This online textbook provides free access to a comprehensive education and training package that brings together the knowledge of how countries, specifically Australia, can adapt to climate change. This resource has been developed through support from the Federal Government’s Department of Climate Change’s Climate Change Adaptation Professional Skills program.

Chapter 6: Urban and Industrial Water Treatment, Reuse and Recycling.

Acknowledgements

The Work was produced by The Natural Edge Project supported by funding from the Australian Government Department of Climate Change under its ‘Climate Change Adaptation Skills for Professionals Program’. The development of this publication has been supported by the contribution of non-salary on-costs and administrative support by the Griffith University Urban Research Program, under the supervision of Professor Brendan Gleeson, and the Australian National University Fenner School of Environment and Society and Engineering Department, under the supervision of Professor Stephen Dovers.

Chief Investigator and Project Manager: Mr Karlson ‘Charlie’ Hargroves, Research Fellow, Griffith University.

Principal Researcher and Author: Dr Michael Smith, Research Fellow, Fenner School of Environment and Society, ANU.

Peer Review

This lecture has been peer reviewed by Associate Professor Margaret Greenway, Griffith University; Environmental Engineering College Board Member, Institution of Engineers Australia; Qld President, Stormwater Industry Association and; Alex Fearnside, Sustainability Team Leader, City of Melbourne.

Peer review for this module was also received from: Harriet Adams - Water Efficiency Opportunities, Commonwealth Department of Environment, Water, Heritage and the Arts. Chris Davis, Institute of Sustainable Futures, University of Technology. Professor Stephen Dovers, Director, Fenner School of Environment and Society, Australia National University. Associate Professor Margaret Greenway, Griffith University; Fiona Henderson, CSIRO Land and Water, Dr Matthew Inman, Urban Systems Program, CSIRO Sustainable Ecosystems, CSIRO; Anntonette Joseph, Director – Water Efficiency Opportunities, Commonwealth Department of Environment, Water, Heritage and the Arts. Dr Declan Page, CSIRO Land and Water. Bevan Smith, Senior Project Officer (WaterWise) Recycled Water and Demand Management, Queensland Government, Department of Natural Resources and Water. Dr Gurudeo Anand Tularam, Griffith University, Associate Professor Adrian Werner, Associate Professor of Hydrogeology, Flinders University, Professor Stuart White, Institute of Sustainable Futures, UTS.

Disclaimer

While reasonable efforts have been made to ensure that the contents of this publication are factually correct, the parties involved in the development of this document do not accept responsibility for the accuracy or completeness of the contents. Information, recommendations and opinions expressed herein are not intended to address the specific circumstances of any particular individual or entity and should not be relied upon for personal, legal, financial or other decisions. The user must make its own assessment of the suitability of the information or material contained herein for its use. To the extent permitted by law, the parties involved in the development of this document exclude all liability to any other party for expenses, losses, damages and costs (whether losses were foreseen, foreseeable, known or otherwise) arising directly or indirectly from using this document. This document is produced for general information only and does not represent a statement of the policy of the Commonwealth of Australia. The Commonwealth of Australia and all persons acting for the Commonwealth preparing this report accept no liability for the accuracy of or inferences from the material contained in this publication, or for any action as a result of any person’s or group’s interpretations, deductions, conclusions or actions in relying on this material.

Enquires should be directed to:

Dr Michael Smith, Research Fellow, Australian National University, Fenner School of Environment and Society, Co-Founder and Research Director 2002-2010, The Natural Edge Project. Contact Details at http://fennerschool.anu.edu.au/people/academics/smithmh.php
**Lecture 6.3: Stormwater Treatment, Harvesting and Reuse.**

**Educational Aim**

Currently, in most coastal cities, significant amounts of water fall onto roads, roofs and simply flow out to sea through stormwater drains. In addition, significant quantities of water are only used once and also then are piped out to sea. This lecture will present the case to turn the problem of stormwater management into a valuable resource. This is important because, with climate change, there is likely to be both more intense storms leading to higher risks of urban flooding events combined with risks of declining rainfall affecting the security of urban water supplies. Urban stormwater thus presents itself as both a potential hazard, and a potential valuable resource of water to help cities adapt to climate change. This lecture seeks to show how capturing, harvesting, treating, storing, reusing and recycling stormwater can both reduce risks of flooding during extreme rainfall events and provide alternative water supply options. This lecture seeks to provide an introduction to this field to help you better plan, manage and reuse stormwater resources. It is supported by extensive online stormwater planning manuals in the further reading section. In particular in the last three years a range of new reports have been published providing national guidelines for stormwater harvesting and reuse. This lecture will help all educators update their training courses in light of these recent publications.

**Key Learning Points**

1. The drainage systems of most cities are focused on minimizing the threat of local flooding.\(^1\) This is due to the majority of urban surfaces being impervious, and hence most rainfall in these areas is converted to run-off. This run-off is controlled by engineering direct and efficient channeling. Consequences of this can include shorter intervals between rainfall events and the resultant run-off impacting waterways, which in turn can result in more high-flow events in those waterways.\(^2\)

2. With so much rainfall ending up as run-off, and not permeating the soil, a larger proportion of inflows, especially during dry weather, are the result of human activity such as watering gardens, etc, in the catchment areas. This is in direct contrast to natural watersheds, where

---


rain generally falls on permeable surfaces (i.e. vegetation and soil), and a greater proportion soaks through into groundwater systems.3

3. Urban environments can be highly polluted. Surface pollutants, for example those that result from construction and transport, are readily washed into waterways.4 The speed and volume of urban run-off means that even though these pollutants may be somewhat diluted, the overall volume of those pollutants in the system can have significant qualitative impacts on waterway environments and ecosystems.5

4. The efficiency of systems engineered to manage the run-off in urban areas is such that relatively minor rainfall events can have significant environmental consequences. These include more frequent flow increases in rivers and streams, which can result in erosion. The pollutants in these flows can contribute to algal blooms and weed infestation which, in conjunction with erosion can alter natural water courses.

5. Stormwater management is the management of storm water quality and quantity. It focuses on effective management so as to control flooding and erosion, and the mitigation of pollution risks by controlling hazardous materials. The engineered and structural controls and systems, together with operational methods, are often referred to as best practice management (BPM).

6. Stormwater BPM has three central components. (i) Implementing source6 and structural control measures that enhance stormwater quality and control stream flow discharges. (ii) Preservation and restoration of wetlands, natural channels, and other natural components of the stormwater system through urban water sensitive design.7 (iii) Controlling the source of stormwater (source control) through limiting qualitative and quantitative changes at the point of origin.

7. Stormwater can be managed in numerous ways. The challenge is to choose the right type and size of these options to achieve targets related to factors such as groundwater recharge, erosion and overbank flooding, and pollutant management.8 Broadly speaking stormwater management options include: (1) protecting, maintaining or rehabilitating existing natural waterways, and (2) effectively integrating hard and soft structures, e.g. integrating wetlands, ponds, open channels and filtering systems with concrete drains and channel, and pipes and thus incorporating (3) urban water sensitive design approaches.9

---


8. Stormwater harvesting, the collection and reuse of run-off, is a relatively new and low cost option for addressing a number of key issues. It is currently used mainly on golf courses and parks. Broadening the reuse of stormwater from that requires health and water quality issues to be addressed. The reuse of storm water has the potential to significantly impact upon public health. Hence, the critical first step in developing a storm water harvesting/reuse system is risk assessment as part of the development of a stormwater management plan. The Australian Guidelines for Water Recycling Stormwater Harvesting and Reuse provides detailed guidance in how this should be approached. Aside from implementing standard risk management measures, it suggests using a project screening tool (PST). Using a PST involves collecting information and data about the intended end uses of the stormwater and analyzing it to assess whether the project can be designed to address the related health and environmental risks. It can identify risks beyond those readily addressed by the standard risk management approach.

9. Urban stormwater has traditionally been seen as a problem, with management focusing on its fast and effective removal in order to reduce flood risk. It is, however, increasingly being seen as a valuable resource. The harvesting of urban stormwater not only provides a valuable water resource, but also reduces flood risk and the threat posed by urban pollutants being flushed into water bodies where they impact on ecosystems.

10. Australia has a rapidly emerging range of case studies of storm water harvesting and reuse through a variety of technologies and approaches including:

   - Stormwater filtration and retention via green roofs
   - Sewer water (blackwater) mining and onsite treatment, e.g. the Melbourne City Council building – CH2.
   - Aquifer storage, transfer and recovery (ASTR), e.g. City of Salisbury, South Australia.
   - The capture, storage and filtration of storm water via wetlands and other urban water sensitive design features. (See Further Reading Section - and also the following Lecture 7.1 on Water Sensitive Urban Design)

10, 11

---


11 Ibid.

12 Ibid


Brief Background Reading

Introduction to Stormwater Management and Reuse

With urbanisation, the area of impervious surfaces within a catchment increases dramatically. Densely developed inner urban areas are almost completely impervious. This high proportion of sealed area greatly reduces the amount of water infiltrating the soil and, consequently, most rainfall is converted to run-off. In addition, urban drainage systems are designed to minimise local flooding by providing smooth and direct pathways for the conveyance of run-off. The physical effects of this are

- more rainfall turning into run-off;
- more frequent high flow events in creeks, rivers and receiving waters;
- reduced time lag between rainfall occurring and run-off reaching a waterway because of piping and channelizing of flows; and
- reduced groundwater inflows to streams during dry weather, with a greater proportion of flows made up from human uses of water in the catchment—such as car washing, garden watering and so on.

The increased flood volumes, peak discharges and velocities in urban waterways cause a significant increase in the amounts of material (loads of pollutants) carried by the flow. Activities such as transportation and construction provide abundant sources of pollutants that are readily available for wash-off on the relatively smooth urban surfaces. Table 6.3.1 lists common pollutant types and their sources. Run-off carries these pollutants into waterways, and although concentrations may be diluted during a run-off event, the total loads can affect the environmental quality of downstream aquatic habitats.

Table 6.3.1 Common pollutants and likely sources found in urban stormwater

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Urban Source</th>
<th>Pollutant</th>
<th>Urban Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment</td>
<td>Land surface erosion</td>
<td>Nutrients</td>
<td>Organic matter</td>
</tr>
<tr>
<td></td>
<td>Pavement and vehicle wear</td>
<td></td>
<td>Fertiliser</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td></td>
<td>Sewer overflows/septic tank leaks</td>
</tr>
<tr>
<td></td>
<td>Spillage/illegal discharge</td>
<td></td>
<td>Animal/bird faeces</td>
</tr>
<tr>
<td></td>
<td>Organic matter (e.g. leaf litter, grass)</td>
<td></td>
<td>Detergents (car washing)</td>
</tr>
<tr>
<td></td>
<td>Car washing</td>
<td></td>
<td>Atmospheric deposition</td>
</tr>
<tr>
<td></td>
<td>Weathering of buildings/structures</td>
<td></td>
<td>Spillage/illegal discharge</td>
</tr>
<tr>
<td>Oxygen demanding</td>
<td>Organic matter decay</td>
<td>pH (acidity)</td>
<td>Atmospheric deposition</td>
</tr>
<tr>
<td>substances</td>
<td>Sewer overflows/septic tank leaks</td>
<td></td>
<td>Spillage/illegal discharge</td>
</tr>
<tr>
<td></td>
<td>Animal/bird faeces</td>
<td></td>
<td>Organic matter decay</td>
</tr>
<tr>
<td></td>
<td>Spillage/illegal discharges</td>
<td></td>
<td>Erosion of roofing material</td>
</tr>
<tr>
<td>Micro-</td>
<td>Animal/bird faeces</td>
<td>Toxic</td>
<td>Pesticides</td>
</tr>
</tbody>
</table>

Stormwater management involves addressing many issues and choosing between many options. (See Figure 6.3.1) So next, we describe principles and performance objectives for the environmental management of urban stormwater to address issues like the risks of water pollution. These principles should provide the basis for the planning of stormwater management programs and the design of new stormwater and drainage infrastructure. Then we overview a methodology for preparing stormwater management plans. This approach is intended principally for local government and should provide a basis for implementing best practice. The rest of the lecture describes a range of tools available to meet the environmental performance objectives. These include both source controls (such as education programs to reduce pollution sources) and structural controls (such as wetlands to reduce nutrient loads). But before we do that first we need to introduce you to the main elements of a stormwater management system.

---


---
Figure 6.3.1 Components of a Stormwater Management, Harvesting and Reuse System encompassing various options for collection, treatment, storage, flood protection and distribution of the recycled stormwater for use.

(Source: Hatt, Deletic, and Fletcher\textsuperscript{20}, 2004)

**Key Components of a Stormwater Management, Harvesting and Reuse System**

The components that are usually employed in stormwater recycling systems are as follows;

*Traps*

**Gross pollutant traps (GPTs)** range from simple screens to more complex structures which remove pollutants that occur as larger objects such as rubbish using various combinations of screening, flotation, settlement and flow separation.

**Sediment traps** stop coarse sediment from travelling down into and silting up more advanced downstream treatment measures. Such traps range from simple earthen or concrete basin designs to complex structures using vortices and secondary flows. Both GPTs and Sediment traps do not remove fine or dissolved pollutants. Hence other systems are needed for this.

*Swales, Buffers and Bio-filters*

**Swales** are open, vegetated channels which create a shallow linear depression with low sloping sides and a broad width-to-depth ratio. Swales help to slow runoff velocity and trap coarse

---

sediments. Their effectiveness in the removal of fine sediments and dissolved pollutants is variable.

**Buffer strips** are grassed landscapes that reduce velocity of flow whilst allowing water to infiltrate and remove coarse sediments and some fine soluble pollutants.

**Bio-filters** are vegetated buffers on top of a filtration medium (e.g. sandy loam, sand and/or gravel). They may also incorporate sub-soil drainage pipes, geotextile layer separation and biologically engineered soils targeted to local pollution characteristics. Like swales and strips they reduce coarse sediments and can remove some soluble pollutants.

**Infiltration and Filtration Systems**

**Porous pavement** have a surface of porous material covering a filter layer which in turn covers a sub-base (which has piping for drainage). The surface can be either modular, comprised of spaced non-porous blocks, or monolithic, comprised of porous concrete or asphalt minus fine aggregate. In some instances it can be appropriate for the porous surface to comprise a modular lattice configuration that can be filled with an infiltration media and planted with grass.

**Sand filters** consist of partially sand filled collection chambers that stormwater passes through. They are an efficient means of removing sediments and absorbed pollutants, and can target specific pollutants through the use of different filtration media. Sediments and oils are held in the upper layer of sand which needs to be removed periodically.

**Biologically engineered soils** contain:

(a) either naturally occurring microorganisms, engineered microorganisms or a combination of the two, These degrade toxic pollutants, e.g. herbicides and pesticides.

organic matter to remove nutrients from stormwater as it passes through the engineered soil.

**Infiltration basins** are a combination of retention and infiltration systems. The basins, which can also be trenches, are designed to allow seepage but to suppress exfiltration. As well as capturing suspended solids and a range of other pollutants, they reduce (storm) flow velocities and provide protection against flooding.

**Wetlands**

Wetlands, both manmade and natural, deliver multiple benefits including flood retention, habitat provision, water quality improvement (i.e. removal of fine sediment and dissolved pollutants) recreational opportunities and landscape amenity. Wetlands fall into two categories:

(a) Free water surface wetlands – basins or channels – minimise seepage with a subsurface barrier, and treat water with emergent vegetation

(b) Subsurface flow wetlands are basins or channels containing an emergent vegetation supporting media i.e. sand or gravel) through which water flows

Vegetation is essential to the effective performance of both wetland types.

**Stormwater Ponds**

**Ponds and basins** are generally open bodies of water. They are usually several metres deep and are built to capture and treat run-off. Treatment takes the form of combined sedimentation, biological uptake, and ultra-violet light exposure.
Urban lakes, dams and ponds, like ponds and basins, are designed to store and treat stormwater. Although generally artificial, they can provide benefits such as recreational opportunities, landscape amenity and habitat provision. They employ the same treatment as ponds and basins.

Other

Conventional drainage systems (i.e. gutter-channel-pipe systems) are the most common means of stormwater collection and delivery into water sensitive urban design systems such as those detailed above. Natural drains, such as small creeks and streams, are natural run-off channelling formations (depressions). Advanced treatment usually involves the sequenced use of several processes that can include microfiltration, dissolved air flotation, reverse osmosis, aeration, electrolysis and biological treatment.

Disinfection methods include ultra-violet (UV) light exposure and chlorination. (See Lectures 5.4 and 6.2 for more information)

Conventional water tanks, as the name suggests, are the traditional structures usually employed in the storage of (rain/roof run-off) water. (See Lecture 7.2)

Aquifer storage and recovery (ASR) is the artificial recharge of, and subsequent recovery and re-use of water from, unconfined or confined aquifers. Recharge is achieved via infiltration trenches, surface spreading basins, infiltration wells or direct injection wells. Not only does ASR deliver benefits such as reductions in groundwater salinity, it can also assist in flood mitigation increased aquifer water allocation potential. National guidelines for aquifer storage and recovery are now available.\(^1\)

Urban stormwater management aims and principles

The following aims and principles should underpin all stormwater management plans and design options.

Aims of Stormwater Management: The central aims of stormwater management, according to the Victorian Stormwater Committee\(^2\), include

- Protecting the beneficial uses of urban waterways through an integrated approach to manage the volume, rate and quality of catchment run-off whilst maintaining and restoring the habitats necessary for supporting a healthy habitat and aquatic community.

- Ensuring adequate flood prevention and public safety for all scenarios including once in a hundred year flood events.

Principles of Stormwater Management: Stormwater management, should be based on the following four principles:

---


- **Preservation and Restoration**: preserve and restoring natural hydrology through existing valuable elements of the stormwater system, such as natural channels, wetlands and stream-side vegetation;

- **Source control**: limit changes to the quantity and quality of stormwater at or near the source. Source controls may be used effectively to avoid a number of stormwater impacts. These measures can include land-use planning, education, regulation and operational practices to limit changes to the quality or quantity of urban run-off before it enters the stormwater system. The Victorian EPA has produced numerous factsheets to help all businesses, communities and households reduce stormwater pollution by practising good source control.

- **Structural Control**: use structural measures, such as treatment techniques or detention basins or water sensitive urban design, to improve water quality and control stream-flow discharges. Structural control, as the name implies, involves building structures (man-made and natural) to reduce or delay stormwater flow, or to intercept or remove pollutants after they have entered the stormwater system.

- **Use a “Multiple Barrier” approach to address risks of pollutants**. Different treatments use different processes to remove pollutants, depending on the size range of the pollutant types. To achieve removal for a range of pollutants a number of treatments will be required and the selection and order in which they are constructed is a critical. Figure 7.2.3 illustrates typical pollutant types and size ranges that can be addressed with structural controls. The particle size fractions are presented and matched with the removal processes that structural treatments employ. Selection of treatment measures should be based on matching the pollutant type with the removal process.


Stormwater Management, Harvesting and Reuse Planning

Given the complexity and range of options to consider when seeking to achieve best practice in the management, harvesting and reuse of stormwater, it is often required by law that relevant authorities and local governments develop detailed “Stormwater Management Plans.” There is now a wealth of online stormwater management guides and manuals to assist in this endeavour (See Further Reading). In addition, the Natural Resource Management Ministerial Council has published a series of guidelines with which stormwater harvesting and reuse need to comply.28

Effective stormwater management plans (SWMPs) are a key way to raise awareness amongst catchment managers, including local government, about the impact of their activities. In developing best practice management strategies and programs, the SWMP should specify actions that enable environmentally effective management of urban stormwater. These should also ensure that the valuable end uses and environmental value of stormwater are recognised.

Aside from technical challenges, the main hurdle to improved stormwater management is, generally, achieving a consensus on management priorities across agencies. However, herein lies

---


the key to an effective SWMP. As with most actions plans, effective outcomes are achieved by (a) involving key stakeholders (ie. local council, state agencies and commercial and community representatives), and (b) through assigning accountabilities. A good process to create an effective SWMP usually involves the three phases and activities outlined in Table 6.3.2.

Table 6.3.2 A Process to Guide the Development of Integrated Stormwater Management, Harvesting and Reuse Plans

<table>
<thead>
<tr>
<th>Stage 1 Preliminary activities</th>
<th>Stage 2 Risk and Opportunities Assessment</th>
<th>Stage 3 Development of a Stormwater Management, Harvesting and Reuse Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Establish Commitment to The Project</td>
<td>1. Consider Stormwater Risks, Threats and Opportunities for Stormwater Harvesting and Reuse.</td>
<td>Consider options for action which address relevant issues and risks through the major areas of activity - such as the collection, treatment, storage and reuse of stormwater.</td>
</tr>
<tr>
<td>2. Agree on Project Framework and Scope</td>
<td>2. Produce a list of risks/activities in order of importance (i.e. threat value = priority).</td>
<td>Develop further in detail the lists of risks and opportunities prepared in Stage 2 to develop recommendations based on correct sizing, cost effectiveness, capability, opportunity.</td>
</tr>
<tr>
<td>3. Define Problems and Information Requirements: - catchments, drainage system, receiving environments; land-use patterns, land-use activities; and pollutants.</td>
<td>3. Produce a list of opportunities/ activities to address each aspect of the stormwater</td>
<td>3. Ensure that your SWMP identifies, considers and addresses - risk and threats to receiving water environments from urban stormwater; - strategies and opportunities for managing urban water sensitive urban design approach to help provide a strategic context for stormwater reuse.</td>
</tr>
</tbody>
</table>

30 Ibid.
Consider the broad context such as:
- the nature of the watershed/water catchment – for example is the project located in an aquifer protected area or a beach protected area?
- The terrain; is the site located in an area that is limited by the local topography or underlying geography? Is it located in an environmentally sensitive area?

management process:
- stormwater to protect receiving environments;
- strategies to address and overcome any potential negative environmental impacts due to the construction of infrastructure associated with a stormwater management scheme (e.g., potential impacts on vegetation or threatened species)
- strategies and opportunities to effectively collect/harvest, treat, store and reuse stormwater.
- opportunities to combine effluent and stormwater reuse schemes.

4. Define Opportunities and Information Requirements.
- what opportunities exist through urban water sensitive design to restore natural habitat and natural hydrological processes.
- what opportunities exist for natural structures to collect and store and help purify stormwater.

4. Establish responsibility, costs, monitoring and review through:
- identify responsibilities for implementing SWMP strategies and actions to improve the environmental management of stormwater; and
- identify opportunities to incorporate into all council management and operations activities actions and strategies to improve the environmental management of stormwater.

(Source: Adapted and Updated by Smith, M. from the Victorian Stormwater Committee’s Urban Stormwater Best-Practice Environmental Management Guidelines, 1999)

**Stormwater Treatment and Storage Measures to Enable Stormwater Harvesting and Reuse.**

The selection and implementation of structural treatment and storage measures involves six steps. These are:

1. **Determine treatment objectives:** establish the pollutants of concern in the catchment (e.g., litter, sediments, nutrients) and the level of pollutant retention required. Are primary, secondary or tertiary treatment levels needed?

2. **Develop treatment train:** assess the treatment processes required and appropriate measures and ordering, including any pre-treatment requirements (e.g., screening of coarse sediments or flow control).

3. **Site identification:** identify potential sites and site constraints (e.g., slopes and soil types).

4. **Short-list potential treatments:** identify all applicable treatments.

---

5 **Compare potential treatments**: compare all potential treatments for removal efficiency, maintenance requirements, social impacts and costs.

6 **Detailed design**: complete detailed design of the optimal treatment. The rest of this lecture reviews the first five steps of this process. The detailed design process requires further, more site specific information and is outside the scope of this lecture.

**Step 1 - Treatment objectives**

Land use and existing management practices are the key determinants of a catchment’s stormwater pollutant profile, and should be closely examined by designers. While sediment run-off can be an issue in developing urban areas, litter and general rubbish can be more of a problem in commercial areas. In order to protect receiving waters, treatments may be required to reduce the impact of one or more of the following pollutant categories:

- **gross pollutants**: trash, litter and vegetation larger than five millimetres;
- **coarse sediment**: contaminant particles between 5 and 0.5 millimetres;
- **medium sediment**: contaminant particles between 0.5 and 0.062 millimetres;
- **fine sediments**: contaminant particles smaller than 0.062 millimetres;
- **attached pollutants**: those that are attached to fine sediments—specifically, nutrients, heavy metals, toxicants and hydrocarbons; and/or
- **dissolved pollutants**: typically, nutrients, metals and salts.

**Step 2 - Developing a Treatment Train.**

Treatment approaches tend to be divided into Primary, Secondary and Tertiary, where “primary treatment” involves physical screening or rapid sedimentation techniques. This addresses litter, gross pollutants and coarse sediments. Secondary treatment involves finer particle sedimentation and filtration technique whilst tertiary treatment involves enhanced sedimentation, advanced filtration, biological uptake, and adsorption onto sediments to treat high nutrient or heavy metal loads. Many pollutant treatments, particularly those targeting fine pollutants, require a number of measures used in sequence to be effective; this is known as a treatment train. Figure 6.3.3 illustrates a relationship between pollutant type and treatment processes. Pollutant size, graded from gross to dissolved, is the key determinant of effective treatment type. Knowing what pollutants are present in water enables the appropriate treatment measures to be applied. Figure 6.3.3 illustrates this relationship, together with the associated hydraulic loading rate (HLR). The HLR, a function of the treatment process, can be used to determine the area required for a particular treatment.
Step 3. Site identification

The characteristics of a particular site can limit the choice of treatment measures suited to the area. The range and choice of treatment measures for a particular site are influenced by physical and social constraints. Physical constraints, which impact construction feasibility and maintenance cost, can include:

- **topography**: e.g. steep slopes;
- **soils and geology**: e.g. erosivity, porosity, depth to bedrock or instability;
- **groundwater**: e.g. geochemistry and water table depth; and
- **space**: limited open space, proximity to underground services, e.g. gas, power.

For this reason, a decentralised multi-dimensional approach to stormwater management is recommended as this provides numerous small scale site options to develop a comprehensive stormwater system that better aligns with natural hydrological and landscape features.

Step 4. Short list Potential Treatments

The next step is to develop a short list of potential treatment techniques that meet the requirements for the target pollutants and site constraints. Various primary, secondary and tertiary
treatment techniques are listed in tables 6.3.3, 6.3.4 and 6.3.5 (see below), along with their pollutant retention efficiencies for a range of contaminants.

To help understand these tables a few terms need to be explained. The pollutant retention efficiencies are based on the desirable hydraulic loading rate and are listed for all six pollutant categories: gross pollutants, coarse sediments, medium sediments, fine sediments, attached pollutants and dissolved pollutants. Pollutant retention efficiencies are graded as follows:

- very high (VH): 80 to 100 per cent of total pollutant load retained;
- high (H): 60 to 80 per cent of total pollutant load retained;
- moderate (M): 40 to 60 per cent of total pollutant load retained;
- low (L): 10 to 40 per cent of total pollutant load retained; and
- negligible (N): less than 10 per cent of total pollutant load retained.

These gradings enable designers to easily rate the effectiveness of a treatment process on target contaminants. For example, in targeting metal or dissolved nutrient contaminants, a designer would only consider tertiary treatments.

**Cost**

Costs differ from site to site in response to rainfall and the particular characteristics of a catchment. A rough cost guide is provided below, based on the total installed cost/hectare of catchment:

- high (H): greater than AUD$1500 per hectare of catchment;
- moderate (M): between AUD$500 and AUD$1500 per hectare of catchment; and
- low (L): less than AUD$500 per hectare of catchment.

Maintenance costs are based on the cost per hectare per annum of the particular treatment type. Once again, broad estimates are categorised as:

- high (H): greater than AUD$250 per hectare of catchment per annum;
- moderate (M): between AUD$100 and AUD$250 per hectare of catchment per annum; and
- low (L): less than AUD$100 per hectare of catchment per annum.

Table 6.3.3 Summary of Primary Treatment Performances.

<table>
<thead>
<tr>
<th>Device</th>
<th>Catchment Area (ha)</th>
<th>Trapping Efficiency</th>
<th>Cleaning Frequency</th>
<th>Head Requirements</th>
<th>Installation Costs</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crate &amp; Entrance Screens.</td>
<td>0.1–1</td>
<td>L</td>
<td>N</td>
<td>M/H</td>
<td>L</td>
<td>L/M</td>
</tr>
<tr>
<td>Side Entry Pit Traps.</td>
<td>0.1–1</td>
<td>M/H</td>
<td>L</td>
<td>N</td>
<td>Monthly</td>
<td>L/M/H</td>
</tr>
<tr>
<td>Litter Collection</td>
<td>2–150</td>
<td>M/H</td>
<td>M</td>
<td>N</td>
<td>Monthly</td>
<td>M/H</td>
</tr>
</tbody>
</table>
Baskets.

<table>
<thead>
<tr>
<th>Device</th>
<th>Catchment Area (ha)</th>
<th>Trapping Efficiency</th>
<th>Head Requirements</th>
<th>Installation costs</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Diversion Systems</td>
<td>10-40</td>
<td>M L/M N/L N N N N</td>
<td>Monthly</td>
<td>L M M/H</td>
<td></td>
</tr>
<tr>
<td>Release Nets</td>
<td>1-50</td>
<td>M/H N/L N N N N</td>
<td>Weekly/ Monthly</td>
<td>L L L/M</td>
<td></td>
</tr>
<tr>
<td>Trash Racks</td>
<td>5-500</td>
<td>L N/L N/L N N N N</td>
<td>Monthly</td>
<td>L/M M M/L</td>
<td></td>
</tr>
<tr>
<td>Gross pollutant traps</td>
<td>5-5000</td>
<td>L/M M M L N N N</td>
<td>Weekly and after any storm events.</td>
<td>H H M/H</td>
<td></td>
</tr>
<tr>
<td>Return flow litter baskets</td>
<td>20-100</td>
<td>M/H M L N N N N</td>
<td>Monthly</td>
<td>L M/H M/L</td>
<td></td>
</tr>
<tr>
<td>Hydraulically operated trash racks</td>
<td>&gt;10</td>
<td>H/VH N/L N N N N</td>
<td>Weekly</td>
<td>L L/M M/H</td>
<td></td>
</tr>
<tr>
<td>Circular screens</td>
<td>5-150</td>
<td>VH H M L/M L N N</td>
<td>Quarterly</td>
<td>L H M</td>
<td></td>
</tr>
<tr>
<td>Downwardly inclined screens</td>
<td>5-500</td>
<td>H/VH N N N N N N</td>
<td>Monthly/ Quarterly</td>
<td>H M/H L/M</td>
<td></td>
</tr>
<tr>
<td>Flexible floating boom</td>
<td>&gt;100</td>
<td>N/L N N N N N N</td>
<td>Weekly/ Monthly</td>
<td>L L M</td>
<td></td>
</tr>
<tr>
<td>Floating debris traps</td>
<td>&gt;100</td>
<td>L N N N N N N N</td>
<td>Weekly/ Monthly</td>
<td>L L M</td>
<td></td>
</tr>
<tr>
<td>Sediment settling basins</td>
<td>10-500</td>
<td>N M/H M L N/L N</td>
<td>Half-Yearly</td>
<td>L L/M M/L</td>
<td></td>
</tr>
<tr>
<td>Circular settling tanks</td>
<td>1-20</td>
<td>L/M H M/H M L/M N</td>
<td>Monthly</td>
<td>L H M</td>
<td></td>
</tr>
<tr>
<td>Hydrodynamic separation</td>
<td>5-100</td>
<td>L/M M/H M M L/M N</td>
<td>Monthly</td>
<td>L H M</td>
<td>L/LM</td>
</tr>
</tbody>
</table>

N = Negligible, L = Low, M = Moderate, H = High, VH = Very High.

(Source: Victorian Stormwater Committee’s Urban Stormwater Best-Practice Environmental Management Guidelines41, 1999)

Table 6.3.4 Summary of Secondary Treatment Performances.

Table 6.3.5 Constructed Wetlands Treatment Performance

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value/Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment area (hectares)</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Trapping Efficiency: gross pollutants</td>
<td>L/M</td>
</tr>
<tr>
<td>Trapping efficiency: coarse sediments</td>
<td>H</td>
</tr>
<tr>
<td>Trapping efficiency: medium sediments</td>
<td>M/H</td>
</tr>
<tr>
<td>Trapping efficiency: fine sediments</td>
<td>L/M</td>
</tr>
<tr>
<td>Trapping efficiency: attached pollutants</td>
<td>M/H</td>
</tr>
<tr>
<td>Trapping efficiency: dissolved pollutants</td>
<td>L/M</td>
</tr>
<tr>
<td>Head requirements</td>
<td>L/M</td>
</tr>
<tr>
<td>Installation costs</td>
<td>H</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>M</td>
</tr>
</tbody>
</table>

N = negligible, L = low, M = moderate, H = high, VH = very high

(Source: Victorian Stormwater Committee’s Urban Stormwater Best-Practice Environmental Management Guidelines42, 1999)

Step 5 – Compare Potential Treatments Including Considering Water Sensitive Urban Design Approaches

Water sensitive urban design takes an integrated approach to stormwater management, viewing it as a resource, not a risk. It looks beyond the mere run-off from a development, being mindful of not only environmental issues, but social and cultural considerations. At its core, this approach presents an alternative to the traditional approach to storm water management: conveyance. It emphasises ideas such as minimising the expanse of impervious surfaces and onsite water re-use so as to minimise changes to the natural water balance. Water sensitive urban design can reduce the requirement for a ‘hard’ structural stormwater management system by implementing water sensitive design approaches such as incorporating flow paths into landscaping.

A key design component of water sensitive urban design is the multi-purpose corridor. This can include habitat protection, water features, and recreation areas. The benefits of multi-purpose corridors include stormwater filtration, mitigation of residential flood risk, and securing wildlife habitats. Water sensitive urban design provides benefits beyond those directly associated with the management of stormwater. It not only delivers improved environmental and social amenity in urban areas, but can also reduce the need for drainage infrastructure (and its associated capital and maintenance costs), through providing a more naturally balanced stormwater system. While stormwater has traditionally been viewed as a nuisance, water sensitive urban design views it as an asset: one that can contribute to an enhanced urban environment through, for example, the inclusion of water features. Table 6.3.6 outlines details the goals of water sensitive urban design. How to develop and implement an urban water sensitive design project is outlined in the next lecture, lecture 7.1.

---

43 Ibid.
Table 6.3.6 Summary of economic benefits and constraints associated with water sensitive urban design.

<table>
<thead>
<tr>
<th>Economic opportunities</th>
<th>Economic constraints/limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost savings reduces capital costs (pipe-work and drains).</td>
<td>Market limitations: the market may be sensitive to new urban forms</td>
</tr>
<tr>
<td>Construction cost savings: reduces construction costs (e.g. grading, tree clearing).</td>
<td>Maintenance/operation costs: can potentially increase maintenance and operation costs.</td>
</tr>
<tr>
<td>Water quality cost savings: potentially reduces the costs of water quality improvement, by retaining existing waterways.</td>
<td>Limited developable lots: potential loss of profits through the reduction in the number of developable lots. This occurs in areas that traditionally have been made available through the piping of water courses</td>
</tr>
<tr>
<td>Developer cost savings: reduces developer contributions for downstream drainage capacities.</td>
<td>Storm events and steep terrain: there may be a possible need to supplement water sensitive treatments (such as swales) with pipes, to accommodate minor storm events and steep terrai</td>
</tr>
<tr>
<td>Improved market value: incorporating water features, water frontages, networked public open space and preserving and enhancing ecological systems tends to make developments more desirable and marketable</td>
<td>Land acquisition difficulties: fragmented land ownership may limit the opportunity to implement water sensitive initiatives.</td>
</tr>
<tr>
<td>Improved resource utilisation: offers cost benefits where areas are unsuitable for residential development, but are suitable for passive recreation and contribute to required public open space allocation</td>
<td>Open space requirements: the benefits may be reduced where potentially attractive residential areas must be reserved as open space</td>
</tr>
<tr>
<td>Improved resource utilisation: offers cost benefits where areas are unsuitable for residential development, but are suitable for passive recreation and contribute to required public open space allocation</td>
<td></td>
</tr>
</tbody>
</table>

**Step 6 Site planning**

To fully realise the benefits of water sensitive urban design, its principles need to be fundamentally incorporated into a development at the site planning phase. This phase presents opportunities for incorporating these principles, together with effective stormwater management, in three main areas: site analysis, land capability analysis, and land-use planning.

**Site analysis**

Site analysis should identify and detail the area’s natural features that will need to be considered in the planning and design for the site. Such features can range from soils, geology, topography, through to wetlands, wildlife corridors and vegetation. Consideration needs to be given to the site’s drainage and storm water needs and constraints. Stormwater management structures, flood control together with treatment measures and the preservation of natural waterway corridors should be addressed. The developer will need to demonstrate to the relevant authority that their plans for the site adequately address stormwater treatment requirements and will not impact systems downstream.

**Land capability assessment**

Land capability assessment determines the land’s physical capacity to tolerate specific sustained uses. Based on the outcome of the site analysis, it sets out a development’s most appropriate size
and layout to ensure it includes water sensitive urban design principles to the greatest extent possible.

**Land-use plans**

Land use plans set out a development’s most appropriate size and layout to ensure it includes water sensitive urban design principles for management of the drainage system. Taking into account the environmentally significant areas identified in the site analysis and capability assessment, the land-use plans identify which areas of the site to develop so as to have a minimal impact on the ecosystem. They must also include the needs of stormwater management (i.e. surface area and location) which can include treatment options such as wetlands, infiltration/retention basins and sediment traps.

There are three key areas in which the land use plan should make recommendations, and assessment of cost-effectiveness:

1) Taking into consideration the site’s soil, geology, topography and land use, what methods of local stormwater retention and detention are most appropriate?

2) How best to minimise the mobilisation and conveyance (both within and from the site) of pollution. How the appropriate landscaping, inclusion of wetlands and habitat provision can improve public amenity.

To conclude, undertaking the above stormwater management planning and decision making processes will ensure the best possible stormwater management, treatment and storage solutions are identified and implemented. This will enable more stormwater to be harvested and reused for non-drinking purposes such as irrigation for urban landscapes, use in toilets in buildings and in industrial processes and cooling systems.

**Key References**


accessed 1 May 2010.

accessed 1 May 2010.

accessed 1 May 2010.

accessed 1 May 2010.

http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp
accessed 1 May 2010.

accessed 2 May 2010.

Healthy Waterways (2006) WSUD Technical Design Guidelines for South East Queensland, Chapter 9 *Aquifer Storage and Recovery*, Queensland Government. Available at:
http://www.healthywaterways.org/FileLibrary/9_aquifer_storage.pdf
accessed 2 May 2010.

accessed 2 May 2010.


A list of papers recently published by Margaret Greenway on constructed wetlands is available at:
http://www.griffith.edu.au/centre/cesr/content_staff_Assoc_Prof_Margaret_Greenway.html
accessed 2 May 2010.


accessed 2 May 2010.