Processes to monitor water movement and water quality improvements through the soil profile or filter media, as well as any discharge to groundwater, will most likely require monitoring mechanisms to be built into the initial structural BMP construction.

Monitoring of performance of structural BMPs using groundwater monitoring methods is subject to similar rules and considerations as surface water monitoring. As such, Section 4 is particularly relevant and many of the same questions must be asked when preparing the Sampling and Analysis Plan.

### *Groundwater monitoring*

The issue of groundwater monitoring is structural BMP specific and requires an understanding of the construction and function of the structural BMP. Groundwater levels and behaviour should also be

understood prior to the design and installation of structural BMPs. Preliminary monitoring should indicate both quantity and water quality aspects of groundwater interactions at the site.

Groundwater separation from the base of structural BMPs can be critical to the capacity and function of the BMPs. This has the potential to contribute unknown or unaccounted for water quality to the structural BMP, impacting on the volumes treated, changed water quality or estimated effectiveness.

The interactions between the structural BMP and the groundwater are dependent on the function and design of the structural BMP. Systems that are not sealed at the base and function by infiltration aim to infiltrate surface water to the groundwater. The water, along with whatever contaminants it contains, will move through the soil profile ultimately reaching the groundwater. Alternatively, in seasons of high groundwater levels and low surface water, the groundwater may rise up through the base of an unlined system and contribute another source of water to the structural BMP.

Flow paths, flow rates and duration are not as easily determined for groundwater as in the case of surface water. These factors will be influenced by soil structure, vegetation type, site contamination (clogging) and hydraulic head. All these factors will vary across sites and even individual structural BMPs and all have the potential to impact on performance and monitoring aspects of structural BMPs. The area and depth over which interaction with the groundwater may be observed is also highly site dependent and harder to quantify than for surface water (see Appendix A and B for methods/tools to collect information on groundwater and groundwater quality).

#### *Environmental health*

Alteration of hydraulic regimes, pooling and management of surface water has the potential to alter or impact on the environment in ways that can affect public health or amenity. Consequently, these environmental health issues have the potential to impact on the longevity and public acceptance of structural BMPs. Information on the risk minimisation and management of public/environmental health issues associated with structural BMPs is presented in Chapter 9.

Further information on environmental health and public health monitoring techniques can be obtained by contacting the Western Australian Department of Health's Environmental Health Directorate or through their website at: <<http://www.health.wa.gov.au/envirohealth/home/index.cfm>>.

#### *Climate change*

'Climate change' or 'drying climate' have implications for the operation and therefore performance monitoring and evaluation of structural BMPs. Performance monitoring and evaluation must be focussed, targeted and flexible enough to effectively monitor and evaluate the performance of the actual BMP.

## 4.1 Purpose

The purpose of performance monitoring of structural BMPs is typically to evaluate the effectiveness of the structural BMP to determine:

- the efficiency and effectiveness of an implemented structural BMP;
- if it is achieving the desired objectives of the structural BMP in situ;
- if management actions are required to optimise the performance of the structural BMP;
- how it performs with a view to implement elsewhere.

The purpose of the monitoring should be clearly stated at the start of the planning process. The objectives of the stormwater management project and the project partners will drive what performance monitoring

is required, if any. Other factors to consider when determining the purpose of the monitoring program include:

- duration of the monitoring program (may vary from one year to five years or more);
- resources available to conduct monitoring (equipment available, personnel and experience, time available to commit);
- budget available (staff salaries, vaccinations, protective equipment; capital costs for equipment, construction, maintenance and decommissioning; costs of chemical analysis, etc.);
- site constraints (access to site, occupational health and safety considerations).

More comprehensive monitoring programs may also aim to collect data for research purposes.

## 4.2 Objectives

As discussed in Section 3B - Objectives, the objectives for the stormwater management project will be derived from the purpose and need to be specific, measurable, achievable, relevant and time-framed, to enable monitoring and evaluation against the project objectives.

Examples of objectives for structural BMP projects include:

- after installation, the structural BMP will reduce the concentration of total nitrogen and total phosphorus in the water column by 20% in baseflow and first flush;
- within four months after installation of the structural BMP, concentration of total phosphorus exported from the drain to the Swan River in baseflow conditions will meet the long-term target of 0.1 mg/L of total phosphorus.

The evaluation questions for the monitoring will flow on from the purpose of the monitoring and the objectives of the structural BMP project.

## 4.3 Evaluation questions and indicators

When the purpose of the monitoring program has been determined and the objectives of the structural BMP project are defined, specific evaluation questions should be formulated to guide the development of the monitoring program. Like the objectives of the structural BMP project, the evaluation questions need to be carefully considered and defined so that the data collected is relevant and sufficient to answer the questions.

This list of questions is a prompt to consider aspects of the structural BMP that may be relevant to evaluate:

- To what degree does the structural BMP control the contaminant levels under typical operating conditions?
- How does the effectiveness vary from contaminant to contaminant?
- How does effectiveness vary with various input concentrations?
- How does effectiveness vary with storm characteristics such as rainfall amount, rainfall intensity and antecedent weather conditions?
- How do design variables affect performance?
- How does effectiveness vary with different operational and/or maintenance approaches?
- Does effectiveness improve, decay or remain stable over time?
- How does the structural BMP's efficiency, performance and effectiveness compare to other structural BMPs?

- Does the structural BMP reduce contaminants to acceptable levels?
- Does the structural BMP cause an improvement or protect downstream receiving environments?
- Does the structural BMP have potential downstream negative impacts?

Typical evaluation questions for structural BMPs might include:

- How effective is the structural BMP at reducing the concentration of nutrients discharged through the stormwater drain in baseflow conditions (other flow conditions or contaminants may also be considered)?
- To what extent has the structural BMP improved the effectiveness of the stormwater drain at reducing the concentration of contaminants discharged through the drain in baseflow conditions?
- How does the water quality downstream of the structural BMP compare to relevant water quality guidelines?
- Are there any patterns in the effectiveness of the structural BMP that might be associated with seasonal variation or different flow regimes?

Answers to these evaluation questions will guide the extent of monitoring that is required. Several iterations may be required to ensure that the proposed monitoring will suit the available resources and budget, answer the evaluation questions, and meet the needs of the project partners and objectives.

## 4.4 Planning

Detailed planning of the monitoring is critical to ensure that the data collected will answer the evaluation questions in the most cost effective way. Before developing the monitoring program, collect any information about the site and likely seasonal changes. Investigate other monitoring programs to learn from their successes and failures. Make use of the local experience and knowledge of project partners when developing and conducting the monitoring program.

Where possible or necessary, the structural BMP should be designed to suit the required monitoring. For example, construct flow control structures (e.g. weirs) where flow rate will be measured. The monitoring program must be planned prior to completion of the design and installation of the structural BMP to ensure that the structural BMP design can be adjusted to suit the proposed monitoring.

The interactions between groundwater and stormwater should be considered at the planning stage. If groundwater readily interacts with the surface water in the drainage system, it may be necessary to quantify the influence of the groundwater in terms of water quality and quantity.

### 4.4.1 Variability in environmental systems

There is a high degree of variability in environmental systems. The location and frequency of sampling must be carefully selected to ensure that it is appropriate for the likely variability of the particular system and what you are trying to observe.

It is highly advisable to undertake a pilot study of the system to be monitored. This will provide information on the variability in the system (in time and space) and contaminants of concern, which will enable the on-going water quality monitoring to be designed to suit the particular system. Using a pilot study will also provide justification for the scope of the ongoing monitoring program. It is important to consider if the results from the pilot study will be applicable for the duration of the sampling program. If the results from a pilot study undertaken in one season are extrapolated to design a monitoring program over several years, changes in hydrodynamics between seasons will need to be factored into the program design.

A pilot study will usually involve monitoring at a high frequency, with extensive spatial coverage, for

a wide range of parameters. At least three sample events in time and space are necessary for statistical analysis of the variability. The frequency of the pilot study monitoring should be sufficient to understand the range of temporal variability in the system that is relevant to the monitoring objectives. For example, if the monitoring program is interested in changes in nutrient concentrations, the pilot study should take samples on a weekly basis and more frequently during storm events. Monitoring at a lower frequency (i.e. monthly) can miss important peaks in contaminant levels and give a deceptive picture of the water quality. Analysis of the pilot study results will indicate the appropriate frequency for ongoing monitoring.

Assessment of the spatial variability through a pilot study should confirm which sites will provide the information required to answer the evaluation questions. It is likely that the proposed monitoring sites will be the major upstream and downstream sites relative to the structural BMP (or inlets and outlets, for instance if the structural BMP is part of a compensating basin). The pilot study may involve sampling at all inlets and outlets, even minor ones, to see if they provide important information. In addition, the pilot study may be necessary to confirm that the proposed sites are representative of the intended 'water parcel' and are behaving as expected. If monitoring near an inlet but just inside the compensating basin, does the sample reflect the inlet water quality, or is it too mixed with the water already in the basin? Perhaps water only flows through the outlet when it is pumped from upstream – will this be a reliable site to sample? Are assumptions about the preferred flow path and extent of mixing valid?

A pilot study may also be used to investigate likely contaminant levels, with the view to narrowing down the list of parameters for ongoing analysis. However, care should be taken when eliminating key parameters based on a few samples taken at one particular time of the year.

Statistical analysis may be conducted to estimate how many events need to be monitored, to capture the expected change in water quality parameters caused by the structural BMP with the desired confidence in a conclusion (i.e. power analysis). This is an important 'reality check' to ensure that the objectives can be actually attained with the available resources.

Following analysis of the pilot study results, the ongoing monitoring can be designed. At this stage, it is critical to document the proposed monitoring in a sampling and analysis plan (SAP). The SAP will be a summary of:

- *Why* the monitoring will be undertaken (the purpose of the monitoring, the objectives of the structural BMP project and the evaluation questions to be answered)?
- *What* monitoring will be undertaken (duration, frequency, sites, parameters)?
- *How* the monitoring will be undertaken (detailed methods)?
- What measures will be taken for *Quality Assurance* of the monitoring data?
- *What* measures are required to protect personnel from contaminants and other occupational safety and health (OSH) threats?
- *Who* will be the custodian of the data collected – storage of data in a stable and accessible format? and
- *What* will be done with the data collected (analysis and interpretation of the data, reporting and communication)?

#### 4.4.2 Duration

The duration of the monitoring program will usually be more than one year, to capture seasonal variations. It is preferable to monitor for at least three years to allow statistical quantification of inter-annual variability; however, this may not be possible depending on available resources. If the evaluation questions consider changes over time or variations in efficiency of the structural BMP depending on input conditions, it will be necessary to monitor for three years as a minimum.

### 4.4.3 Frequency

Frequency may be very intense to capture changes during storm events, or anything down to once per year (for instance, to measure accumulation of sediment). Clearly, more frequent monitoring will provide more comprehensive results but will be more expensive. To capture seasonal variation it is preferable to monitor at least monthly, preferably fortnightly. More information on frequency and how it relates to interpretation of data is provided in Chapter 3 of *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARMCANZ 2000).

If the evaluation questions concern changes in efficiency during different input conditions (e.g. different flow conditions or storm intensities) then it will be necessary to select the times for monitoring based on capturing a range of different input conditions. Regardless of how many different input conditions are defined, it is necessary to collect at least three samples for each of the different input conditions. This will provide a minimum level of data to allow assessment of statistical differences.

### 4.4.4 Site selection

Careful selection of sites will ensure that a scientific assessment of the structural BMP effectiveness can be made. A typical plan for measuring structural BMP effectiveness is to monitor upstream and downstream of the structural BMP, both before and after it is installed. The 'before' sampling (also called baseline sampling) establishes the initial efficiency of the site before installation of the structural BMP, and is used as a control. A control is subject to the same conditions as the test site, except for the structural BMP that you are testing. The 'after' sampling (also called evaluation sampling) is used to determine the effectiveness of the structural BMP and to determine how much difference it has made. If there is no control data, it is not possible to conclude that water quality treatment at the site is due to the structural BMP; the site may have already had a capacity for improving water quality (for example).

If the structural BMP is installed at a site that has multiple inlets or outlets, it may be necessary to monitor some or all of these. Typically, only major inlets and outlets convey water regularly. Minor inlets and outlets may not be monitored at all, or may be monitored less frequently when they are conveying water (e.g. immediately after storms).

For structural BMP types or applications where there is no clear 'upstream' then a control or reference area must be identified. In this case sampling either several control locations, or several sites within a control area, assists the interpretation of data by making it easier to account for other, potentially confounding, causes of variability in natural environments. Reference areas may also be considered if the structural BMP involves restoring native vegetation or ecological functions to a stream or wetland. In this case the reference sites will provide valuable information on species and key ecological processes and functions to be restored.

Site selection may also be limited by physical constraints or health and safety issues. For instance, if the upstream site is entirely piped, it may be difficult to get access to the water to take samples. Sites with steep sides or near busy roads should be sampled with care and not alone. Safe working procedures should be developed and implemented to overcome hazards.

It is important to ensure that the sites selected fulfil the criteria they are assumed to represent. For example, when sampling an inlet as it enters a water body, ensure that the water sampled is representative of the inflow water, not the mixed water in the water body.

### 4.4.5 Parameters

A wide range of parameters may be monitored, depending on the evaluation questions to be answered. Appendix A provides a summary of parameters that may be relevant to evaluation of structural BMPs, including what is measured, factors that may affect the parameter, and when it may be relevant to measure.

While the selection of parameters is issue, site and BMP specific, a list of common parameters for structural BMP monitoring is:

- physical parameters (conductivity, pH, temperature, dissolved oxygen)
- flow rate
- total suspended solids (TSS)
- nutrients (TN, TP, NO<sub>x</sub>-N, NH<sub>3</sub>-N/NH<sub>4</sub>-N, DOrgN, SRP)

Dissolved organic carbon (DOC) or biological oxygen demand (BOD) also provide useful information on the ecological processes relating to carbon cycling. If funds are available, consideration should be given to measuring one of these analytes also. Parameters that are more expensive but still of interest may be monitored less frequently (e.g. BOD, heavy metals). A useful guide to selection of parameters is *A Guideline for the Development of Surface Water Quality Monitoring Programs* (Department of Water 2006a). This document outlines parameters that may be relevant depending on local land use practices, and also discusses other aspects of the design of water quality monitoring programs.

#### 4.4.6 Methods for water quality monitoring

There are a range of methods at different scales for monitoring structural BMPs. The method chosen will depend on available budget, capacity to procure and install infrastructure and the comprehensiveness of data required.

**Table 5. Water quality sampling method characteristics**

	Sampling method	Description
Decreasing cost, infrastructure required, and thoroughness of data collection ↓	Water quality transducers and data loggers	Probes installed at a fixed location, which measure parameters continuously or at fixed frequent intervals (e.g. every 5 mins, 60 mins). Limited by what the probes can measure – usually physical parameters, such as water depth, flow velocity, conductivity, temperature, dissolved oxygen, chlorophyll, etc. The data measured are stored in the logger on-site, and it is becoming more common to broadcast the data to a central computer via modem.
	Automated sampling	A sampler installed at a site and programmed to collect samples in particular conditions (e.g. during storm events). Consists of a pump system, a controller and an array of sample bottles within a housing. Parameters that will change significantly between the time of collection and when the sample is retrieved and analysed are not appropriate to measure with automated samplers (e.g. pH, nutrient fractions (NO <sub>x</sub> -N, NH <sub>3</sub> -N, etc)).
	Integrated sampling	Samplers that integrate water samples over a fixed time period or volume. For example, materials that quantitatively adsorb organic contaminants or metals can be placed in a water body over an extended time, and will measure contaminants that are at low concentrations or infrequently present in the water column (passive samplers). Typically used for metals or organic contaminants.

	Sampling method	Description
Decreasing cost, infrastructure required, and thoroughness of data collection 	Manual sampling throughout storm events and different flow regimes	Water quality can vary considerably during different flow regimes. If the infrastructure required for automated sampling is too demanding, manual sampling during different flow regimes may capture some of the water quality variability. For example, collecting a series of manual samples throughout the course of a storm event. However, this requires a quick response to storm events, and may require sampling at odd hours and in hazardous conditions. It is also necessary to quantify the flow rate during each sampling event. Parameters that may not be appropriate to measure by automated sampling can be measured by manual sampling.
	Regularly spaced manual sampling	Manual sampling at a regular frequency will provide a general overview of the water quality. The sampling must be frequent enough so that changes in water quality are observable on the timescale that is relevant to the monitoring goals. A pilot study is recommended to determine the required frequency of sampling.
	Composite samples	Samples may be composited in time (e.g. integrated samples as discussed above, manual samples collected from one site but 5 min apart, etc.) or in space (e.g. samples from different depths, all inlets to a water body, etc.). Composite samples will account for more of the environmental variability without having to pay for analysis of many different samples. However, variability between the different sub-samples in the composite sample will be lost.
	Infrequent samples	Sampling infrequently or irregularly will provide data that is of limited use for evaluation purposes. However, it may be appropriate when investigating possible pollutants or to get a snapshot of the water quality.

#### 4.4.7 Flow data

The flow rate puts all other parameters in context. The importance of the water quality from a particular source will depend on the volume of water that is conveyed from that source, as much as the concentration of contaminants in the water. Contaminant concentration is also influenced by rain events – if there is a high flow rate due to a recent storm, the contaminants may be diluted. In contrast, contaminant concentration is usually higher at the start of storms, when contaminants are washed from urban catchments. Discussing water quality in terms of concentration only, without describing flow conditions, can be inaccurate and misleading.

The influence of flow rate can be captured by expressing the contaminant in terms of load. Load is the total amount of a substance that is transported past a particular point, and is the product of concentration and flow rate. Flow events are usually the major influence on nutrient loading. Sampling at fixed intervals may misrepresent the load, as peaks and variations that occur during flow events are not fully captured. Using automated samplers and gauging flows is the best way to capture variability during flow events. However, this may be prohibitively expensive in many situations. Moreover, automated samplers can only be used to sample certain parameters – for example they are not suitable for dissolved nutrients.

Another way to present water quality data and account for flow events is using the event mean concentration. The event mean concentration is the total contaminant load divided by the total runoff volume. Like loads, event mean concentrations are not directly measured but calculated, and also require the flow rate to be measured.

Like water quality, flow rate can be measured in a variety of ways (see Appendix C for some suitable tools and methods). The particular technique chosen will vary depending on the situation. Flow rate can only effectively be measured when the water passes over a stable and confining cross-section of the channel that can be well defined. This usually occurs when water passes over a weir or similar structure. A summary of flow measurement approaches is presented below.

**Table 6. Flow sampling method characteristics**

	Sampling method	Description
Decreasing cost, infrastructure required, and thoroughness of data collection ↓	Continuous quantitative	Probe that measures parameters continuously or at fixed frequent intervals (e.g. every 5 minutes). Flow rate is often measured by water pressure or water depth over a known cross-section where the relationship between water level and flow rate is stable. The flow monitoring site must be gauged by experienced personnel to establish a relationship between static water measurements and flow rate during different flow regimes. The relationship is called a rating curve. The data measured may be stored in the logger on-site, or broadcast to a central computer via modem.
	Non-continuous quantitative	A quantitative method for measuring flow at regular intervals or whenever samples are taken. For example, a water level indicator that can be read manually on-site to indicate the water level, and thereby calculate the flow rate from a derived relationship between water level and flow rate, known as a rating curve. As for continuous quantitative measurements, the site must be gauged to establish the water level to flow rate relationship.
	Non-continuous qualitative	Flow rate is described each time a sample is taken (e.g. fast flow rate, flow rate increasing, flow at peak, flow in recession, rained at this site today, no discernible flow, etc.). This will give an indication of the flow regime that may help when interpreting data.

#### 4.4.8 Maintenance information

Most structural BMPs require ongoing maintenance. The party responsible for undertaking performance monitoring and evaluation of the structural BMP must also source details of all maintenance activities for the duration of the monitoring program. Maintenance activities can explain variations from expected performance and/or unusual monitoring results. Assessment of the extent of maintenance required can also feed into a cost-benefit analysis of the structural BMP.

## 4.5 Implementation

Implementation is the stage of undertaking the monitoring that has been planned. Careful and consistent methodology must be followed to ensure that the samples collected are not compromised by sampling error.

The Department of Water has prepared Field Sampling Guidelines for manual collection of water quality samples (Department of Water 2006b). These guidelines are a good reference for standard sampling techniques. They can also be inserted into the SAP to describe how the data were collected. Specific methods for collection of samples for common parameters have also been prepared (Department of Water 2006c).

It is important to ensure that the sampling plans are followed, and any major deviations from the planned monitoring are recorded. While putting hard work and resources into undertaking monitoring, it is critical to ensure that the data collected are stored appropriately and are of good quality.

### 4.5.1 Data management

Good data management allows project managers to make defensible decisions based on good science, using data of a known quality. It allows central availability so that the data can have multiple uses and it allows for querying and manipulation of data whilst preserving the raw data. Finally it provides long-term security of data in which considerable time and money has been invested, from collection through to analysis and reporting.

Good data management begins before samples are collected and should be applied throughout the process. It is based on standards, follows an established process and is a good investment as it results in data that are trustworthy and useable, and become more valuable over time.

On the other hand poor data management can result in data that are incomplete or lost completely, of dubious quality, not traceable to original collection sources or standards, isolated and not centrally available to those to whom it may be of use, without context, and difficult or impossible to query or manipulate. Poor data management is a waste of valuable time and resources in terms of the original sampling costs and effort, the need to gather the data again, and inadequate environmental management. In short, poor quality data are worse than no data.

The basic requirements for good data management are:

- Use standardised sampling procedures (based on national standards - AS/NZS 5667.1:1998: Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples, National Water Quality Management Strategy guidelines).
- Use reliable sample analysis methods. Laboratories should be National Association of Testing Authorities (NATA) accredited for both the analytes and matrices and independently audited.
- Use standard operating procedures during sample collection.
- Always record how and where data was collected and analysed. Be specific, so that someone could use your method to repeat the sampling.
- Record where the samples were collected, and use the same sites consistently.
- Enter the data into a maintained database, for security and availability now and in the future.
- Ensure that all data entered into the database meets all the requirements outlined above.

### 4.5.2 Quality assurance and quality control

Quality assurance and quality control are often treated as the same thing, but actually they are not.

***Quality control*** is the generation of data for the purpose of assessing and monitoring how good the sampling and analysis method is and how well it is operating. This is the process of collecting quality

control samples, for instance to test for contamination when collecting or transporting samples. Further information on quality control is available in *A Guideline for the Development of Surface Water Quality Monitoring Programs* (Department of Water 2006a).

**Quality assurance** by contrast, comprises all the steps taken to assure those who are using the data that the data is real, meaningful and of a high quality. Quality assurance encompasses quality control but also includes many other aspects, including, but not limited to:

- having prepared a documented sampling and analysis plan;
- conducting sampling in accordance with standardised and consistent procedures that are documented in the sampling and analysis plan including the use of ‘chain of custody’ forms;
- ensuring that equipment is well maintained, cleaned and fully calibrated before use, by means of specific, fully documented procedures;
- ensuring that individuals that carry out the sampling are competent and trained to do so;
- having dedicated systems, such as the Water Information database that carefully process and store data via standardised procedures, and allow data retrieval at a later date.

## 4.6 Analysis and interpretation

Prior to analysis, the quality of the data should be confirmed by reviewing the quality control results and checking for data input errors. Following quality assurance, presentation and analysis of the data can commence.

The data must be presented in an appropriate format. For most purposes, a table or graph is an effective way to summarise the data. Decide whether the raw data will be presented, or if it will be summarised some way.

Firstly, present and describe the baseline data (monitoring undertaken before the structural BMP was installed):

1. What is the water quality at each site? Are there any patterns in the changes in water quality, and how can they be explained? Consider flow data and/or rainfall data.
2. Is the water quality the same for all sites? If not, what could be some of the reasons why the water quality varies (consider land uses for example)?
3. How do the results compare to national water quality guidelines (e.g. ANZECC & ARMCANZ 2000)?
4. What is the baseline removal efficiency for the parameters of interest at the site where the structural BMP is proposed? If there is sufficient data, calculate the removal efficiency for a range of flow conditions and storm events.
5. What other changes in water quality are observed between the inlet(s) and the outlet(s)? Consider parameters such as dissolved oxygen and total suspended solids, which may be not stated in the project objectives but are relevant to ecosystem functioning.
6. Are there any patterns (seasonal, different flow regimes) in the baseline removal efficiency?

Secondly, present and describe the evaluation data (monitoring after the structural BMP was installed):

1. What is the water quality at each site? Are there any patterns in the changes in water quality, and how can they be explained? Consider flow data and/or rainfall data.
2. Is the water quality the same for all sites? If not, what could be some of the reasons why the water quality varies (consider land uses for example)?
3. How do the results compare to local guidelines, local reference sites and baseline data as well as national water quality guidelines (e.g. ANZECC & ARMCANZ 2000)?

4. What is the removal efficiency of the structural BMP for the parameters of interest? If there is sufficient data, calculate the removal efficiency for a range of flow conditions and storm events.
5. What other changes in water quality are observed between the inlet(s) and the outlet(s)? Consider parameters such as dissolved oxygen and total suspended solids, which may be not stated in the project objectives but are relevant to ecosystem functioning.
6. Are there any patterns (seasonal, different flow regimes) in the removal efficiency?

Thirdly, compare the results from monitoring the site before and after installation of the structural BMP, to assess the effectiveness of the structural BMP:

1. Has the removal efficiency for the parameters of interest improved since the structural BMP was installed?
2. How has installation of the structural BMP affected other parameters, compared to before the structural BMP was installed?

Finally, answer each of the evaluation questions, making use of the results from previous analysis and discussion.

#### 4.6.1 Efficiency

The efficiency of stormwater structural BMPs can be calculated in a number of ways. More thorough calculations require more data to be collected. When using simpler calculations, it is important to be aware of the limitations and assumptions involved. Being aware of the requirements of the calculation method will allow the monitoring program to be designed appropriately.

One method of calculating removal efficiency is presented below. This method can be adapted depending on what data is available. It is generally used to average different contributions throughout an event, to take into account natural variability and sampling artefacts. Further methods and limitations of assessing structural BMP efficiency are discussed in *Urban Stormwater BMP Performance Monitoring* (USEPA 2002).

Firstly, calculate the event mean concentration (EMC) for each site for the parameter you are interested in. The EMC is defined as the total constituent mass divided by the total runoff volume, and is calculated as:

$$EMC = \frac{\sum load}{\sum flow\_rate}$$

The load is the product of the flow rate and the concentration of the parameter. The sum of the loads is the sum of all data available during an ‘event’. Similarly, the sum of the flow rate is all flow rate data during an event. It is assumed that a number of samples, measuring both flow rate and concentration, are collected during each event. If this is not the case, then EMC will simply be equal to the concentration (or average concentration) of the parameter.

The EMC is calculated using all the data available for each ‘event’. An event is typically a storm event, but a similar principle may be applied to assess the removal efficiency during other flow conditions. For example, ‘baseflow during summer’ may be treated as one event, for the purposes of this calculation.

Secondly, the EMCs are used to calculate the removal efficiency of the structural BMP:

$$removal\_efficiency = \frac{average\_inlet\_EMC - average\_outlet\_EMC}{average\_inlet\_EMC}$$

The average\_inlet\_EMC is the mean of the EMCs for all the inlets (if there is more than one inlet). Likewise the average\_outlet\_EMC is the mean of the EMCs for the outlets. This will give a removal efficiency for each 'event', so that different flow conditions can be considered separately.

This method is most effective when there are a number of flow and concentration measurements taken at the inlets and outlets throughout one event. If there is only one sample taken, the lag time between the inlet(s) and the outlet(s) is not accounted for. It is assumed in the calculation that the sample taken at the inlet(s) is from the same slug of water that is sampled at the outlet(s). Unless this lag time is quantified (e.g. through tracer studies) and samples taken appropriately, the calculated removal efficiency may be inaccurate.

The USEPA recommends the use of the effluent probability method for quantifying structural BMP efficiency. Firstly, statistical tests are used to establish whether the inlet and outlet EMCs are statistically different – is the structural BMP providing treatment? When this has been established, a cumulative distribution function of standard parallel probability plot of the inlet and outlet quality is examined. The differences between the inlet and outlet graphs at different concentrations will indicate the level of treatment that the structural BMP is providing. This method can indicate differences in structural BMP effectiveness at different inlet contaminant concentrations. Details on undertaking this method of assessment are provided in *Urban Stormwater BMP Performance Monitoring* (USEPA 2002).

#### 4.6.2 Effectiveness

The effectiveness of a structural BMP is measured by the extent to which it achieves the project objectives. For a structural BMP, the project objectives will typically be stated as a quantifiable improvement to water quality. The effectiveness would consider:

1. Does the calculated removal efficiency of the structural BMP achieve the anticipated improvements to water quality?
2. To what extent has the structural BMP improved the situation, compared to before it was installed?

#### 4.6.3 Standards and guidelines

Baseline data and reference sites are useful in establishing suitable water quality guidelines; these figures are likely to be representative of local processes and conditions. Results from the monitoring may be compared to standards and guidelines to consider if the water or sediment quality is satisfactory for the receiving environment. Useful references include:

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1*, Canberra, Australian Capital Territory. Available via <<http://www.deh.gov.au/water/quality/nwqms/index.html>>.

Department of Environment 2003, *Contaminated Sites Management Series: Assessment Levels for Soil, Sediment and Water (Draft)*, Department of Environment, Perth, Western Australia.

### 4.7 Report and recommendations

It is advisable to prepare an interim report on the project. Annual analysis of the data will reduce the amount of work required when producing the final report, and will ensure that any problems with the data of the project are detected prior to the completion of the monitoring.

At the conclusion of the monitoring program, a single comprehensive technical report should be prepared.

This report will describe the project and evaluate it in terms of the project objectives. The report should be written with the target audience in mind.

Reports (interim and final) should cover the following broad areas:

1. Background – information about the site, why the project was implemented.
2. Purpose and objectives – the objectives of the structural BMP project, why it was decided to monitor and evaluate the structural BMP, evaluation questions to be answered by the monitoring program.
3. Monitoring plan – summarise the monitoring sites, frequency and parameters, with reference to the SAP for further details.
4. Methods – a reference to the SAP should be sufficient, unless unusual methodology is employed.
5. Quality assurance (QA) assessment – review the laboratory QA data and any quality control samples taken. QA assessment should be done as soon as possible after each sampling occasion so this will hopefully be a summary of previous results.
6. Results – present and describe the monitoring data, including broad patterns in the baseline and evaluation data. Tables or graphs are useful.
7. Discussion – discuss patterns observed in the results and what they might indicate. This is where the efficiency and effectiveness are assessed. Address each of the evaluation questions in detail.
8. Conclusions – summarise the results in terms of the purpose of monitoring and the evaluation questions.
9. Recommendations – for future management or monitoring of the structural BMP, or for application of the structural BMP at other sites.
10. References
11. Appendices

#### 4.7.1 Communication

The outcome from the structural BMP monitoring and evaluation should be communicated to key stakeholders. With a wide range of stakeholders, communications may need to be tailored to suit the intended audience. It may not be appropriate to distribute the entire evaluation report to all stakeholders indiscriminately. However, distribution of information about the monitoring and evaluation of structural BMPs to other people or organisations involved in this area will increase knowledge and avoid repetition of mistakes and promote lessons learnt.

##### **Example 1**

A Swan River Trust (SRT) project, the Liege Street Wetland in Cannington was designed to target the removal of nutrients in low flows, provide flood storage capacity for high flows, and increase habitat and amenity value. This is an example of how the generic process has been applied to monitor and evaluate a structural BMP. The Liege St Wetland treats water from the Liege St and Cockram St main drains before they discharge into the Canning River upstream of the Kent St Weir. Construction of the Liege St Wetland was complete in July 2004, immediately followed by planting which continued into 2005.

The *purpose* of the Liege St Wetland monitoring program was to evaluate the performance of the wetland at improving water quality, habitat and public health. It was appropriate to undertake extensive monitoring of the Liege St Wetland, as this was a demonstration site which could be used to assess the effectiveness of constructed wetlands on the Swan Coastal Plain for stormwater treatment.

The *objectives* of the project were to:

- improve water quality being delivered into the Kent Street Weir Pool, with a particular focus on reducing the delivery of nutrients in summer and autumn, when the risk of algal blooms is high;

- provide adequate storage and attenuation of peak flows;
- improve wildlife habitat;
- provide passive recreation and education opportunities;
- provide information on wetland maintenance requirements and costs, both in establishment and long term; and
- fill knowledge gaps in performance of wetlands at improving water quality and habitat.

These objectives appropriately describe the overall outcomes sought; however they are difficult to assess.

The *evaluation questions* to be answered to assess the performance of the Liege St Wetland were:

1. Does the actual hydrology of the wetland match that of the design intent?
2. What is the wetland treatment efficiency for a range of different parameters (nutrients, sediment, metals etc.) under different hydrological conditions (baseflow, rising limb, falling limb of various storm events)?
3. How effective is each main element of the wetland (e.g. sumplands versus open water, flow path lengths)?
4. What is the ability of the wetland to treat stormwater over time and with age?
5. How does effectiveness vary with different operational and/or maintenance approaches?
6. Does the wetland cause an improvement in or protect biotic communities?
7. Can the operation and maintenance of the wetland be improved?

Again, these questions are appropriate in terms of the outcomes sought but are difficult to evaluate. For instance, question 4 asks ‘what is the ability of the wetland to treat stormwater over time and with age?’ However, this does not explain what aspects of treating stormwater will be considered – reducing nutrient concentrations. The question also does not describe how the ‘ability’ will be measured – percentage reduction, reduction of concentration, reduction of total loads?

For most projects, a precise definition of the project objectives and monitoring questions will enable the monitoring to be planned to answer the specific questions of interest within the available budget. This was not as critical for the Liege St Wetland, as an extensive monitoring program was designed to collect as much information as possible to fill knowledge gaps.

#### *Planning and implementation*

The monitoring undertaken at Liege St Wetland encompassed more than most other structural BMP monitoring programs would require. Aspects that were monitored included the surface water, groundwater, sediment, hydrology and biota. The surface water and hydrology (flow rate) sampling will be discussed here.

Limited *baseline data* was collected before construction of the wetland, as the project was initiated and constructed in a tight time-frame. Surface water was sampled on an ad hoc basis from 1999 and then from December 2003 to April 2004 on a monthly basis for nutrients (TN, TP, NO<sub>x</sub>, NH<sub>4</sub>-N, SRP), physical properties (dissolved oxygen, pH, conductivity, temperature), biochemical oxygen demand, total suspended solids and heavy metals. Ideally, at least one year of baseline data should have been collected, at the same frequency and with the same parameters as the planned evaluation sampling.

*Evaluation sampling* of the Liege St Wetland was conducted from November 2004 on a monthly basis by taking *manual samples* for the following parameters:

- nutrients (TN, TP, NO<sub>x</sub>, NH<sub>4</sub>-N, DOrgN, SRP)
- total suspended solids (TSS)
- dissolved organic carbon (DOC)
- biochemical oxygen demand (BOD)

These parameters were selected to enable interpretation of nutrient cycling within the wetland, refine modelling of the catchment and understand organic matter fluctuations and oxygen demand. This suite of parameters will provide information on key aspects of the wetland ecology that contribute to algal blooms, by describing all the nutrient fractions, possible sediment loads of nutrients, organic carbon concentrations and demand for oxygen.

*Manual samples* were also taken on a quarterly basis at the same sites, and analysed for total heavy metals, chlorophyll and alkalinity. Sampling at a reduced frequency for these parameters is appropriate as they are not as critical to nutrient dynamics and algal growth.

Sampling at a monthly *frequency* is a common fallback method when undertaking monitoring and evaluation. This frequency is usually selected as a compromise between weekly or fortnightly sampling, and quarterly sampling. However, unless a pilot study is undertaken or high frequency historical data is available, it is not possible to understand what variability is missed by sampling at this frequency.

The *sites* were selected to be representative of a particular segment of the wetland, such as the inlets, open water bodies, and outlet. This is an appropriate site selection strategy. Again, with such a large area to investigate, the selection of sites ideally would be supported by a pilot study to understand the flow paths and how the different parts of the wetland interact.

Surface water samples were also collected by *automated sampling*, using a load measuring unit (LMU). This consists of a flow measurement device, a logger, an autosampler, a pump, and an array of bottles stored in a cool housing unit. The autosampler is programmed to collect samples in response to certain flow conditions. At Liege St Wetland, the autosamplers took samples when the water velocity reached a certain speed – that is, during rain events. The parameters analysed from the LMU samples were total nitrogen, total phosphorus and total suspended solids. As the samples are stored in the cool housing for up to a week at a time, it is not appropriate to analyse these samples for any parameters that might change (e.g. cannot analyse for nutrient fractions, as the relative amounts of each species may change after sitting in a bottle for a week). The LMUs at Liege St Wetland were located at the two main inlets and the outlet from the wetland.

*Flow rate* was measured at Liege St Wetland in a variety of ways. Firstly, at the same sites as the LMUs, Dopplers were installed. The Dopplers measure water velocity, hydrostatic pressure (to calculate water depth) and temperature. Information from the Dopplers is recorded on a data logger on-site and downloaded periodically. This is an example of *continuous quantitative flow data*.

In addition, staff gauges with peak level indicators (PLIs) and capacitance probes were installed in two of

the ponds in Liege St Wetland and at the outlet from the wetland. Capacitance probes measure and record the water level, another example of *continuous quantitative flow data*. PLIs indicate the highest water level until they are re-set, which is an example of *non-continuous quantitative flow data*.

#### *Analysis, interpretation and reporting*

An internal document, the *Liege St Constructed Wetland Annual Monitoring Report 2005*, reported the first year of monitoring data for the Liege St Wetland to the Swan River Trust. The main aims of the report were to:

- make recommendations to the SRT for updating the Liege Street Wetland monitoring program;
- make recommendations to the SRT for improved management of Liege Street Wetland; and
- provide an initial evaluation of Liege Street Wetland performance (water quality treatment).

This was an interim monitoring report providing a review of available data collected in the first year of wetland monitoring. The wetland was not expected to achieve full treatment capability for a number of years after construction and planting. The surface water quality data was compared to the ANZECC & ARMCANZ (2000) trigger values for physical-chemical stressors and toxicant values.

The available data provided an initial indication of wetland performance. The efficiency and effectiveness of the wetland were not assessed in this report, largely because of delays in availability of the flow data. The performance of the wetland was qualitatively described, by summarising broad changes in nutrient species between the inlets and the outlets in different seasons.

## 5. Non-structural BMP performance monitoring

### 5.1 Context for non-structural BMP monitoring

Non-structural stormwater best management practices (non-structural BMPs) are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management (Department of Environment and Swan River Trust 2005). They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments (Taylor & Wong 2002). Chapter 7 defines non-structural BMPs for stormwater management into five principal categories: town planning controls; strategic planning and institutional controls; pollution prevention procedures; education and participation programs; and regulatory controls.

It is often perceived to be difficult to measure the degree of the success of non-structural BMPs and people tend to feel that they are less important than structural controls (NSW DEC 2004). However, they are essential in stormwater management as the key to improved stormwater quality and quantity heavily depends on behaviour change. Therefore, it is vital that the success of achieving change using non-structural BMPs is effectively evaluated through a properly designed and implemented performance monitoring and evaluation plan.

## 5.2 Non-structural BMP purposes and objectives

The outcomes of non-structural BMPs can be grouped as follows:

- the BMP has been fully implemented;
- there has been a change in awareness and knowledge of specific stormwater issues within a segment of the community;
- the BMP has changed people's attitude (usually self-reported);
- the BMP has changed people's behaviour;
- there have been actual changes in behaviour;
- the BMP has improved stormwater quality and quantity;
- there has been a change in the receiving environment quality.

## 5.3 Defining non-structural BMP success

What will qualify as a successful outcome for a non-structural BMP needs to be determined prior to implementation. By preparing an outcomes hierarchy for the non-structural BMP (Section 3), the levels of success can be determined. It is important to note that achieving one level of outcome for a project will not necessarily directly lead to achieving a higher level of outcome. For example, if there was a change in the behaviour of a community, then it may be incorrectly inferred that this would have some effect on quality or quantity of stormwater. If the quality or quantity of stormwater in the area improved then it may be assumed that the behaviour change had some role in the change but showing a direct causal link may be expensive and difficult (McKenzie-Mohr & Smith 1999).

It is important to be aware that changes in a community's knowledge as the result of the implementation of a non-structural stormwater BMP does not necessarily lead to changes in behaviour as a result of that knowledge (Smyth 1996).

## 5.4 Variables that affect non-structural BMP success and things to consider

The success of non-structural BMPs is heavily dependent on human behaviour, significantly more than structural controls which once installed can make a difference to the receiving environment as long as they are well maintained. Existing knowledge, values, attitudes and beliefs will shape the behaviour and motivations of people (Smyth 1996; Mira et al. 2003).

The success of town planning controls, pollution prevention procedures and regulations require that they have incorporated current best practice knowledge and practice in the regulations. Other variables that effect success for these tools include: that the application of the controls is correctly interpreted and applied; and how effectively these tools are enforced.

Institutional and strategic planning controls tend to have a range of implementation options such as licensing, legislation, regulation, administrative directions, reporting and taxation and service delivery. These controls may be unsuccessful because either the controls could not be implemented as designed, or the control was implemented as designed but did not achieve the desired objective.

Environmental education and participation programs aim to influence individuals to act in a manner that the benefits the environment. They will be successful if they have a holistic approach that includes appropriate and credible information, overcoming the barriers to action, choosing the right behaviours to promote, using effective educational tools and evaluating for success (Sheeley 2005).

Gunn (1978) identified reasons for which policy implementation failed and many authors have since built on this work. The following checklist provides a list of variables which influence success that could be considered when preparing a non-structural project implementation and monitoring and evaluation program. Performance monitoring and evaluation questions may ask whether these variables had an effect on the project.

**Table 7. Check list of variables that influence non-structural BMP success**

Understanding and agreement on project objectives and outcomes	Detailed specification of tasks to be completed
Communication and coordination	Compliance
Competence	Influence of external constraints
Agreement and support	Adequate time
Adequate resources	Suitable combination of resources
Valid theory and premise behind the designed project	Things change during the life of the project
Single implementation responsibility	

Given that the variables that will influence success are identified, baseline information needs to be gathered before the non-structural BMP is implemented (e.g. awareness levels prior to a stormwater awareness campaign). In addition, for some types of BMPs (e.g. educational campaigns), a pre-implementation monitoring exercise can be an extremely valuable input to help the design of the BMP (e.g. to clearly identify who is littering, where, when and why) (Taylor & Wong 2003).

Often, the timing of the ‘monitoring and evaluation tasks’ needs to be carefully synchronised with the ‘BMP implementation tasks’. This is where the performance monitoring and evaluation program and a working group outlined in Section 3 is important as it highlights all the tasks for the program, who is responsible for their implementation and when they will be done.

## 5.5 Styles and techniques for non-structural BMP performance monitoring and evaluation

There are many approaches to evaluating the success of non-structural BMPs. When using the performance monitoring and evaluation generic process as outlined in Section 3, project managers will need to decide at stage A - Purpose, what monitoring and evaluation methodology is appropriate. This section discusses the approaches available. Once the non-structural control monitoring approach has been decided the rest of the generic performance monitoring and evaluation process can be followed.

Taylor and Wong (2003) classified seven styles of evaluation based on the desired outcomes of the programs implemented. The Department of Water encourages the use of these styles of monitoring for non-structural BMPs. Widespread adoption of these styles of monitoring using uniform data recording templates will allow comparative monitoring between performance monitoring and evaluation programs, leading to an improved understanding of the non-structural BMP’s effectiveness.

The monitoring protocols for the seven styles of evaluation and data reporting templates are covered in Taylor and Wong (2003) and a copy is provided at <<http://stormwater.water.wa.gov.au>> or at <<http://www.catchment.crc.org.au/>>.

## Choosing the evaluation style for non-structural controls

This section outlines appropriate evaluation styles to help stormwater managers make a decision based on specific BMPs, knowledge of the likely costs, degree of difficulty, time-frames, and the resources commonly available to local government authorities. The following advice is based on Taylor and Wong's (2003) work.

It is recommended that expert advice be sought early when preparing a performance and monitoring and evaluation plan to help select a suitable evaluation style (or styles). Stormwater managers in Department of Water, research bodies and expert consultants can assist with this process.

A range of evaluation styles are described in Table 8. This decision is a very important one, and should be made after consideration of the following factors:

### 1) The **objective(s)** of the BMP that will be evaluated.

For example, if the objective is simply to raise awareness of stormwater pollution within a target audience through an educational program then Style No. 2, monitoring changes in people's awareness or knowledge, would be appropriate. However, if the objective is to improve erosion and sediment control compliance 'on the ground', Style No. 5 would be the most appropriate as this would monitor changes in people's actual behaviour. For multiple objectives, several styles of evaluation may be needed.

It is recommended that evaluating the nature of BMP implementation (evaluation Style No. 1) always be attempted, as this provides a simple basis for more advanced forms of evaluation and often helps to explain the evaluation results (Taylor & Wong 2003). For example, if an enforcement program involving a new local law is found to be unsuccessful in changing people's behaviour, knowledge about the nature of enforcement activities (e.g. how many fines were issued, how many fines were successfully challenged in court, etc.) would be needed to help explain this outcome.

### 2) The **resources** available to the monitoring agency.

Generally the evaluation styles are ranked from the least resource intensive (evaluation Style No. 1) to the most costly (evaluation Styles No. 6 and 7). Typically the Styles No. 6 and 7 will be beyond the resources of most local government authorities in Australia (Taylor & Wong 2003).

### 3) The **time-frame** over which monitoring needs to occur.

For example, a monitoring and evaluation plan may be developed using Style No. 1, 5 and 7 which provides some evaluation results in the short term (e.g. whether the BMP has been fully implemented as planned), in the medium term (e.g. whether the BMP changes people's actual behaviour) and in the long term (e.g. whether waterway health in the region has improved). Short and medium term reporting may be essential to keep stakeholders confident that the program is 'on track', particularly if the ultimate outcomes may not occur for years or even decades (Taylor & Wong 2003).

### 4) The **purpose** of the evaluation.

Consideration should be given to how the findings of the evaluation will be used, by whom, and their specific needs. This is covered in Section 3.

#### 5) The **nature of the BMP**.

Some styles of evaluation are intrinsically suited to specific BMPs because of the nature of the BMP. For example, an industry education program could easily be evaluated by a pre- and post-campaign audit of industry practices (Style No. 5) to see if actual behaviour had changed. This style of evaluation would however be far more difficult if the BMP was an educational campaign promoting a change to fertilisation rates on residential lawns.

**Table 8. Evaluation frameworks for non-structural BMPs that aim to improve stormwater quality and quantity management (source: Taylor & Wong 2003), includes management response evaluation and condition evaluation**

Style of evaluation	Description	Who Typically Does It	Example of Monitoring Tools	Advantages	Disadvantages
1. BMP implementation	Evaluation of whether the BMP has been fully implemented.	Stormwater management agencies (e.g. local or State government authorities) or community groups.	Auditing with checklists.	<ul style="list-style-type: none"> <li>Inexpensive.</li> <li>Provides the basis for more advanced styles of evaluation (see below).</li> <li>Simple to design and implement.</li> <li>Useful for BMPs that have a relatively low risk of failure once implemented</li> <li>Can usually also evaluate the quality of implementation (e.g. feedback on the relevance and quality of training materials as well as the quality of its delivery).</li> </ul>	<ul style="list-style-type: none"> <li>Provides no information on whether the BMP has changed people's behaviour or water quality.</li> <li>Desktop evaluation may not truly reflect what is happening 'on the ground'.</li> </ul>
2. Changes in awareness and knowledge	Evaluation of whether the BMP has increased levels of awareness and/or knowledge of a specific stormwater issue within a segment of the community.	Stormwater management agencies, often with the help of specialist community survey consultants.	Surveys that examine people's level of awareness and knowledge.	<ul style="list-style-type: none"> <li>Relatively inexpensive (depending on the level of confidence needed in the results).</li> <li>Relatively fast.</li> <li>Can directly examine levels of awareness and knowledge (i.e. this style of evaluation does not need to rely on self-reported changes to awareness and/or knowledge).</li> <li>Can gather valuable information that helps to improve the design of the BMP (e.g. a baseline survey for an educational program may find that a high percentage of people mistakenly believe that stormwater is a minor risk to waterway health in the region).</li> <li>Can usually monitor changes in people's awareness/knowledge, attitudes and/or self-reported behaviour with the same instrument (e.g. a survey).</li> </ul>	<ul style="list-style-type: none"> <li>Changes in awareness and/or knowledge do not necessarily lead to a change in people's attitudes, behaviour or water quality.</li> </ul>

Style of evaluation	Description	Who Typically Does It	Example of Monitoring Tools	Advantages	Disadvantages
3. Changes in attitude (self-reported)	Evaluation of whether the BMP has changed people's attitudes (either towards the goal of the BMP, or towards implementing the BMP itself) as indicated through self-reporting.	Stormwater management agencies often with the help of specialist community survey consultants.	Surveys that examine peoples self-reported attitudes.	<ul style="list-style-type: none"> <li>• Relatively inexpensive (depending on the level of confidence needed in the results).</li> <li>• Relatively fast.</li> <li>• Can gather information that helps to improve the design of the BMP (e.g. people's attitudes may be based on incorrect assumptions that could be easily clarified).</li> <li>• Can usually monitor changes in people's awareness/knowledge, attitudes and/or self-reported behaviour with the same instrument (e.g. a survey).</li> </ul>	<ul style="list-style-type: none"> <li>• Changes in people's attitudes towards stormwater management do not necessarily lead to changes in behaviour.</li> <li>• The evaluation process and social norms may influence self-reported attitudes (e.g. some survey respondents may report a 'socially acceptable' attitude rather than their actual attitude).</li> <li>• Potential for confusion exists depending upon the attitude being monitored (e.g. some builders may have the unchanged attitude that new erosion and sediment control laws are unnecessary, but their attitude towards compliance may have changed simply because of the financial consequences).</li> </ul>
4. Changes in behaviour (self-reported)	Evaluation of whether the BMP has changed people's behaviour as included through self-reporting.	Stormwater management agencies, often with the help of a specialist community survey consultant.	Surveys with survey forms that examine people's self-reported behaviour.	<ul style="list-style-type: none"> <li>• Relatively inexpensive (depending on the level of confidence needed in the results).</li> <li>• Relatively fast.</li> <li>• Can examine types of behaviour that are very difficult and expensive to directly observe or monitor (e.g. infrequent application of lawn fertiliser, disposal of used engine oil).</li> <li>• Can usually monitor changes in people's awareness/knowledge, attitudes and/or self-reported behaviour with the same instrument (e.g. a survey).</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported behaviour can be a very poor indicator of actual behaviour in some contexts (e.g. littering in public places).</li> </ul>

Style of evaluation	Description	Who Typically Does It	Example of Monitoring Tools	Advantages	Disadvantages
5. Changes in behaviour (actual)	Evaluation of whether the BMP has changed people's behaviour as indicated through direct measurement.	Specialists (e.g. research bodies, specialist consultants, trained staff from stormwater management agencies).	Observational studies or audits with checklists.	<ul style="list-style-type: none"> <li>Change in actual behaviour is a very good indicator for likely changes to stormwater quality and waterway health.</li> <li>Data from such evaluations can be used to model predicted changes to stormwater quality and waterway health.</li> <li>Such evaluations can provide valuable information that can be used for BMP design or improved evaluation strategies (e.g. highlighting errors associated with monitoring self-reported behaviour and identifying why certain forms of behaviour occur).</li> </ul>	<ul style="list-style-type: none"> <li>Can be very difficult and costly to apply in some contexts due to issues such as invasion of people's privacy and the need to monitor a large number of infrequent events.</li> <li>People's behaviour that influences stormwater quality is inherently complex, and is typically influenced by many variables (e.g. people's age, whether they are in groups, surrounding infrastructure, economic circumstances, etc.). Designing evaluation strategies to accommodate this complexity can be challenging.</li> </ul>
6. Changes in stormwater quantity and quality (and quantities)	Evaluation of whether the BMP (or set of BMPs) has improved stormwater quality in terms of loads and/or concentrations of pollutants.	Specialists (e.g. research bodies or stormwater management agencies with a very high level of in-house expertise).	Stormwater quantity and quality monitoring programs or pollutant export modelling (immediate local scale of the BMP).	<ul style="list-style-type: none"> <li>Directly measures changes in stormwater quality (the primary aim of these non-structural BMPs).</li> <li>The information collected may allow non-structural BMPs to be included in pollutant export modelling exercises when undertaking major stormwater quality management decisions (along with structural BMPs).</li> <li>Can be used for individual non-structural BMPs or combinations of BMPs (e.g. monitoring the collective effect on stormwater quality over time of implementing a new city-wide urban stormwater management plan).</li> </ul>	<ul style="list-style-type: none"> <li>Relatively expensive and time-consuming (depending upon the desired level of confidence in the results).</li> <li>Usually requires a very high level of technical expertise to design the monitoring program and analyse the results.</li> <li>Can be difficult to measure subtle changes in stormwater quality, given the very high spatial and temporal variability of urban stormwater quality.</li> <li>Can be difficult to find and maintain suitable control sites or catchments.</li> <li>Typically, a variety of pollution sources and other types of BMPs heavily influence stormwater quality in areas where non-structural BMPs are applied.</li> </ul>

Style of evaluation	Description	Who Typically Does It	Example of Monitoring Tools	Advantages	Disadvantages
7. Changes in environmental quality (receiving environment quality)	Evaluation of whether the BMP (or set of BMPs) has improved the health of receiving waters.	Ecological health monitoring programs (e.g. trend analysis). Alternatively, receiving water quality modelling can be used to predict the ecological effect of known changes in stormwater quality (e.g. in estuary systems).	Ecological health monitoring programs or ecological effect of known changes in stormwater modelling.	<ul style="list-style-type: none"> <li>• Directly measures changes in aspects of waterway health (the ultimate goal of stormwater quality measures which are implementing non-structural BMPs).</li> <li>• Can be an efficient form of evaluation where BMPs involve a specific stormwater pollutant with few sources (e.g. an education campaign to phase out the use of specific pesticide in an urban catchment) or where a case-effect relationship has already been established (e.g. the relationship between sewer overflows and ambient water quality in a river).</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively expensive and time-consuming (depending upon the desired level of confidence in the results).</li> <li>• It is often very difficult to attribute subtle, long-term changes in waterway health to the use of any particular BMP. This style of evaluation is mainly used to evaluate the collective effect of all catchment management activities over time.</li> <li>• Usually requires a very high level of technical expertise to design the monitoring program and analyse the results.</li> </ul>

## Example 2

The following is a summary of the methodology of the monitoring and evaluation for the South East Regional Centre for Urban Landcare (SERCUL) Industrial Survey and Inspection Program (ISIP). The project facilitated direct engagement of light industrial small and medium enterprises (SMEs) by Local Government Association Environmental Health Officers (LGA EHOs) in a supportive and educational environment, to assess, record and educate SMEs regarding environmental management practices, particularly stormwater, chemical and waste management.

The study was conducted with 268 businesses in five local government areas including eight different industrial areas. These were all located within the SERCUL Natural Resource Management (NRM) region in southern Perth, Western Australia, from September 2005 to May 2007. The process is described according to the generic process outlined in Chapter 10.

This approach can be described as promotion of structural and non-structural BMPs, focussing on pollution prevention using environmental risk management, education and participation and, to a lesser extent regulatory controls.

### **A. Purpose**

To assess if light industrial SME environmental management is improved by LGA EHO engagement in a support and education approach.

The project evolved out of a literature review of related studies and personal contact with stakeholders in the area of interest, to establish that data regarding current practices and barriers to change had not been collected previously. The literature review provided significant guidance in the approach taken in the SERCUL study.

### **B. Objectives**

The overarching objectives for the SERCUL study were:

- Measure SME owner/manager awareness of stormwater contaminants and legal obligations;
- Establish SME barriers to environmental management and preferred information and communication sources;
- Measure changes in SME environmental risk management and identify contributing factors;
- Establish the cost of implementing the approach;
- Assess suitability of LGA EHOs as service provider.

Measuring non-structural best management practice success can be challenging. In the SERCUL study, measuring organisational change for environmental risk management was chosen over water quality monitoring, which was considered too difficult to control the range of variables for reliable results. Similarly change of awareness does not necessarily equal behaviour change or improved environmental outcomes, and was not considered after the initial survey suggested a relatively high SME awareness of stormwater contaminants and legal obligations.

### **C. Evaluation questions and indicators**

Evaluation questions were determined using the outcomes hierarchy below.

Outcomes hierarchy for evaluation of the SERCUL industrial survey and inspection project						
	Project aims	Evaluation questions	Data sources	Instruments for collecting data	Comments	
Ultimate aims	1 Improvement in SME environmental management (stormwater protection)	Has SME environmental management improved as a result of LGA intervention?	SME EHO	Risk management (RM) survey Premise inspection	Assessed stage 2	
	2 Assessment of appropriate CBSM tools for SME behaviour change	Have CBSM tools deployed contributed to improved environmental management?	SME	RM survey Premise inspection	Assessed stage 2	
	3 Productive relationships developed between LGAs and SMEs	Have productive relationships been developed between LGAs and SMEs? Has this influenced environmental management?	LGA SME	SME evaluation survey LGA survey	Assessed stage 2	
Intermediate aims	4 Identification of LGA barriers to SME regulation	What are the LGA barriers to SME regulation?	LGA	LGA survey	Stages 1 and 2	
	5 Establish cost estimate of an LGA-SME engagement program	What is the cost of an LGA-SME regulation program based on this model?	SERCUL LGA	LGA survey SERCUL industrial survey and inspection pilots	Stages 1 and 2	
	6 Profile businesses with high and low risk of contamination of stormwater	What are the relationships contributing to high and low stormwater contamination risk ratings?	SERCUL	RM surveys (SPSS analysis)	Stages 1 and 2	
Immediate aims	7 Identification of SME barriers to environmental management	What are the SME barriers to environmental management?	SME	RM survey	Assessed stage 1	
	8 Identification of preferred SME information and communication modes	What are the preferred SME information and communication modes?	SME	RM survey	Assessed stage 1	
	9 Assessment of current SME environmental management	What is the current level of SME environmental management (stormwater management)?	SME EHO	RM survey Premise inspection	Assessed stage 1	

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**Key**

SME	Small and Medium Enterprises
EHO	Environmental Health Officer
LGA	Local Government Association
CBSM	Community-based Social Marketing
BMP	Best Management Practices
UDR	Unauthorised Discharge Regulations 2004
SERCUL	South East Regional Centre for Urban Landcare
SPSS	Statistical Package for Social Scientists

It is appropriate to seek expert advice in the design of evaluation questions and indicators as the study design will determine the type of analysis that can be performed and the reliability of results. The SERCUL study used a range of evaluation styles as described by Taylor and Wong (2003) incorporating elements of Styles 1 through to 5. Multiple evaluation styles added value to the study, acknowledging the challenge in obtaining resources, access and funds to carry out this type of research.

The SERCUL survey used an interview style with open and closed questions; responses to some questions were measured by a Leichart scale to determine the strength of barriers and preferences. Other recordings in the survey were simple judgements about the acceptability of environmental management procedures and practices being used.

The performance indicator chosen to identify improvements in environmental legislative compliance was represented by the field 'Onsite activities discharge to stormwater'. A significant reduction in discharge to stormwater on repeat surveys represents the program operating successfully in achieving the protection of stormwater quality through implementation of environmental risk management.

Indicators for the development of rapport are established through questions such as ‘Do you consider LGA visits improve your environmental management?’ and ‘Has the approach used in this program contributed to a positive relationship with your LGA?’.

The combination of a measured reduction in the number of businesses discharging to stormwater and a positive response to LGA engagement indicates the program is performing as anticipated and would contribute to a positive evaluation of the overall program.

A Leichart scale was also used for SMEs to rate the usefulness of interventions implemented. The intention was to establish if the program was achieving improved SME environmental risk management and to establish the likely contributing factors.

#### **D. Planning**

A Community Based Social Marketing (CBSM) analysis was chosen to assess which interventions were likely to be effective. The SERCUL study used collated barriers and benefits data from previous Australian studies for the initial CBSM analysis and collected barriers data from survey participants to confirm or reject the assumptions of the initial analysis.

An assessment was made regarding the available resources, skills, time and access to the study group when considering which actions would be implemented from the CBSM analysis.

The intention was to perform field based research at SME premises, a group acknowledged as difficult to attract away from their place of business. Past literature suggested a face-to-face, individual and site specific approach. Previous studies indicated LGA EHOs had the required skills to perform the environmental management audits, credibility and access, and could possibly carry out the function over the long term. It was therefore essential to attract LGA partnership in the study.

SERCUL chose to measure organisational environmental risk management due to the non-prescriptive structure of the relevant legislation, i.e. Environmental Protection (Unauthorised Discharge) Regulations 2004. A scored environmental risk assessment allowed the measurement of practical uptake and application of the environmental management education and advice being provided.

Each pilot was coordinated with the participating LGA distributing letters to SMEs regarding the survey, survey dates, printed materials, transport and report writing.

The electronic survey instrument was designed to collect data about current environmental management, barriers to improved management, preferences for communication and information and perceived improvement versus assessed achievement in environmental risk reduction.

Appropriate technology aids were identified and obtained. Data collected was imported into a database on Microsoft Excel and transferred to a Statistical Package for Social Scientists (SPSS) database for further analysis.

The intention was to focus on the development of rapport with SMEs and engagement in continuous improvement beyond regulatory compliance. A regulation and enforcement approach was considered to be unlikely to develop the necessary rapport and is an approach that cannot be used beyond basic legislative compliance.

### **E. Implementation**

Interviews were used to collect data in stages one and two and were conducted at light industrial SME premises with owner/managers from pre-arranged appointments with businesses initially targeted by the following criteria:

- water used in processing on-site
- liquids or manufactured chemicals stored on-site

A door-to-door cold canvas approach was used to initially establish whether the criteria applied. Official letters from the participating LGA were handed over explaining the purpose of the study. Participation was voluntary. Electronic recording (a laptop) was used to test effectiveness in the light industrial SME survey and audit application. Electronic recording made data storage, transfer and analysis much simpler.

The electronic survey was conducted by a Natural Resource Management Officer from SERCUL and the premise inspections by an Environmental Health Officer from the participating LGA.

Examples of interventions taken include a survey of environmental risk, a premise inspection and advice, distribution of information packs for SME environmental management, stencilling of stormwater drains, repeat LGA EHO visits, waste and recycle directories, environmental improvement plans and follow up industry specific information packs.

The first stage of surveys measured awareness of legal obligations (particularly for stormwater), barriers to environmental management, preferred communication and information sources and a scored environmental risk audit.

The second stage measured perceived improvement in environmental management, attitude to the effectiveness of the interventions taken and a repeat of the scored environmental risk audit to be compared with the initial results.

## **F. Analysis and interpretation**

Mathematical statistical analysis asks appropriate logical questions and measures the limitations of answers;

i.e. Data input quality (and/or appropriateness of test chosen)  $\Rightarrow$  Data output quality.

Statistical analysis usually adds significant value to the data and study as a whole. Statistical analysis may not be so important if you are simply trying to bring attention to an issue without the need for an immediate investigation.

SERCUL chose to collect qualitative and quantitative categorical data with a predicted normal (Gaussian) distribution. Chi squared and Bivariate analyses were chosen to test for strength and significance of relationships in the data. More rigorous statistical tests were not chosen because it was felt that it was difficult to control some variables in the study, and that the conditions could be met for the tests chosen and would provide adequate insight into the research questions from the data collected.

## **G. Report and recommendations**

A report was produced for each LGA pilot providing the results as descriptive statistics and a description of the barriers and issues raised by SME participants. Recommendations were made regarding the achievement of environmental legislative compliance in an approach that encourages the development of rapport and engagement in beyond compliance environmental management and sustainability initiatives.

A final report for each stage of the project (consisting of five pilots) was compiled including conceptual models illustrated as diagrams to demonstrate the likely reasons for the project outcomes, to help evaluate success and provide guidance on how to adapt the approach to improve program efficiency.

Reports to other stakeholders have changed in format and style depending on the audience that is being targeted.

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## 8. Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BMP	Best management practice
CBSM	Community based social marketing
DEC	Department of Environment and Conservation
DoW	Department of Water
EHO	Environmental Health Officer
EMC	Event mean concentration
EW	Ecological water requirement
GPT	Gross pollutant trap
ISIP	Industrial survey and inspection program
LGA	Local government authority
LMU	Load measuring unit
MAR	Managed aquifer recharge
NATA	National Association of Testing Authorities
NRM	Natural resource management
OSH	Occupation safety and health
QA	Quality assurance
RM	Risk management
SAP	Sampling and analysis plan
SERCUL	South East Regional Centre for Urban Landcare
SME	Small and medium enterprises
SPSS	Statistical package for social scientists
SRT	Swan River Trust
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UDR	Unauthorised Discharge Regulations
WSUD	Water sensitive urban design

## Appendix A - Summary of common water quality parameters

Parameter	Abbrev.	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
<b>Physical Parameters</b>						
Specific conductivity	SpCond	mS/cm (micro-siemens /cm)	Water	How well water can pass an electric current. Indicates presence of inorganic dissolved solids. Standardised to 25°C.	Geology of the catchment, fertiliser runoff, acid mine drainage, salinity.	Simple physical parameter that most probes will measure. Provides general information about the water quality.
Dissolved oxygen	DO	mg/L %	Water	Concentration of oxygen dissolved in the water.	Water temperature, algae growing in water, water velocity, organisms respiring in water.	Dissolved oxygen is necessary to support aquatic life and is an important measure of physical water quality.
pH	pH	-	Water	Hydrogen concentration in water, on a logarithmic scale. pH 7 is neutral.	Carbon dioxide in water decreases pH (makes the water more acidic). Runoff from acid sulphate soils also decreases pH.	Simple physical parameter that most probes will measure. Provides general information about the water quality.
Salinity	Sal	ppt	Water	Dissolved salt content (salt being ions).	Influences from oceanic water, dry-land salinity, etc.	Simple physical parameter that most probes will measure. Provides general information about the water quality.
Temperature	Temp	°C	Water	Water temperature.	Atmospheric temperature, direct sunlight, water colour, inputs of warm or cold water.	Simple physical parameter that most probes will measure. Temperature regulates the rate of metabolic and reproductive activities in aquatic organisms, and strongly influences dissolved oxygen concentration.

Parameter	Abbrev.	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Turbidity		NTU (Nephelometric Turbidity Units)	Water	The cloudiness of the water, how much light is scattered by suspended particles (measured by turbidimeter). May also be measured by Secchi disk, in which case the measurement is metres below the surface that the disk can be seen.	Erosion, runoff from urban areas carrying particles, algae, decomposition of organic matter, suspended solids, high flow rate.	Turbidity can indicate high concentrations of suspended solids, algae growth or possible microbial growth.
Flow rate		m <sup>3</sup> /s	Water	Measures the velocity of water flowing through a given cross-section.	Rainfall and runoff are main factors that influence flow rate. Groundwater flow or other inputs of water can contribute.	The flow rate puts all other parameters in context, e.g. high concentrations of contaminants in a trickle of water are not as concerning as high concentrations in a high flowing stream. It is desirable to measure flow rate, or at least qualitatively describe it, when any other measurements are taken.
Moisture content		%	Sediment	The percentage of water in sediment.	Soil type.	
Particle size distribution	PSD	%	Sediment	Percentage of soil in different size fractions.	Soil type, erosion, urban development.	

Common Chemical Parameters						
Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Total suspended solids	TSS	mg/L	Water	Solids in water that can be trapped by a filter.	Erosion, runoff from urban areas carrying particles, decomposition of organic matter, suspended solids, high flow rate.	High levels of TSS can block light to submerged vegetation, interfere with aquatic fauna (e.g. block fish gills) and often correlates with higher levels of pollutants (often attached to sediment particles). Common parameter to measure.
Total nitrogen	TN	mg/L	Water; Sediment	All forms of nitrogen in the water (organic + inorganic, soluble + particulate).	Discharge from wastewater treatment of septic systems, animal excreta (e.g. cows, birdlife), fertiliser runoff.	An important parameter to measure, nitrogen is a key nutrient contributing to algal growth.
Total oxidised nitrogen	TON NO <sub>x</sub> -N	mg/L	Water	Nitrate (NO <sub>3</sub> <sup>-</sup> ) and nitrite (NO <sub>2</sub> <sup>-</sup> ). Measured from a water sample that has been filtered.	Both highly soluble inorganic nitrogen species. Ammonium is converted to nitrite then nitrate by bacteria. Nitrate is taken up by plants.	An important parameter to measure, nitrate is the form of nitrogen most readily available to algae.
Ammonium/ ammonia	NH <sub>3</sub> -N / NH <sub>4</sub> <sup>+</sup> -N	mg/L	Water	Ammonium (NH <sub>4</sub> <sup>+</sup> ) and ammonia (NH <sub>3</sub> ). Measured from a water sample that has been filtered.	Highly soluble inorganic nitrogen species. In oxygenated waters, ammonium is quickly converted to nitrate.	An important parameter to measure to understand the contributions of different nitrogen species.
Dissolved organic nitrogen	DOrgN	mg/L	Water	Includes urea, amino acids, amines, polypeptides, etc. Measured from a water sample that has been filtered.	Organic sources.	An important parameter to measure to understand the contributions of different nitrogen species. DOrgN is not readily available to plants and algae, but is converted to available inorganic forms by bacteria and fungi.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Total Kjeldahl Nitrogen	TKN	mg/L	Water	NH <sub>3</sub> -N / NH <sub>4</sub> -N plus DORgN plus particulate nitrogen.	As for the individual components.	This parameter is generally calculated by the labs, not directly measured. It is an outdated term carried over from when chemistry techniques did not allow separate identification of the separate nitrogen components. There is no need to specifically measure or describe this parameter.
Total phosphorus	TP	mg/L	Water; Sediment	All forms of phosphorus in the water (soluble + particulate, inorganic + organic).	Discharge from wastewater treatment of septic systems, animal excreta (e.g. cows, birdlife), fertiliser runoff, detergents, urban sources.	An important parameter to measure, phosphorus is a key nutrient contributing to algal growth.
Soluble reactive phosphorus	SRP	mg/L	Water	Ortho-phosphate (PO <sub>4</sub> <sup>3-</sup> ) (also called reactive phosphate). Measured from a water sample that has been filtered.	Produced by natural processes, also present in sewage.	An important parameter to measure. SRP is readily available to plants, and phosphorus is usually the limiting nutrient for plant/algae growth in freshwater systems.
Dissolved organic carbon	DOC	mg/L	Water	The component of organic carbon that is readily available to organisms, including polysaccharides, amino acids, peptides, other organic acids, and carbohydrates. Measured from a water sample that has been filtered.	Runoff from urban catchments, organic matter, sewage.	DOC is metabolised by bacteria, using oxygen in the process. High concentrations of DOC can draw a lot of oxygen from the water, causing anoxic conditions. The decomposition of DOC can also emit odours.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Total organic carbon	TOC	mg/L	Water; Sediment	Highly sensitive, non-specific measurement of all organics present in a sample, including organic matter, hydrocarbons, etc.	Highly variable depending on type of organic compound.	Can indicate organic chemical discharge. An indicator of pollution but does not specify type of pollution.
Biological (or biochemical) oxygen demand	BOD	mg/L	Water	The amount of oxygen used in the metabolism of biodegradable organics.	Dead plant matter, algae, manure, sewage, grass clippings, food waste, etc. can all contribute to higher BOD.	Indicator of the degree of contamination by organic waste. High BOD indicates the potential for anoxic conditions, as the oxygen is used for decomposing the organic waste. An indirect measure, depending on the application it may be more useful to measure TOC or DOC.
Total heavy metals (suite may include Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn)		mg/L	Water; Sediment	Metal species to be measured must be specified. Measures soluble and insoluble fractions.	Manufacturing processes, factories, release from acid sulphate soils, motor vehicles (fuel, exhaust), groundwater (e.g. iron). Solubility of metals is strongly influenced by pH and carbonates ( $\text{CO}_3^{2-}$ , $\text{HCO}_3^-$ ), which precipitate some metals; alkalinity should be measured whenever metals are measured.	Useful to get an indication of general pollutants, but not as critical to ecosystem function as parameters such as nitrogen and phosphorus. Total heavy metals are appropriate for investigative purposes.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Soluble heavy metals (suite may include Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn)		mg/L	Water	Metal species to be measured must be specified. Measures soluble fractions only. Measured from a water sample that has been filtered.	Solubility of metals is strongly influenced by pH and presence of carbonates ( $\text{CO}_3^{2-}$ , $\text{HCO}_3^-$ ), which precipitate some metals; alkalinity should be measured whenever metals are measured.	Soluble heavy metals indicate the portion of metals that are bioavailable. The effect of pH on solubility should be considered.
Total alkalinity as $\text{CaCO}_3$	Alk	mg $\text{CaCO}_3/\text{L}$	Water	The concentration of alkaline compounds in water (e.g. $\text{HCO}_3^-$ ).	Geology and soils, pH, cleaning agents.	Indicates the buffering capacity of the water, the capacity to neutralise acids. Also can reduce toxicity of metals by binding with metals and forming precipitates.
Other Chemical Parameters						
Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Polycyclic aromatic hydrocarbons	PAHs	$\mu\text{g/L}$	Water; Sediment	A group of over 100 different hydrocarbon compounds that have multiple benzene rings in their chemical structure.	Can be formed during the incomplete burning of coal, oil garbage, etc. Typical component of asphalts, fuels, oils, and greases. Some PAHs are manufactured.	Analysis for these parameters is expensive. They may be used for investigative purposes or to detect suspected pollutants.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Polychlorinated biphenyls	PCBs	µg/L	Water; Sediment	A family of man-made chemicals that contain 209 individual compounds with varying levels of toxicity, used for a variety of applications including heat transfer, lubricants, etc. Manufacture of PCBs is now prohibited.	PCBs have low solubility in water and do not degrade readily. Once in the air, PCBs can be carried long distances.	Analysis for these parameters is expensive. They may be used for investigative purposes or to detect suspected pollutants.
Organochlorine and organophosphorus pesticides	OC/OP pesticides	µg/L	Water; Sediment	A pesticide is an all-encompassing term to refer to a substance or mixture of substances intended to prevent, destroy, repelling, mitigating pests or defoliating or desiccating plants.		
Phenoxy Acid Herbicides		µg/L	Water; Sediment	A group of organic herbicides with high selectivity and ease of translocation.		
Anionic surfactants as methylene-blue active substances	MBAS	µg/L	Water; Sediment	A compound comprising of a strongly hydrophobic group and a strongly hydrophilic group. The hydrophilic group in this case is anionic (has a negative charge).  Anionic surfactant examples are alcohol ethoxylated sulphate (AES); linear alky/benzene sulphonates (LAS).	Surfactants often enter waters and waterways by discharge of aqueous wastes from household and industrial laundering and other cleansing operations.	

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Benzene, toluene, ethylbenzene, xylenes.  Total recoverable hydrocarbon fractions: TRH: C <sub>6</sub> -C <sub>9</sub> , TRH: C <sub>10</sub> -C <sub>14</sub> , TRH: C <sub>15</sub> -C <sub>28</sub> , TRH: C <sub>29</sub> -C <sub>36</sub>	BTEX TRH	µg/L	Water; Sediment	Liquid geologically-extracted hydrocarbons.  Benzene, toluene, ethylbenzene, and xylene isomers are analysed as they make up part of the C <sub>6</sub> to C <sub>9</sub> petroleum hydrocarbons (which are quite volatile).	Motor vehicles and other sources of petroleum.	Analysis for these parameters is expensive. They may be used for investigative purposes or to detect suspected pollutants.
Chromium reducible sulphur set			Sediment	Includes an analysis of the chromium reducible sulphur (S <sub>CR</sub> ), plus determination of the existing acidity and potential acidity, plus the acid neutralising capacity.	Acid sulphate soil or potential acid sulphate soil.	
<b>Biological Parameters</b>						
Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Faecal (thermo-tolerant) coliforms (presumptive thermo coliforms (count <10-1,000,000 cfu/100 mL))		Presumptive thermo-tolerant coliforms CFU/100 mL	Water	Coliform bacteria of faecal origin are referred to as faecal coliforms and grow at higher temperatures (44.5°C or higher).	Septic tank failure, poor pasture and animal keeping practices, pet waste, and urban runoff.	Can indicate pollution of water by faeces of humans or other warm-blooded animals. Used as an indicator of pathogenic bacteria.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR Effect of this parameter
Enterococci (confirmed enterococci (count <10-24000 MPN/100 mL))		Confirmed enterococci MPN/100 mL	Water	Faecal streptococci are normal inhabitants of the intestinal tract of humans and other animals. The enterococci portion of the faecal streptococci group includes <i>S. faecalis</i> , <i>S. gallinarum</i> and <i>S. avium</i> .	Sewage, excreta of higher animals.	Enterococci are the best indicators of faecal contamination from warm-blooded animals in marine waters.
Phytoplankton species			Water	Phytoplankton is microscopic algae.		The particular algae species present may indicate where algae originated, proportions of nutrients in the water, etc., and can help in determining treatment options.
Chlorophyll	Chl	µg/L	Water	The concentration of chlorophyll in the water sample.	Chlorophyll is the green pigment in algae that is used in photosynthesis.	Indicates concentration of algae in the water, but may be influenced by algae species.

## Appendix B - Groundwater data collection methods

Method	Data Provided	Description	Use
Suction cup lysimeter	Collects water samples from various depths to allow analysis.	Porous ceramic cups set at specific depths to capture unsaturated leaching.	Allows targeted monitoring of leachate at different depths of unsaturated soil profile.
Piezometer	Provides information regarding the depth to groundwater.	Monitoring wells constructed to allow measurement of the hydraulic head in an aquifer.	Assists in developing an idea of groundwater behaviour in an area and possible interaction with surface water.
Groundwater bores	Allows access to extract groundwater samples.	Monitoring bores constructed for generalised characterisation of water quality within an aquifer.	Analysis of extracted groundwater gives an indication of groundwater quality in the area.
Neutron moisture meter	Moisture levels at different depths in the soil profile.	Reflection of emitted neutrons is measured at different depths of a lined casing, calibrated to indicate soil moisture.	Accurate measurement of soil moisture levels and depth.
Lysimeters	Provides access to water samples moving through saturated soil profile.	A system to capture saturated flow leachates (generally involving a large PVC pipe driven into the ground, removed, end-capped and fitted with tubing to allow sampling of leachate waters).	Allows water quality analysis of leachate from different depths in the soil column.

## Appendix C - Flow data collection methodology

Method	Data Provided	Preposition	Use
Peak level indicator (without rating)	Provides an indication of the peak water level since the last observation.	Device installed to register the peak level.	Useful for understanding the maximum water levels in parts of a system (e.g. drain, swale, or compensating basin).
Peak level indicator (with rating)	Provides an indication of the peak water level and peak flow rate since the last observation.	Device installed to register the peak level together with a known relationship between level and flow rate (rating curve). The rating curve may be obtained by the use of a weir or developed empirically.	Useful for understanding the maximum water levels in parts of a system (e.g. drain, swale, or compensating basin) and for understanding the maximum flow rates in drains.
Continuous logger with stable structure, i.e. weir	Provides an ongoing record of flow and stage heights.	Device installed to constantly measure stage height and obtain accurate flow measurements.	Used to accurately gauge flows through a well-maintained fixed point.

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Further  
Information



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*Cover photograph: Participants in a training course practising how to clean up spills at commercial and industrial sites, to prevent stormwater and site contamination. (Source: Perth Petroleum Services.)*

# Stormwater Management Manual for Western Australia

## 11 Further Information

Prepared by Emma Monk and Tania Liaghati, Department of Water  
Consultation and guidance from the Stormwater Working Team



Department of **Water**  
Government of **Western Australia**

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Department of Environment and Conservation  
Department of Environment and Conservation  
Department of Health  
Department of Water  
Eastern Metropolitan Regional Council  
Housing Industry Association  
Institute of Public Works Engineering Australia  
Institution of Engineers Australia  
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## Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000).

Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how these pollutants can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia, where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in Western Australia as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a RESOURCE – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater Management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, Industry, Local Government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the Western Australian Government's response to the State Water Strategy (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Drainage and Waterways Branch of the Department of Water.

## Western Australian Stormwater Management Objectives

### **Water Quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions.

### **Water Quantity**

To maintain the total water cycle balance within development areas relative to the pre development conditions.

### **Water Conservation**

To maximise the reuse of stormwater.

### **Ecosystem Health**

To retain natural drainage systems and protect ecosystem health .

### **Economic Viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public Health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of Property**

To protect the built environment from flooding and waterlogging.

### **Social Values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural solutions.

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# 1 Introduction

## 1.1 Aim of the further information chapter

The aim of this chapter is to provide a glossary of terms used in the manual and some useful contacts, websites and references for obtaining further information about stormwater management.

## 2 Glossary

- **Adaptive environmental management:** A type of environmental management where the approach to managing water resources in urban areas will evolve over time as new ideas, information, drivers for change and technologies emerge.
- **Adsorption:** The adhesion of a substance to the surface of a solid or liquid; often used to extract contaminants by causing them to be attached to adsorbents such as activated carbon or silica gel. Hydrophobic or water repulsing adsorbents are used to extract oil from waterways when oil spills occur. Heavy metals such as zinc and lead and nutrients such as phosphorus often adsorb onto sediment.
- **Aeration:** The injection of air through diffusers into water bodies, or rapid mixing (e.g. via riffles) of the surface of water bodies to promote transfer of atmospheric air into the water column. A treatment process adopted in situations of high loading of oxygen demanding substances. (ARMCANZ & ANZECC 2000.)
- **Aerobic or oxic zone:** An environment in which there is free oxygen (ARMCANZ & ANZECC 2000).
- **Anaerobic or anoxic zone:** An environment devoid of oxygen (ARMCANZ & ANZECC 2000).
- **Aquifer:** A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water (Water and Rivers Commission 2000a).
- **Armouring or stabilisation:** The use of rock, geotextile and/or vegetation to bind the soil forming the bank or bed of channels such as to resist erosion by elevated flow velocities (ARMCANZ & ANZECC 2000).
- **Atmospheric deposition:** Contaminants accumulating across urban surfaces as a result of deposition of fine airborne solids (ARMCANZ & ANZECC 2000).
- **At-source controls:** Non-structural or structural best management practices implemented at the site where stormwater runoff is created, to minimise the generation of excessive stormwater runoff and/or pollution of stormwater.
- **Attenuation:** The reduction in the magnitude of flows, concentrations or loads of contaminants (ARMCANZ & ANZECC 2000).
- **Average recurrence interval (ARI):** ARI is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. ARI events can be grouped into:
  - Small: Less than and up to 1 year ARI events ( $x < 1$  year ARI events).
  - Minor: Greater than 1 year and less than 10 year ARI events ( $1 \text{ year} < x < 10$  year ARI events).
  - Major: 10 year to 100 year ARI events (10 – 100 year ARI events).
  - Extreme: Greater than 100 year ARI events ( $x > 100$  year ARI events).
- **Bankfull flow:** The dominant channel forming discharge (Water and Rivers Commission 2001). The flow rate at which a channel is filled from bank to bank. The frequency of bankfull conditions is commonly adopted as the criterion for maintaining the channel cross-section and freedom from sedimentation in the longer term. This frequency will vary according to climatic regions (ARMCANZ & ANZECC 2000), but usually occurs once every 1.5 years.
- **Bank stabilisation:** See ‘armouring or stabilisation’.

- **Baseflow:** The underlying flow rate that cannot be directly attributed to storm events (ARMCANZ & ANZECC 2000). The part of the total flow in a water body derived from groundwater discharge (Department of Environment 2003).
- **Best management practices (BMPs):** Devices, practices or methods for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters (Taylor & Wong 2002) and for reducing the volume of stormwater runoff.
- **Biochemical oxygen demand (BOD):** The oxygen consumption (respiration) resulting from bacterial breakdown of organic material, or as a result of some inorganic oxygen reducing species (ammonia) (ARMCANZ & ANZECC 2000).
- **Biodiversity:** The variability among living organisms from all sources (including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part) and the diversity within and between species and of ecosystems (ARMCANZ & ANZECC 2000).
- **Biofilm:** A gelatinous sheath of algae and micro-organisms, including benthic algae and bacteria, formed on surfaces such as gravel, sediment and plants (ARMCANZ & ANZECC 2000).
- **Bioretention:** A stormwater management device that consists of an excavated basin or trench that is filled with porous media and planted with vegetation.
- **Bore:** A narrow, lined hole drilled to withdraw or monitor groundwater.
- **Brownfield:** Areas of land that have been developed into urban land uses.
- **Buffer strip:** Areas of vegetation through which runoff passes while travelling to a discharge point and which are therefore aligned perpendicular to the direction of flow.
- **Capacity building program:** A holistic approach to knowledge building and transfer, which fosters skill development, competency, innovation and confidence. It is also a means to facilitate network building, linkages and training for continuous improvement.
- **Catchment:** A topographically defined area draining surface water to a single outlet point.
- **Channel:** The bed and banks of a stream or constructed drain (ARMCANZ & ANZECC 2000) that carries all flows except floods.
- **Clay (soils):** A fine-grained mineral soil consisting of particles less than 0.002 mm in equivalent diameter (Charman & Murphy 1991).
- **Colloids:** Fine abiotic and biotic particles of typically 0.1  $\mu\text{m}$  to 1 nm in diameter (ARMCANZ & ANZECC 2000).
- **Compaction:** Any process whereby the density of soils is increased. This process results in lower permeability and poorer soil aeration. (Charman & Murphy 1991.)
- **Constructed wetland:** A vegetated detention area designed and built to remove contaminants from stormwater runoff, but which can also provide secondary benefits of habitat enhancement/creation and active and passive recreational and educational opportunities.
- **Contaminant:** A substance that presents or has the potential to present a risk of harm to human health, the environment or any environmental value (Department of Environment and Conservation 2006).
- **Controlled groundwater level (CGL):** The controlled (i.e. modified) groundwater level (measured in metres Australian Height Datum) at which drainage inverts are set.
- **Conveyance systems:** A mechanism for transporting stormwater from one point to another, including swales, bioretention systems, living streams, pipes and channels.
- **Denitrification:** The reduction of nitrate or nitrite to nitrogen gas, in the absence of oxygen (ARMCANZ & ANZECC 2000).
- **Detention/detain:** The process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design ARI event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.
- **Detention (ephemeral/dry) basins:** Areas, usually landscaped, formed by simple dam walls, by excavation below ground level or by utilisation or enhancement of natural swales or depressions, designed to temporarily detain stormwater to attenuate peak flows downstream to acceptable levels.

- **Detention time:** The theoretical time required to displace the contents of a stormwater treatment facility at a given rate of discharge (volume divided by rate of discharge).
- **Directly connected impervious surface:** An impervious surface connected directly to a receiving water body via a hydraulically efficient conveyance device (e.g. pipes or constructed drains/channels).
- **Discharge:** The rate at which a volume of water passes through a cross section in a unit of time (Water and Rivers Commission 2000b).
- **Dissolved fraction:** The part of a water sample passing through a 0.45 µm pore size filter paper. It will include both a truly dissolved and colloidal material fraction. (ARMCANZ & ANZECC 2000.)
- **Drainage network:** The system of channels and pipes and overland flow pathways which drain a catchment area (ARMCANZ & ANZECC 2000).
- **Drainage water:** Consists of stormwater runoff and/or shallow groundwater that has been intercepted by drains.
- **Ecological values:** Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and economic activities, and which require protection from the effects of pollution, waste discharges and deposits (ARMCANZ & ANZECC 2000) and from the effects of altered water regimes.
- **Ecological water requirements (EWRs):** The water regimes needed to maintain ecological values of water dependent ecosystems at a low level of risk (Water and Rivers Commission 2000a). Also see 'environmental water provisions'.
- **Economic values:** Includes water body uses, stormwater use, economic values of the receiving environment (e.g. fishing and tourism), values of land used for stormwater management and values of land adjacent to stormwater management devices.
- **Education and participation program:** One of the five principal categories of non-structural BMPs for stormwater management. Examples include training programs and involving the community in the development and implementation of stormwater management plans.
- **Effective imperviousness:** The combined effect of the proportion of constructed impervious surfaces in the catchment, and the connectivity of these impervious surfaces to receiving water bodies (adapted from Walsh et al. 2004).
- **Effectiveness:** The extent to which project outcomes (see 'outcomes') are achieving project objectives (Bullen undated).
- **Efficiency:** The extent to which project outputs (see 'outputs') are maximised for the given level of inputs. Efficiency is concerned with the processes (activities/strategies/operations) by which the project is delivered and which produce the outputs of the projects. BMP Efficiency: Measures how well a BMP or BMP system removes or controls contaminants. Although 'percent removal' is the most common form of expressing BMP efficiency (when used alone), it is a poor measure of BMP efficiency compared with alternatives such as the 'effluent probability method'. (US EPA 2002; Taylor & Wong 2003.)
- **Effluent:** Sanitary, industrial or agricultural discharge from wastewater treatment plants or treatment lagoons (ARMCANZ & ANZECC 2000).
- **Environmental management systems (EMS):** The part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining an environmental policy (Standards Australia 1996).
- **Environmental water provisions (EWPs):** The water regimes that are provided as a result of the water allocation decision-making process taking into account ecological, social and economic impacts. They may meet in part or in full the ecological water requirements. (Water and Rivers Commission 2000a.) See 'ecological water requirements'.
- **Erosion:** The process by which the land surface is detached and transported away by the action of water, wind, ice or gravity.

- **Evaluation:** A periodic but comprehensive assessment of the overall progress and worth of a project (Woodhill & Robins 1998). The term used for final assessment of whether a BMP has achieved its pre-defined objectives.
- **Event:** A single precipitation and associated runoff occurrence (ARMCANZ & ANZECC 2000).
- **Event mean concentration:** The average concentration of a contaminant over the period of an event discharge. It is normally determined by the sum of the concentrations (for multiple samples taken during the period of the event discharge) multiplied by the flow weighted volume of the sample, divided by the cumulative volume of the samples. (ARMCANZ & ANZECC 2000.)
- **Filter:** A layer of granular material designed to intercept fine particulate material. It may be used as part of a subsoil drain, or as a structure to treat surface runoff prior to recharge to groundwater or discharge to a drain. (ARMCANZ & ANZECC 2000.)
- **Filter strip:** See ‘buffer strip’.
- **First flush:** Describes situations when contaminants (e.g. sediments) that have accumulated on impervious surfaces are transported at the beginning of a rainfall event. This results in high pollution concentrations at the start of the runoff hydrograph, reducing to lower levels before the flood peak occurs. (Argue 2004.)
- **Flashiness:** Where water levels rapidly peak and decline.
- **Floodplain:** The portion of a waterway valley next to the channel which is covered with water when the waterway overflows its banks during major flow events (Water and Rivers Commission 2000c).
- **Freeboard:** The distance between the maximum water surface elevations anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions, and/or events greater than the maximum design event of the structure.
- **Frequency:** See ‘average recurrence interval’.
- **Geomorphology:** Of, or relating to, the forms of the earth’s surface and the processes associated with them (e.g. erosion, weathering, transport and deposition) (Water and Rivers Commission 2002).
- **Geotextile:** A thin, flexible permeable sheet of synthetic material used to allow the transmission of water through the pores of the material, while preventing the transmission of soil particles (ARMCANZ & ANZECC 2000).
- **Goals or aims:** General descriptions of what a project will achieve (Woodhill & Robins 1998).
- **Grain size distribution:** The statistical distribution of grain (by weight) passing a range of sieve sizes (ARMCANZ & ANZECC 2000).
- **Gravel:** A mixture of coarse mineral particles larger than 2 mm, but less than 75 mm in equivalent diameter (Charman & Murphy 1991).
- **Greenfield:** Land zoned for urban development and located on the fringe of an urban area (Western Australian Planning Commission 2004).
- **Gross pollutant traps (GPTs):** A type of litter and sediment management system. GPTs typically consist of a sediment trap with a weir and trash rack at the downstream end of a piped drainage system.
- **Groundwater:** Water found under the land surface that occupies pores and crevices of soil and rock (Water and Rivers Commission 2000a).
- **Gully pit/inlet pit/side entry pit:** A roadside inlet pit designed to collect stormwater runoff from paved surfaces and to intercept sediment and litter prior to entry into the drainage network (ARMCANZ & ANZECC 2000).
- **Heavy metals:** Metals of high specific gravity ( $>5 \text{ g/cm}^3$ ) that are present in the environment from natural and anthropogenic sources such as municipal and industrial wastes and urban runoff, and pose long-term environmental hazards. Such metals include: arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), vanadium (V) and zinc (Zn).
- **Hydraulic conductivity:** A measure of the ease of flow through a pore space or fractures. Hydraulic conductivity has units with dimensions of length per time (e.g. m/s, m/min, or m/d).

- **Hydraulic head:** The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head and head loss.
- **Hydrodynamic condition:** The condition that influences the flow of water.
- **Hydrologic regime:** A description of the variation of flow rate or water level over time (adapted from Water and Rivers Commission 2000a).
- **Hydrological cycle:** The continual cycle of water between the land, the ocean and the atmosphere.
- **Hydrology:** The science of the behaviour of water in the atmosphere, on the surface of the earth and within the soil and underlying rocks. This includes the relationship between rainfall, runoff, infiltration and evaporation.
- **Illicit connections:** Illegal or improper connections to drainage systems and receiving waters. The most obvious of these connections include trade wastes from commercial and industrial premises and wastewater from domestic premises.
- **Impermeable or impervious surface:** The part of the catchment surfaced with materials, either natural or constructed, which prevent or limit the rate of infiltration of stormwater into the underlying soil and groundwater (ARMCANZ & ANZECC 2000) and subsequently increases stormwater runoff flows.
- **Indicators:** The specific characteristics or phenomena that tell you about the project and what impact it is having on the problem or issue it was set up to tackle (Woodhill & Robins 1998).
- **Indirect drainage:** The breaking of the direct connection of stormwater pipes and impervious area runoff to the drainage network, by their discharge to pervious areas or infiltration devices.
- **Infiltration:** The movement of water from the surface to the subsoil and at times, ultimately to the underlying aquifer.
- **Infiltration system:** A drainage facility designed to use the hydrologic process of stormwater runoff soaking into the ground, commonly referred to as percolation. Examples include infiltration basins and trenches, soakwells and pervious paving.
- **Inlet:** A form of connection between the ground surface and a stormwater structural control for the admission of stormwater runoff.
- **Integrated water cycle management (IWCM):** The integration of water supply, sewerage and stormwater, so that water is used optimally within a catchment resource, State and national policy context. It promotes the coordinated planning, development and management of water, land and related resources (including energy use) that are linked to urban areas and the application of WSUD principles within the built urban environment. (National Water Commission 2006.)
- **Litter and sediment management (LSM) system:** Any structural device designed to intercept coarse particulate material (by sedimentation) and litter and debris (by physical screening). May also be referred to as a stormwater pollutant trap (SPT). Types of LSM systems include side entry pit traps, gross pollutant traps, trash racks and litter booms.
- **Living stream:** A drainage conveyance system featuring stabilised vegetated banks and a more natural morphology than traditional straight drains, providing diverse habitats for native plants and animals.
- **Loading:** The total mass of a contaminant discharged during a storm event. The term may also be used to describe the mass of contaminant intercepted ( $\text{g/m}^2$ ) by a device during a storm event, or on an annual basis. (ARMCANZ & ANZECC 2000.)
- **Managed aquifer recharge (MAR):** The controlled infiltration or injection of water into an aquifer. The water can be withdrawn at a later date, left in the aquifer for environmental benefits, or used as a barrier to prevent saltwater or other contaminants from entering the aquifer.
- **Monitoring:** The collection of data by various methods for the purpose of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures.
- **Monitoring and evaluation program:** Development of monitoring and evaluation activities to determine the success or otherwise of measures put in place as part of stormwater management projects.

- **Multiple use corridors:** Facilities performing a range of functions (e.g. stormwater management, landscape, recreation and wildlife habitat).
- **Non-point source pollution:** Pollution from diffuse sources without a single point of origin or specific discharge point (ARMCANZ & ANZECC 2000).
- **Non-structural controls:** Institutional and pollution-prevention practices designed to prevent or minimise contaminants from entering stormwater runoff and/or reduce the volume of stormwater requiring management (US EPA 1999). They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), education and/or economic instruments (Taylor & Wong 2002).
- **Nutrients:** Essential chemicals such as nitrogen (N) and phosphorus (P) needed by plants and animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms.
- **Objectives:** Specific statements about what a project intends to achieve.
- **Offline:** A management system located adjacent to but off a stream or major flow pathway, such as to treat low flows or the discharge of a major flow system (ARMCANZ & ANZECC 2000).
- **Oil trap/separators:** A stilling tank configured to separate lighter oily matter, scums and hydrocarbons from stormwater.
- **Online:** A management system located within the original stream or flow pathway/drainage channel to treat event flows (ARMCANZ & ANZECC 2000).
- **On-site and off-site:** On-site facilities are located on individual lots to enhance local stormwater retention/detention and interception of contaminants. Off-site facilities are located on stormwater networks to provide area-wide stormwater retention/detention and interception of contaminants. (Adapted from ARMCANZ & ANZECC 2000.)
- **Outcomes:** The results of the activities or products of a project (Woodhill & Robins 1998). All the impacts or consequences of the project beyond its outputs (see 'outputs'). Outcomes are often delayed or long term and they may be intended or unanticipated (Bullen undated).
- **Outlet:** Point of water discharge from a waterway or stormwater structural control.
- **Outputs:** The activities completed or products made during a project (Woodhill & Robins 1998). Outputs are within the direct control of the project.
- **Overland flow:** The component of rainfall (excess) that is not removed by infiltration or use and discharges down-gradient as surface flow (ARMCANZ & ANZECC 2000).
- **Peak discharge rate:** The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.
- **Peak flow:** Maximum flow rate in a flood, measured in m<sup>3</sup>/s (Department of Environment 2003).
- **Performance indicator:** A specific type of indicator that looks at outcomes (see 'outcomes') to see if they are meeting the project's objectives (see 'objectives').
- **Performance monitoring:** Gathering of information to measure the success of strategies implemented when compared to objectives (see 'objectives').
- **Permeable soils:** Soil materials with sufficiently rapid infiltration rate, therefore reducing or eliminating stormwater runoff. Coarse textured soils tend to have large, well-connected pore spaces and hence high permeability.
- **Pervious (permeable/porous) pavement:** Pavements comprising materials that facilitate stormwater infiltration and transfer to the underlying subsoil (ARMCANZ & ANZECC 2000).
- **pH:** A measure of the hydrogen ion concentration of water or wastewater; expressed as the negative log of the hydrogen ion concentration [H<sup>+</sup>]. A pH of 7 is neutral, pH less than 7 is acidic and pH greater than 7 is basic.
- **Point source pollution:** Contamination from a localised source, such as leaky storage tanks and drums or sewage discharge.
- **Pollutant retention:** The proportion of pollutant load intercepted and retained by a device, either on an event or annual basis (ARMCANZ & ANZECC 2000).

- **Pollution prevention procedures:** One of the five principal categories of non-structural BMPs for stormwater management. Examples include maintenance practices (e.g. maintenance of the stormwater drainage network) and elements of environmental management systems (e.g. procedures on material storage and staff training on stormwater management at government, commercial and industrial sites).
- **Porosity:** Porosity is calculated as a ratio of pore volume to total volume.
- **Potable water:** Water generally considered suitable for human consumption.
- **Precautionary principle:** If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- **Rational method:** A means of computing storm drainage flow rates (Q) by use of the formula  $Q = CIA$ , where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.
- **Receiving environment:** Areas that receive stormwater runoff, including wetlands, waterways, coastal waters/dunes, groundwater and bushland areas.
- **Receiving water bodies:** Include waterways, wetlands, coastal marine areas and shallow groundwater aquifers.
- **Recharge:** Water infiltrating to replenish an aquifer.
- **Recycled water:** Treated stormwater, greywater or black water suitable for a range of uses, e.g. toilet flushing, irrigation, industrial processing or other suitable applications (ARMCANZ & ANZECC 2000).
- **Regulatory controls:** One of the five principal categories of non-structural BMPs for stormwater management. Includes controls such as enforcement of local laws to improve erosion and sediment control on building sites, the use of regulatory instruments such as environmental licences to help manage premises likely to contaminate stormwater or groundwater, and programs to minimise illicit discharges to stormwater management systems (e.g. drains).
- **Remobilisation:** The transformation of sedimented contaminants by microbial or chemical processes into a dissolved form and transfer by diffusion from the sediment pore water into the water column (ARMCANZ & ANZECC 2000).
- **Re-suspension:** The physical entrainment of sedimented particles by elevated flows, or as a result of sediment bio-turbation (ARMCANZ & ANZECC 2000).
- **Retention/retain:** Retention is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation. Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design ARI event. It is the difference between total precipitation and total runoff.
- **Retrofitting:** Retrofitting employs additional or alternative stormwater management devices or approaches which are installed or undertaken in an existing developed area. Retrofitting can occur at the lot, block/neighbourhood or catchment scale.
- **Riffles:** High points in the channel floor, representing bedrock bars or accumulations of relatively coarse material. Water flow is typically relatively shallow, fast and rough over riffles. (Water and Rivers Commission 2002.)
- **Riparian vegetation:** Vegetation growing within the channel and the along banks of waterways, extending laterally away from the bank and ending at the extent of the floodplain.
- **Riprap:** Rock riprap consists of a layer or layers of well-graded rocks placed on stream banks to protect them from erosion.
- **Risk:** The chances of something happening that will have an impact on objectives. It is measured in terms of consequences and likelihood. (Standards Association of Australia 1999.)
- **Risk assessment:** The process of risk analysis and risk evaluation.
- **Roughness coefficient:** A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's  $n$  is a commonly used roughness coefficient.

- **Runoff:** Water that flows over the surface of a catchment area, including streams.
- **Sand:** A soil separate consisting of particles between 0.02 and 2.0 mm in equivalent diameter. Fine sand is defined as particles between 0.02 and 0.2 mm, and coarse sand as those between 0.2 and 2.0 mm. (Charman & Murphy 1991.)
- **Sediment:** Solid fragment of organic and inorganic material that is transported, suspended and/or deposited by water and wind.
- **Sedimentation:** The physical process of settling of suspended particulates under the force of gravity (ARMCANZ & ANZECC 2000).
- **Sediment trap:** A structure designed to intercept and retain sediment transported by water flow (ARMCANZ & ANZECC 2000).
- **Silt:** A soil separate consisting of particles between 0.002 and 0.02 mm in equivalent diameter (Charman & Murphy 1991).
- **Social/cultural values:** Social values include public health and safety, recreational uses and visual amenity. Cultural values include historical and spiritual significance, and scientific and educational uses.
- **Sodic soils:** Soil sodicity is assessed by the ratings of the exchangeable sodium percentage (ESP). Soils with a relatively high proportion of exchangeable sodium (greater than 6 per cent) are considered sodic (Charman & Murphy 1991). Soil sodicity causes increased soil dispersion and swelling of clays, which adversely impacts the soil structure and results in reduced infiltration, reduced hydraulic conductivity and the formation of surface crusts.
- **Soil amendment:** Involves adding an agent, such as clay or crushed limestone, to the soil to improve its structure, porosity, water holding capacity and nutrient recycling capacity.
- **Soil permeability:** The ease with which gases, liquids or plant roots penetrate or pass through a layer of soil.
- **Soil stabilisation:** The use of measures or materials, such as rock lining or vegetation, to prevent the movement of soil when loads are applied to the soil.
- **Source controls:** Non-structural or structural best management practices designed to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source and protect receiving environments.
- **Stormwater:** Water flowing over ground surfaces and in natural streams and drains, as a direct result of rainfall over a catchment. Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow.
- **Stormwater quality:** The chemical, physical and biological characteristics of stormwater.
- **Stormwater quantity:** The volume characteristics of stormwater.
- **Strategic planning and institutional controls:** One of the five principal categories of non-structural BMPs for stormwater management. Examples include controls such as the use of strategic, regional or citywide urban stormwater management plans and stable funding arrangements to support the implementation of these plans.
- **Street sweeping:** The removal of particulates and litter from street surfaces by sweeping or vacuuming (ARMCANZ & ANZECC 2000).
- **Structural controls:** Engineered devices implemented to manage runoff quality and quantity, to control, treat, or prevent stormwater pollution and/or reduce the volume of stormwater requiring management.
- **Sub-catchment:** A topographically defined area drained by a tributary of a primary stream (ARMCANZ & ANZECC 2000).
- **Subsurface drain:** A drain designed to intercept subsoil water and thereby limit the seasonal maximum groundwater level.
- **Superficial (unconfined) aquifer:** An aquifer containing water with no upper non-porous layer to limit its volume or to exert pressure. The upper surface of the groundwater within the aquifer is called the watertable.

- **Surface water:** Water flowing or held in waterways or wetlands on the surface of the landscape (adapted from Water and Rivers Commission 2000a).
- **Suspended solids:** Organic or inorganic particles that are suspended and transported by water. This includes sand, mud and clay particles (and associated contaminants) in stormwater.
- **Swale:** A drainage interception and conveyance system with relatively gentle side slopes and shallow flow depths.
- **Target:** A numerical concentration limit or descriptive statement relating to an aspect of water management aspired to as part of a stormwater management project.
- **Time of concentration:** The time required for a drop of water to travel from the most hydrologically remote point to the point of discharge.
- **Threat:** An activity or land use with potential to damage the local or receiving environment's social/cultural, ecological or economic values, via impacts to stormwater quantity or quality.
- **Total phosphorus (TP):** The total phosphorus that is contained within the matrix.
- **Total suspended solids (TSS):** A water quality measurement referring to the dry-weight of particles in a sample that is trapped by a filter of specified pore size.
- **Town planning controls:** One of the five principal categories of non-structural BMPs for stormwater management. An example includes the use of town planning instruments to promote water sensitive urban design features in new developments.
- **Toxicity:** The quantity or degree to which a substance is poisonous or harmful to plant, animal or human health.
- **Treatment train:** In most situations, a number of management measures may be implemented in series or concurrently forming a treatment train approach to stormwater management. To achieve the best stormwater management outcomes, both structural and non-structural techniques should be used in particular combinations to suit the local conditions. This arrangement will satisfy the water quantity and quality objectives that might be unachievable if relying on a single BMP. Additionally, the impact from the failure of one device will be reduced by the operation of the other devices in the treatment train.
- **Triple-bottom-line assessment:** A process which uses multi-criteria analysis to evaluate the economic, social and ecological costs and benefits of possible BMPs.
- **Underdrain:** Plastic pipes with holes, installed at the base of impervious bioretention systems to collect treated water for conveyance downstream.
- **Urban:** Land used for residential, rural-residential, commercial or industrial development (includes regional towns).
- **Values:** Values may include economic values (e.g. water use, aquaculture and stormwater reuse), ecological values (e.g. aquatic fauna and flora, urban bushland) and social/cultural values (e.g. historical, public health and safety, recreational, visual amenity, spiritual).
- **Vegetated swales:** A swale with vegetation covering the side slopes and base. Vegetation can range from grass to native sedges and shrubs, depending on hydraulic and landscape requirements.
- **Water bodies:** Waterways, wetlands, coastal marine areas and shallow groundwater aquifers.
- **Watercourses:** A river, stream or creek in which water flows in a natural channel, whether permanently or intermittently.
- **Water dependent ecosystems:** Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers (Water and Rivers Commission 2000a).
- **Water sensitive urban design (WSUD):** A design philosophy that provides a framework for managing water-related issues in urban areas. WSUD incorporates the sustainable management and integration of stormwater, wastewater and water supply into urban design. WSUD principles include incorporating water resource management issues early in the land use planning process. WSUD can be applied at the lot, street, neighbourhood, catchment and regional scale.

- **Waterways:** All seasonal, intermittent or permanent streams, creeks, rivers, estuaries, coastal lagoons, inlets and harbours.
- **Wetlands:** Areas of seasonally, intermittently or permanently waterlogged or inundated land, whether natural or otherwise, including lakes, sumplands, playas, damplands, floodplains, barlkarras, palusplains, paluslopes, palusmonts or tidal flats.

## 3 Contacts

### Department of Water:

For stormwater management policy/guideline information, contact the Drainage and Waterways Branch, Department of Water. Phone: 6364 7600. Address: The Atrium, Level 4, 168 St Georges Terrace, Perth WA 6000. Mail: PO Box K822, Perth WA 6842. Department of Water Stormwater web page: <<http://stormwater.water.wa.gov.au>>.

For local water management advice and assessment, contact the regional office of the Department of Water. For the most up to date regional contact details, go to the Contacts tab on the Department of Water website: <<http://www.water.wa.gov.au>>.

### New Water Ways capacity building program:

For information about the new integrated water cycle management capacity building program for Western Australia 'New Water Ways', contact the New Water Ways Project Manager, c/- Western Australian Local Government Association (WALGA). Phone: 9213 2033. Address: 15 Altona St, West Perth WA 6005. Mail: PO Box 1544, West Perth WA 6872.

## 4 Websites

Australian Water Association (AWA) website: <<http://www.awa.asn.au>>.

Bureau of Meteorology website: <<http://www.bom.gov.au>>.

Bush Forever web page via the Western Australian Planning Commission's website: <<http://www.wapc.wa.gov.au>>, search for Bush Forever.

Conservation Council of Western Australia Inc. website: <<http://www.conservationwa.asn.au>>.

Department of Agriculture website: <<http://www.agric.wa.gov.au>>.

Department of Environment and Conservation (DEC) website: <<http://www.dec.wa.gov.au>>.

Department of Environment and Conservation's Florabase website: <<http://florabase.dec.wa.gov.au>>.

Department of Health's Environmental Health website: <<http://www.health.wa.gov.au/envirohealth/home/index.cfm>>.

Department of Indigenous Affairs (DIA) website: <<http://www.dia.wa.gov.au/Heritage>>.

Department of Water (DoW) website: <<http://www.water.wa.gov.au>>.

Department of Water's stormwater web page: <<http://stormwater.water.wa.gov.au>>.

Department for Planning and Infrastructure (DPI) website: <<http://www.dpi.wa.gov.au>>.

Environmental Protection Authority (EPA) website: <<http://www.epa.wa.gov.au>>.

Landgate (formerly Department of Land Information) website: <<http://www.landgate.wa.gov.au>>.

Housing Industry Association (HIA) website: <<http://www.hia.com.au>>.

ICLEI Local Governments for Sustainability Australia/New Zealand website for information about the WA Water Campaign: <<http://www.iclei.org/anz>>.

Institution of Engineers Australia (Engineers Australia) website: <<http://www.engineersaustralia.org.au>>.

Institute of Public Works Engineering Australia (IPWEA) website: <<http://www.engineersaustralia.org.au>>.

Main Roads Western Australia website: <<http://www.mainroads.wa.gov.au>>.

Midge Research Group: <<http://www.cockburn.wa.gov.au/midges/index.html>>.

Natural resource management (NRM) councils' websites:

- Avon Catchment Council: <<http://www.avoncm.org.au>>
- Northern Agricultural Catchments Council (NACC): <<http://www.nacc.com.au>>
- Rangelands NRM Co-ordinating Group: <<http://www.rangelandswa.info>>
- South Coast Regional Initiative Planning Team (SCRIPT): <<http://www.script.asn.au>>
- South West Catchments Council (SWCC): <<http://www.swcatchmentscouncil.com>>
- Swan Catchment Council: <<http://www.wrc.wa.gov.au/swanavon/pages/council.html>>

Shared Land Information Platform (SLIP) website: <<https://www2.landgate.wa.gov.au/slip/portal/home/home.html>>.

Stormwater Industry Association (SIA) Inc. website: <<http://www.stormwater.asn.au>>.

Swan River Trust website: <<http://www.swanrivertrust.wa.gov.au>>.

Urban Development Institute of Australia (UDIA), Western Australia Division Incorporated website: <<http://www.udiawa.com.au>>.

Urbanwater.info website: <<http://www.urbanwater.info>>.

Water Corporation website: <<http://www.watercorporation.com.au>>.

Western Australian Land Information System (WALIS) website: <<http://www.walis.wa.gov.au>> for general queries about spatial information.

Western Australian Local Government Association (WALGA) website: <<http://www.walga.asn.au>>.

Western Australian Museum website: <<http://www.museum.wa.gov.au>>.

Western Australian Museum's Faunabase website: <<http://www.museum.wa.gov.au/faunabase>>.

Western Australian Planning Commission website: <<http://www.wapc.wa.gov.au>>.

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## 6 Further reading

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Government of Western Australia 2006, State Planning Policy 2.9, *Water Resources*, State Law Publisher, Perth, Western Australia. Available via <<http://www.wapc.wa.gov.au/Publications>>.

## 7 Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARQ	Australian Runoff Quality
ARR	Australian Rainfall and Runoff
ASS	Acid sulphate soils
ASR	Aquifer storage and recovery
BOD	Biochemical oxygen demand
BMP	Best management practice
CGL	Controlled groundwater level
DIA	Department of Indigenous Affairs
DEC	Department of Environment and Conservation
DoW	Department of Water
DPI	Department for Planning and Infrastructure
DWMS	Drainage and water management strategy
EMS	Environmental management system
EPA	Environmental Protection Authority
EWP	Environmental water provision
EWR	Ecological water requirement
GIS	Geographic information system
GPT	Gross pollutant trap
IWCM	Integrated water cycle management

LSM	Litter and sediment management
MAR	Managed aquifer recharge
NRM	Natural resource management
POS	Public open space
PRI	Phosphorus retention index
SMP	Stormwater management plan
SPT	Stormwater pollutant trap
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UWMP	Urban water management plan
WALGA	Western Australian Local Government Association
WALIS	Western Australian Land Information System
WAPC	Western Australian Planning Commission
WIN	Water Information Network
WSUD	Water sensitive urban design