National Water Quality Management Strategy

Australian Guidelines for Urban Stormwater Management

2000

Agriculture and Resource Management
Council of Australia and New Zealand

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Telephone (02) 6274 1428
Facsimile (02) 6274 1858

For further information, contact:

The Secretary
Agriculture and Resource Management Council
of Australia and New Zealand
Department of Agriculture, Fisheries and Forestry
GPO Box 858
CANBERRA ACT 2600
Tel: (02) 6272 5216
Fax: (02) 6272 4772

or

The Secretary
Australian and New Zealand Environment
and Conservation Council
GPO Box 787
CANBERRA ACT 2600
Tel: (02) 6274 1428
Fax: (02) 6274 1858

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PREAMBLE

These guidelines are one of the suite of documents of the National Water Quality Management Strategy (the Strategy or NWQMS). Accordingly, the emphasis of these guidelines is on quality management rather than quantity management. The guidelines and documents which form part of the Strategy are detailed in Appendix 1.

National Water Quality Management Strategy

The Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) are working together to develop the Strategy. The National Health and Medical Research Council is involved in aspects of the Strategy which affect public health.

The main objective of the Strategy is:

'To achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development'.

The Strategy emphasises the importance of the following principles in water quality management:

- ecologically sustainable development;
- integrated (or 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.

As water resource management is mainly a state and territory responsibility, implementation of the Strategy involves:

- national guidelines developed under the Strategy;
- state and territory water policies;
- community preferences on the use and values of local waters;
- the current water quality of local waters; and
- the economic and social impacts of maintaining current water quality or of meeting new local water quality goals.

Implementation of the Strategy should include:

- catchment, groundwater and coastal water quality management plans;
- an appropriate level of service provided by water authorities for water and sewerage services; and
- further development of regulatory and market frameworks.

Community views form a crucial part of the Strategy and public comment is sought during its development and implementation.

National Guidelines

These papers provide guidance on many aspects of the water cycle including ambient and drinking water quality, monitoring, groundwater, rural land and water, urban stormwater, sewerage systems and effluent management for specific industries. Further information can be found on the Strategy website at http://www.affa.gov.au/nwqms. The *NWQMS Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000a) and the *NWQMS Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARMCANZ, 2000b) are key documents of the Strategy.

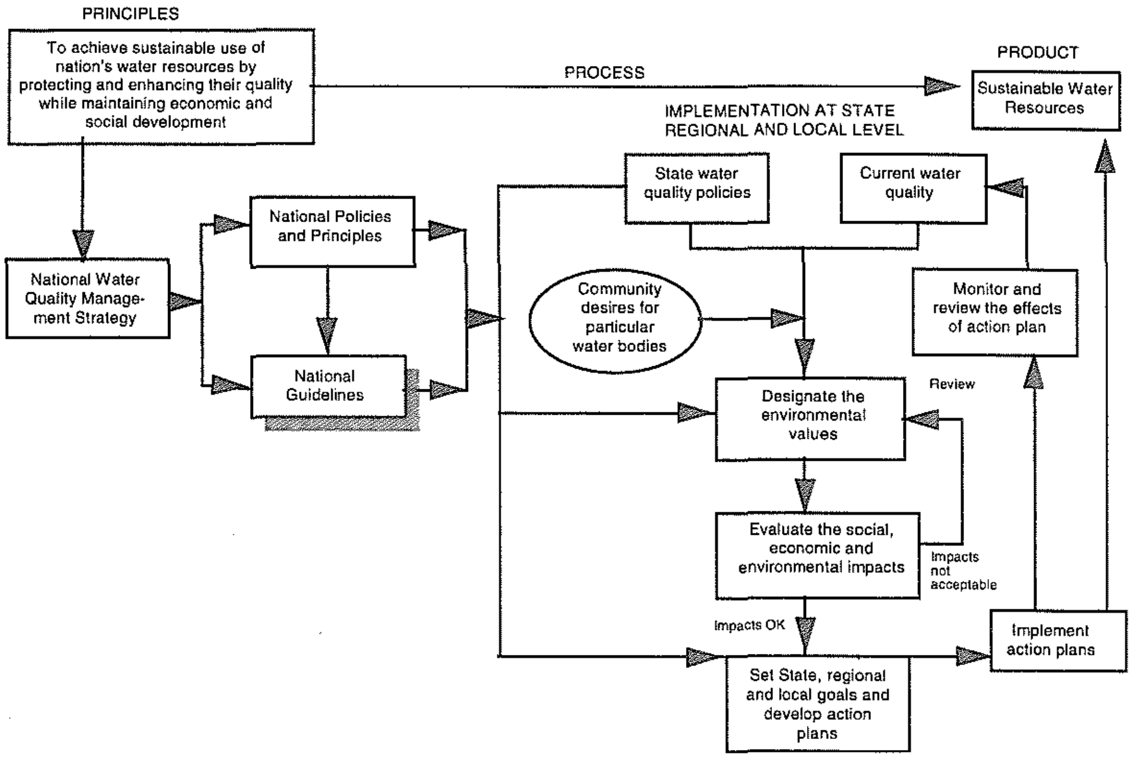

Figure 1 - National Water Quality Management Strategy

Acknowledgements

The preparation of these guidelines was initiated by the Water Resources Management Committee of the Australian Water Resources Council (now the Agriculture and Resource Management Council of Australia and New Zealand).

Preparation of 1996 Draft for Public Comment

Members of the working group were Messrs Kwame Asumadu (DPIE), Pat George (WAWA), Nigel Alexander/Max Giblin (Dept Primary Industry & Fisheries), Ian Lawrence (ACTPA), Gordon McIntosh (EWSD), Professor Geoff O'Loughlin (Sydney University of Technology), Richard Peck (Melb Water), Rolf Rees (WRC Qld), & Lionel Wood (DPIE). Following the decision that the guidelines should be a joint ANZECC and ARMCANZ document, Mr Digby Habel (EPA Canberra) joined the working group as the ANZECC representative. The support of water resource agencies nationally in commenting on progressive drafts, and in resourcing the drafting by the working group, is gratefully acknowledged.

Preparation of Revised Draft, 1999 – 2000

In July 1999, Environment Australia took the lead in finalising the draft guidelines. Environment Australia gratefully acknowledges the contributions of Chris Chesterfield (Melbourne Water), Ian Lawrence (CRC for Freshwater Ecology), Mike Sharpin (NSW EPA) and Janet Meuronen, Megan Scott and Tara Hewitt (Environment Australia) throughout the revision process.

1 INTRODUCTION

1.1 Urban stormwater

Urban stormwater is runoff from urban areas, including the major flows during and following rain as well as dry weather flows. Dry weather drainage flows generally originate from groundwater, garden watering, washdown, leaking water pipes, and illegal discharges. In most systems, overflows from sewerage systems or septic tanks may also become part of stormwater flows during wet and dry weather. Management of sullage in small towns can also present a problem, as some properties have inadequate provision for on-site treatment and discharge directly to stormwater systems (NWQMS Guidelines for Sewerage Systems - Sewerage System Overflows are currently under development, see Appendix 1).

In many Australian cities stormwater runoff is seen as a nuisance to be disposed of as quickly as possible. Urban drainage systems have often been developed to minimise the risk of flooding, without due consideration of other important values such as resource conservation, environmental quality, public safety, and amenity.

It is now clear that a new approach to stormwater management is needed - an approach that addresses issues of stormwater quality and aquatic ecosystem health, as well as stormwater quantity. We need an approach that recognises the environmental impacts of urbanisation, the linkages between land and water management, and the importance of community values and involvement.

> *Urban stormwater presents a management challenge in terms of **quantity** (flood and drainage management, stormwater reuse), **quality** (litter, nutrients, chemicals, sediments) and **aquatic ecosystem health** (aquatic habitats, riparian vegetation, stream stability and environmental flows).*

1.2 Purpose of these guidelines

These guidelines aim to provide a nationally consistent approach for managing urban stormwater in an ecologically sustainable manner. The approaches outlined in this document represent current best practice in stormwater planning and management in Australia. In particular, these guidelines will help managers to identify objectives for stormwater management (including protecting social, environmental and economic values) and to integrate management activities at the catchment, waterway, and local development level.

The tools and approaches in these Guidelines will assist managers to undertake integrated stormwater management planning in accordance with the values and conditions of the local environment, while integrating these activities into the catchment context.

The Guidelines also outline:

- why we need to manage our stormwater;
- what are the challenges;
- how to involve the community;

- the management tools available; and
- preparing, implementing and monitoring Stormwater Management Plans.

It is important to recognise that different jurisdictions may have different legislative and resource management requirements relating to stormwater management. Many State, local and regional governments have developed comprehensive technical guidelines on specific stormwater management techniques and practices, many of which are referred to in these guidelines. Managers should approach their relevant state, territory or regional agency for information on any specific requirements than need to be met, or technical information that may assist in their stormwater planning and management activities.

1.3 Impacts of urbanisation

With progressive changes in the Australian landscape from forest or other indigenous vegetation to rural or urban environments, the natural movement of water has changed dramatically. The growth of urbanisation has led to a substitution of vegetated ground with land covered by large impervious surfaces such as roofing and paving. Topography has also radically changed through land levelling and grading, and natural watercourses have been replaced with gutters, pipes and channels.

It is difficult to make generalisations about what impacts urbanisation will have on aquatic ecosystem health. Generally, reduced water quality and a lower diversity of aquatic flora and fauna can be expected. The composition of ecological communities may also be altered, or the relative abundance of species tolerant to the altered conditions may increase. Left unmanaged, these impacts may not only be detrimental to the environmental values of urban waterways, but may also pose a risk to public health and restrict potential opportunities for the community to benefit from the waterway.

A detailed discussion of the impacts of urbanisation on the stormwater environment is provided in Appendix 2. These include changes in:

- catchment hydrology - increased frequency and intensity of runoff and flooding events, higher runoff volumes and peak flows, more rapid peaking of storm flows, and reduced base flows in watercourses.
- water quality - elevated levels of suspended solids, nutrients, micro-organisms, heavy metals and organic materials.
- waterway channels - channel form may be changed by increased erosive force of flows, removal of riparian vegetation, and sedimentation.
- riparian vegetation - removal of riparian vegetation and replacement with exotic species can lead to, for example, higher water temperatures, loss of aquatic and terrestrial habitats, and decreased bank stability.
- aquatic habitats - aquatic habitats may be lost through 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.
- watercourse barriers and constrictions - structures such as bridges and culverts may alter flow patterns, fauna movement, and sediment transport patterns.

The magnitude and nature of these impacts will be specific to individual catchments. They may also be influenced by other factors such as pre-development land uses.

From a management perspective, there are two key points that should be noted:

- actions should be tailored to the catchment – generic solutions are not appropriate; and
- changes to runoff patterns should be minimised. This reduces a range of other environmental impacts.

2 STORMWATER MANAGEMENT FRAMEWORK

2.1 What do we want to achieve in Stormwater Management?

There is no single objective that is appropriate for the management of all urban stormwater systems. A multiple objective approach should be adopted, considering objectives such as:

- ecosystem health, both aquatic and terrestrial;
- flooding and drainage control;
- public health and safety;
- economic considerations;
- recreational opportunities;
- social considerations; and
- aesthetic values.

These objectives often need to be addressed in two contexts:

- restoring existing stormwater systems; and
- minimising the impacts of stormwater from new developments.

In established urban areas, the first context will be the most common. There will, however, be the need to appropriately manage the impacts of redevelopment projects and seek opportunities for restoration and upgrading. In urban growth areas, the second context will be dominant. This is an important responsibility for stormwater managers in these areas. It is generally more economical and effective to minimise the impacts of new developments than it is to mitigate these impacts from completed developments.

The applicability of many stormwater management techniques will depend on whether restoration, rehabilitation and/or prevention are the goals. In many existing areas, constraints such as existing properties, heritage classified waterways and bridges may prevent management objectives from being fully realised.

2.2 Integrated Catchment Management

Integrated Catchment Management (ICM) or Total Catchment Management (TCM) recognises the catchment-wide relationships between resource use and management. It also addresses the need for community involvement in identifying issues and management solutions. It has been adopted in a number of States and Territories and embraces:

- a holistic approach to natural resource management within catchments, marine environments and aquifers, with linkages between water resources, vegetation, land use, and other natural resources recognised;
- integration of social, economic and environmental issues;
- co-ordination of all the agencies, levels of government and interest groups within the catchment; and
- community consultation and participation.

Integrated Catchment Management is increasingly becoming the 'umbrella' for sustainable resource management.

2.3 Ecologically Sustainable Development

Ecologically Sustainable Development (ESD) represents one of the greatest challenges facing Australia's governments, industry, business and community in the coming years. While there is no universally accepted definition of ESD, in 1990 the Commonwealth Government suggested the following definition for ESD in Australia:

> *'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.'*

Put more simply, ESD is development which aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations. To do this, we need to develop ways of using those environmental resources, which form the basis of our economy in a way which maintains and, where possible, improves their range, variety and quality. At the same time we need to utilise those resources to develop industry and generate employment.

The 1992 National Strategy for ESD identifies core objectives and guiding principles designed to achieve development that improves the total quality of life in a way that maintains the ecological processes on which life depends.

The principles of ESD are:

(a) The precautionary principle. Namely, that 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.

(b) 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.

(c) Conservation of biological diversity and ecological integrity. Conservation of biological diversity and ecological integrity should be a fundamental consideration.

(d) Improved valuation, pricing and incentive mechanisms. Environmental factors should be included in the valuation of assets and services.

The challenge in ESD is 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.

2.4 Ecosystem Health Management

Stormwater management is currently undergoing a paradigm shift. The traditional focus on flood management is being broadened to address stormwater quality considerations. A further shift is emerging, where stormwater managers are addressing aquatic ecosystem or river health. This involves the management of all aspects of the water environment to achieve the best outcome for the health of watercourses, lakes, estuaries and the marine environment. Streamflow, water quality, aquatic habitats and riparian vegetation are all considered when management decisions are made.

2.5 Water quality objectives

Ambient water quality objectives have been, or are in the process of being, established for waterways in many States, Territories and regions. These objectives can provide a goal for urban stormwater management. This is, however, complicated by:

- water quality being affected by other pollution sources, such as point sources, agricultural runoff and sewer overflows; and
- difficulties in establishing relationships between ambient water quality concentrations and wet weather stormwater discharges.

Guidelines for fresh and marine water quality have been prepared by ANZECC and ARMCANZ (ANZECC & ARMCANZ, 2000a) to provide governments and the community, particularly catchment/water managers, regulators, industry and community groups, a sound set of tools for assessing and managing ambient water quality. Also several NWQMS Guidelines relating to sewerage systems and effluent management have been, or are in the process of being, developed (see Appendix 1).

2.6 River flow objectives (water for the environment)

Objectives for river or environmental flows are being developed in some States, Territories and regions. These objectives recognise that waterway health is influenced by the flow regime, which may be affected by landuse change and water extraction. River flow objectives can also provide a framework for urban stormwater management, although in many large catchments, urban areas may be only a small component of the catchment. The *National Principles for the Provision of Water for Ecosystems* (Sustainable Land and Water Resources Management Committee Subcommittee on Water Resources 1996) provides some guidance for river flow objectives.

2.7 Public health and safety

Management objectives to minimise public health and safety risks can include:

- designing structural controls and waterways to minimise the risk of trapping people caught in waterways during floods;
- minimise the risk of injury to the public and maintenance staff from structural controls; and
- minimising public risks associated with vectors such as mosquitos from constructed wetlands.

2.8 Integrated Water Cycle Management

Traditionally, stormwater, water supply and sewage have been managed separately. There are, however, opportunities available to integrate these aspects of the water cycle in a way that improves environmental and community outcomes, sometimes at reduced cost. From a stormwater perspective, the most common approach is stormwater reuse, generally for non-potable purposes. This reduces the demand on the potable water supply and reduces runoff volumes and flow rates. Schemes have also been developed that reuse both stormwater and treated effluent.

Contemporary approaches to stormwater management also include ensuring that water supply systems allow for environmental flows in streams below extraction points, the sustainable management of extractions for irrigation, and mimicking natural flow regimes in managed streams. These approaches recognise that stormwater management needs to identify both the environmental values of streams as well as the opportunities to utilise stormwater as it passes its way through the urban water cycle.

2.9 Urban stormwater as a resource

In the past, the main aim of urban stormwater management was collecting and removing excess runoff as quickly and cheaply as possible. This was to avoid flooding during major rains and to provide general amenity drainage. As growing urban communities approach or exceed the economically viable limits of water supplies, opportunities associated with use of local water sources such as urban stormwater and groundwater are being recognised. Better management of the water cycle at the residential block needs to be achieved to reduce demand for domestic irrigation. Where urban areas are located over or adjacent to groundwater aquifers, there is potential for stormwater to be used to recharge aquifers provided the water quality is protected. This requires very careful management as potential issues include rising water tables, salt problems and groundwater extraction rights.

The quality of urban open space has often been compromised by the loss of natural urban streams to restricted hard engineering drainage structures. This can be due to poor planning of the urban form as part of the original urban development and the requirement to ensure a certain flood immunity and drainage standard. The loss of natural urban streams can adversely affect the amenity of surrounding areas, ecological health and water quality. In new developments it is essential that stormwater is recognised as a resource prior to allotment layouts being finalised.

Long term social, environmental and economic benefits can be achieved for open space drainage corridors through planning and design approaches which recognise urban stormwater and streams as valuable resources. Opportunities to retrofit pollution control devices and re-establish an aesthetically appealing environment to degraded drainage corridors by habitat restoration should also be investigated.

2.10 Community values and participation

Managing stormwater only for flood protection is no longer an adequate response to changing community values which now reflect concern for protecting the environment, ecologically sustainable development, and improved access to open space and recreational facilities.

Most urban dwellers enjoy a very high level of flood protection due to the works done in the past. These need maintenance and, at times, upgrading. Demand should now focus equally on improved environmental quality and recreational opportunities.

The NWQMS paper, *Policies and Principles - A Reference Document (1994),* seeks to respond to these community values by adopting the objective of *'achieving sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development'*.

Community participation helps to:

- identify strategies which are responsive to community concerns;
- explore problems, issues, community values and alternative strategies openly;
- increase public ownership and acceptance of proposed solutions;
- generate broader decision making perspectives not limited to past practices or interests; and
- reflect the community's life style values and priorities.

2.11 Economic Sustainability

A wide range of stormwater management practices is available. The capital and ongoing operations and maintenance costs of these practices are highly variable. It is important for stormwater managers to adopt solutions that are economically sustainable. This is particularly relevant when choosing structural water quality controls. The annual operating and maintenance costs of these devices may represent a large percentage of, or exceed, their initial capital cost. Management authorities may find this cost difficult to afford on an ongoing basis. This may then compromise the effectiveness of the device in meeting its treatment objectives.

3 STORMWATER MANAGEMENT TECHNIQUES

3.1 The management hierarchy

A complex interaction exists between the hydrological (streamflow), water quality, channel form, aquatic habitat and riparian vegetation characteristics of a watercourse. These interactions will also impact on human health, recreation and aesthetic considerations. To maintain the long-term integrity of these values a holistic approach is necessary.

Similarly, managing only one aspect of a stormwater system is unlikely to address all of the relevant considerations. Stormwater management should consider the hydrological, geomorphological, ecological, soil, land use and cultural characteristics of a catchment and its watercourse network. If the interactions noted above are not recognised, there is the potential for well-intended management techniques to have a greater environmental impact than unmitigated stormwater runoff.

A set of broad and holistic principles that can be followed for effective stormwater environment management are:

- hydrological: minimising the impacts of urbanisation on the hydrological characteristics of a catchment, including wet weather and low flows. If the pre-development land use resulted in an inappropriate streamflow regime (eg runoff from an agricultural catchment causing erosion), this should be mitigated where practical;
- water quality: minimising the amount of pollution entering the stormwater system and removing an appropriate amount of any residual pollution by implementing stormwater management practices;
- vegetation: maximising the value of indigenous riparian, floodplain and foreshore vegetation; and
- aquatic habitat: maximising the value of physical habitats to aquatic fauna within the stormwater system.

While these principles are strongly inter-related, their relative importance can vary within and between catchments. It may be necessary to compromise between these principles at any particular site to achieve a balanced outcome that maximises overall environmental, social and economic benefits. However, given that runoff rates and volumes often, directly or indirectly, cause many potential social, economic and environmental impacts in urban areas, managing these specific runoff characteristics is imperative.

A stormwater management hierarchy can be identified to define preferred stormwater management practices (**Figure 2**). This is:

1. **Retain and restore (or rehabilitate) valuable ecosystems**: retaining or restoring (if degraded) existing valuable elements of the stormwater system, such as natural channels, wetlands and riparian vegetation;
2. **Source control: non-structural measures**: non-structural techniques for limiting changes to the quantity and quality of stormwater at the source;
3. **Source control: structural measures**: constructed management techniques installed at or near the source to manage stormwater quantity and quality; and
4. **In-system management measures**: constructed management techniques installed within stormwater systems to manage stormwater quantity and quality prior to discharge into receiving waters.

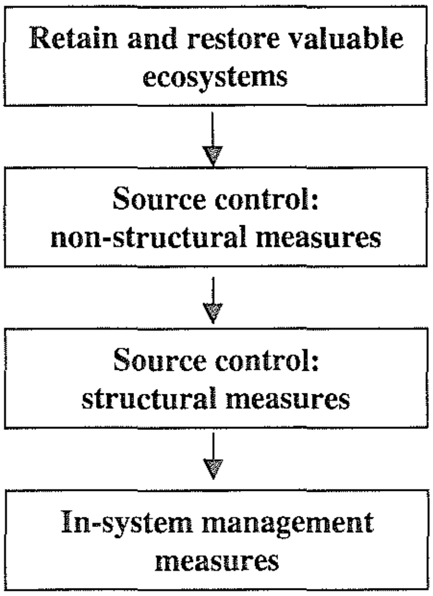

Figure 2 – Stormwater Management Hierarchy

This approach focuses on **pollution prevention** in accordance with the principles of ESD. These steps firstly seek to preserve the valuable features of the water environment, then promote cost-effective stormwater management by minimising and controlling stormwater pollution at the source, and only propose management measures within stormwater systems for the residual impacts that cannot be cost-effectively mitigated by source or near-source controls.

The *NWQMS Australian and New Zealand Guidelines Water Quality Guidelines for Fresh and Marine Waters* (ANZECC & ARCANZ, 2000a) adopt three levels of protection in respect to ecosystems:

- Pristine to slightly modified systems – protection;
- Slightly to moderately modified systems – restoration opportunities; and
- Highly modified systems - local identification of the values to be secured.

The bulk of stormwater related ecosystems will fall into the third category. There may however be a number of areas where either the level of acceptable change is confined to the slightly to moderately disturbed level, or where reasonable opportunities exist to restore impacted ecosystems to the slightly to moderately disturbed level.

3.2 Runoff management

3.2.1 Flow management goals

The traditional approach to managing the impacts of urbanisation on flow patterns has focused on mitigating the effects of increased peak flows from infrequent events (eg the 100-year average recurrence interval event). This approach has been based on reducing human health risks and damage to property and infrastructure.

From an environmental management perspective, emphasis needs to be placed on the management of flows from frequent events of relatively small magnitude. This is primarily because in urban environments, the most significant changes to the hydrological regime occur in the frequency and magnitude of the smaller, more frequent runoff events.

3.2.2 Run-off source controls

Runoff source controls generally include infiltration techniques or stormwater reuse practices.

Infiltration techniques range from those implemented on individual housing blocks to those incorporated within the stormwater system. These include:

- infiltration trenches, pits, wells and soakaways for infiltration of roof runoff;
- directing roof runoff to ponding areas in back yards for infiltration;
- grassed swales;
- pervious stormwater pipes;
- porous pavements; and
- infiltration trenches and basins (installed within the drainage system).

These systems are suitable for infiltrating runoff with low sediment levels in areas with relatively high permeability soils. Grassed swales have the advantage of slowing flow velocities and can be used instead of kerbs and gutters. Porous pavements have a relatively high failure rate. To be effective in the long term, infiltration techniques need to be appropriately designed, used in low-trafficked areas and infiltrate stormwater with negligible sediment levels.

In selecting the most appropriate infiltration technique, managers should consider whether pre-treatment of the runoff is required to ensure these techniques continue to function in the long term. Any potential for groundwater pollution or aggravation of urban salinity problems is also an important consideration. Managers should also consider the measures that can be taken to improve management of septic tank systems, sullage discharges and sewerage system overflows.

Stormwater reuse can provide an effective runoff control approach, with the further benefit of providing an additional water resource. Reuse measures can be undertaken at either individual block level or on a catchment or sub-catchment basis. These may include rainwater tanks or similar devices for collecting roof runoff, and wet basins or constructed wetlands. The water collected can be used for non-potable purposes, including industrial processes, irrigation, garden watering and toilet flushing. As the volume of water stored in these devices will vary, they should not be used as a substitute for any on-site detention requirements needed for flood mitigation. The storages can, however, be designed for multiple objectives. Storage could be provided for both stormwater reuse and flow attenuation.

3.2.3 Structural Controls

In large and infrequent storm events, infiltration is likely to be minimal. Peak flows can be reduced by temporary storage to minimise public health risks, property damage, aquatic habitat disturbance and channel erosion. Retarding (or retention) basins are commonly used to mitigate flows from infrequent events, such as the 100-year average recurrence interval flood, in the catchment. In individual developments, on-site detention can also be used to reduce flow peaks.

Retarding basins can also be designed to attenuate the peak flows of more frequent events, such as the 1-2 year average recurrence interval event. This can result in no increase in the frequency of occurrence of the bank-full flow after urbanisation. It does, however, result in the lengthening of the flow hydrograph. This may result in channel erosion. These basins need to be carefully designed to optimise their performance. Designing retarding basins to meet more than one discharge criterion can provide beneficial outcomes for ecological management without compromising drainage and flood protection requirements.

3.3 Water quality management

3.3.1 Stormwater quality management goals

The greatest change in pollutant loads discharged to waterways from urban areas occurs during the more frequent storm events. Non-urban aquatic ecosystems are generally not subject to runoff from smaller and frequent storm events, due to their ability to infiltrate rainfall far better than urban environments. Reducing runoff volumes from these storm events will assist in reducing pollutant loads.

The ASCE & WEF (1993) note the following regarding this approach:

> *'The design runoff selected for sizing water quality controls is considerably different from that used for the design of drainage facilities. The damage done to a receiving water ecosystem by uncontrolled pollutant runoff in the 50 year ARI event is inconsequential compared to the hydraulic damage that results naturally to aquatic habitats from such an event:*
> (a) *drainage systems are designed for large infrequent runoff events* [10, 25, 50 or 100 year ARI];
> (b) *design events for runoff quality control are small frequent events* [smaller than the 1 year ARI runoff event].'

A significant proportion of the long-term (eg annual) runoff volume from urban catchments occurs from frequent, smaller flood events and from a proportion of larger events. Commonly in urban areas, approximately 90-95% of the mean annual runoff volume occurs at flows less than the 3-

month average recurrence interval event (approximately 25-50% of the 1-year flow in temperate areas). These frequent events are the target of most stormwater quality controls.

Stormwater quality controls should be implemented during both the construction and post-construction phases of urban development. Both source control and "end-of-pipe" management practices are appropriate.

3.3.2 Construction site stormwater quality management

Water quality management from construction sites falls into two categories:

- erosion and sediment control; and
- management of wastes, chemicals and fuel.

The general management principles for erosion and sediment control involve:

- minimising the extent of disturbed areas;
- rapidly revegetating disturbed areas;
- diverting runoff from undisturbed catchments around work areas; and
- trapping eroded sediment from disturbed sites as close to the source as practical by, for example, sediment fences, traps and basins.

These principles apply to construction sites of all sizes, from major urban developments and freeways to single house construction. The success of this approach is heavily dependent on:

- appropriate planning prior to the commencement of construction activities;
- appropriate monitoring and maintenance of the management practices; and
- education and diligence of contractors, consultants and council officers in the planning and management of these techniques.

The management of wastes and chemicals at a construction site generally relates to appropriate storage, handling and disposal practices. The practices should ensure:

- chemicals and fuels should be stored and handled in a manner which ensures that no pollutants are discharged to stormwater;
- wastewater from building activities (such as washdown water from concrete trucks or cooling water from brick cutting) should be contained on-site; and
- litter from building operations should be adequately stored and disposed of.

3.3.3 Source controls – existing urban areas

What is source control?

Source control of stormwater pollution from established urban areas aims to minimise the amount of pollution entering the drainage system. It is based on the premise that it is generally easier and more cost-effective to control pollution at the source, rather than subsequently removing pollution from within the drainage system. Further, stormwater treatment measures may not be able to reduce pollutant loads to desired levels in the long term. In many cases, a combination of source and in-system management techniques may be necessary.

Source control techniques can be categorised into:

- non-structural source control: techniques that aim to change human behaviour to reduce the amount of pollutants that enter stormwater systems (pollution prevention); and
- structural source-control: techniques that aim to reduce the quantity and improve the quality of stormwater at or near its source by using infrastructure or natural physical resources.

Non-structural source control can include community education, council management, operations and maintenance activities, and land use and site planning.

The main advantages of using non-structural source controls are:

- long term sustainabilty;
- cost-effectiveness;
- minimisation or prevention focus;
- reduced ongoing operation or maintenance liability (compared with structural controls); and
- effective use of all resources – including the community.

Community education

Community education can play a significant role in the improvement of stormwater quality. Stormwater pollution from residential, industrial and commercial areas is the result of many actions at various locations within a catchment. The impact of allowing a can to leak oil, washing paint brushes into drains, not cleaning up after dogs or inappropriate use of household chemicals may seem relatively minor. However, when the individual impacts are added across the catchment, these actions become a significant source of pollution entering waterways.

In addition to stormwater pollution, other impacts of community activities on the health of waterways include:

- increased runoff rates caused by increased impervious areas (such as roads, roofs and paving);
- removal of riparian vegetation adjacent to watercourses and other waterbodies; and
- degradation of aquatic habitats such as pools and rapids in creeks and wetlands.

People are often unaware that their activities at work, while travelling or at home 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. There is a valuable role for local community networks, local councils and state government agencies to assist communities to play a constructive role in stormwater management.

Education programs may not result in an immediate change as they are not the only factor that influence a person's behaviour – particularly in the short term. A person's behaviour is also influenced by:

- the social values and standards passed on in the home, at school, through social groups and 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.

Education programs are more likely to show results if they are planned and implemented as one of a number of complementary approaches that address issues arising from people's behaviour. Complementary approaches to consider are:

- **Enforcement**: making better use of policy, legislation and regulation.
- **Economics:** examining market incentives and disincentives for changing behaviour.
- **Engineering, science and technology**: promoting and assisting development of new technologies and services.
- **Evaluation, monitoring and research:** examining the barriers and information needs to facilitate change.

Community education is a process used to:

- create **awareness** of issues;
- enhance people's **knowledge, understanding and skills;**
- influence people's **values and attitudes;** and
- encourage more responsible **behaviour.**

The following steps could be adopted in developing an education program:

1. **Analyse the issue or problem** - Find out what's causing concern and break the issue down into its components. 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.
2. **Identify stakeholders** - Identify the stakeholders, involve them and find out where they stand in relation to the issue and look for common ground where the stakeholders may be able to work together to solve the issue.
3. **Know your target group** - Identify, get to know and involve your target group early in the project.
4. **Objective and outcomes** - Determine the result you want from your community education project.
5. **Design your methods** - Investigate the methods, tools and techniques you could use to achieve your goal, objectives and outcomes.
6. **Consider funding** - Identify possible funding sources and the benefits for potential funding organisations.
7. **Make an action plan and implement it** - Prepare an action plan to ensure that you achieve your project's goal and objectives.
8. **Monitor and evaluate** - Monitor and evaluate the project and tell people about it.

Auditing of commercial and industrial premises

Audits can be undertaken of commercial and industrial premises within catchments, targeting premises with the potential for stormwater pollution. It is often more effective for this to be undertaken initially by an independent party, rather than a regulator. This is likely to result in a greater degree of cooperation with the management of the premises. The audits can be considered as part of a community education program.

Premises undertaking activities likely to cause stormwater pollution can be encouraged to rectify them and, for larger premises, prepare an environmental management plan. Follow up visits can be undertaken. If the management of a premises is uncooperative and it is suspected that activities with a potential for stormwater pollution are being undertaken, this could be referred to a regulatory authority.

Council management activities

Local councils can influence the quality of stormwater within a catchment when planning and managing construction and maintenance activities and during day to day management decisions. It is also important for councils to be seen to be setting the right example for the community and other organisations to follow.

Table 1 notes some council management activities that have a direct or indirect influence on stormwater management. It is important that these influences on stormwater management be recognised and considered.

Management activities undertaken by council that can used be to maximise councils effort in managing stormwater pollution include:

- conducting internal reviews;
- performance monitoring;
- internal training and education;
- internal communication;
- financial management;
- development and building approvals; and
- enforcement of site controls.

Simple maintenance activities that can be implemented at minimal cost can also achieve significant improvement in the quality of stormwater run-off. Proper planning of operational procedures for each activity is the key element to success in minimising the impact each may have on the stormwater quality. Activities where this can be undertaken include:

- Maintenance of roads, footpaths and bridges;
- Maintenance of stormwater systems and waterways;
- Open space management;
- Depot operations; and
- Waste collection.

Table 1 – Council activities and potential influence on stormwater

Council activities	Potential influence on stormwater
Environmental/Land Use Planning - Strategic planning	• Urban capability assessment • Developer contribution plans for stormwater management
Environmental/Land Use Planning - Development control	• Stormwater management practices for new developments
Building approvals and inspection	• Soil and water management for building sites
Environmental Health	• Trade waste, discharges to stormwater
Parks and Gardens	• Maintenance activities (eg tree planting, fertiliser application, grass cutting)
Road Maintenance	• Various maintenance activities
Drainage system maintenance	• Various maintenance activities
Waste collection	• Litter management
Road and drainage design	• Road route selection, drainage system design
Finance	• Budgets for stormwater management
Library	• Community education

Urban capability assessment

Urban (or land) capability can be considered as the capacity of an area to sustain a proposed land use without having a significant impact on the health of aquatic ecosystems or exceeding the physical capability of the land to support the development.

Urban capability assessment is an important part of stormwater management. If an assessment is not carried out for a new development, the opportunity to mitigate many of the impacts may be lost or may only be overcome at significant cost to the developer or the community. It is important that each development is tailored to the characteristics of the development site. The optimal time for assessing urban capability in the development process is at the land use planning stage.

The results of an urban capability assessment can be presented in a *Constraints and Opportunities Map*. These maps indicate the features of the water environment and any limitations imposed by the environmental and physical characteristics of the site. The maps may be presented as a series of overlays, each containing a different suite of features or limitations.

3.3.4 Stormwater Treatment – Existing urban areas

Different stormwater treatment measures for managing stormwater quality from urban areas post-construction will provide different levels of treatment (**Figure 3**). In some cases, a particular treatment measure may overlap two or more treatment levels depending on its specific design features. In most situations, however, a combination of different treatment measures that reduce pollutants through different processes will provide the best overall treatment. These treatment measures need to be appropriately selected, planned, designed and maintained if their pollutant retention objectives are to be met in the long term.

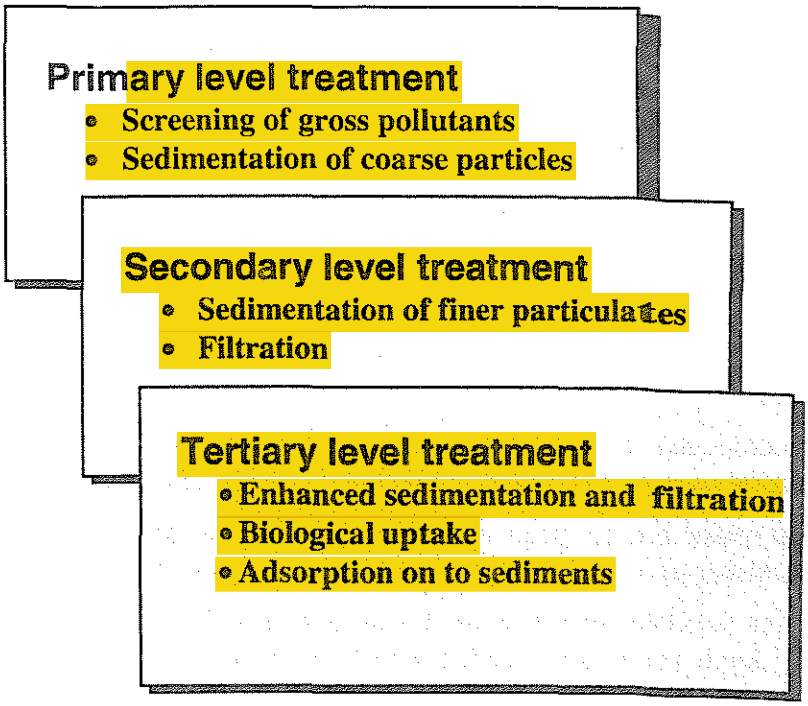

Figure 3 - Levels of stormwater treatment

Primary treatment measures generally target litter and other gross pollutants, and coarse sediments. Examples commonly used include:

- **litter basket** - a basket installed in an inlet pit to collect rubbish directly entering the stormwater system from road surfaces;
- **litter (control) pit** - a basket located in a stormwater pit, where it collects litter from the upstream drainage system;
- **litter (trash) rack** - a rack installed within a stormwater channel, or at the downstream end of a sediment trap;
- **sediment trap** - a formal 'tank' or a less formal pond structure for trapping coarse sediment;
- **gross pollutant trap** – a sediment trap with a litter rack; and
- **litter boom** - floating device installed in channels and waterways to collect floating litter and oil.

Many proprietary primary treatment devices have been developed.

Secondary treatment measures generally target sediments, with some removal of nutrients and bacteria. Commonly used examples include:

- **filter strips** (also known as buffer zones or buffer strips) - grassed or vegetated areas that treat overland flow, often adjacent to watercourses;
- **grass swales** - grass-lined channels for conveying runoff from roads and other impervious surfaces;
- **extended detention (dry) basins** - basins that store runoff for 1–2 days and drain to an essentially dry condition between storm events. These differ from conventional dry retarding basins, which generally store runoff for up to a few hours;
- **sand filters** - beds of sand (or other similar media) through which runoff is passed. The filtered runoff is then collected by an underdrain system;

- **infiltration trenches** - shallow, excavated trenches filled with gravel (or any high porosity material, including proprietary units) into which runoff, of an appropriate quality, drains to groundwater;
- **infiltration basins** - open excavated basins designed to infiltrate runoff through their floors; and
- **porous pavements** - pavements that allow runoff to drain through a coarse graded concrete/asphalt pavement or open paving blocks, subsequently to infiltrate to the underlying soil (refer to the notes on porous pavements in Runoff Management).

Infiltration should only be adopted for relatively "clean" runoff (eg roof water). Runoff containing high levels of nutrients and micro-organisms should not be infiltrated.

Tertiary treatment techniques aim to remove nutrients, bacteria, fine sediments and heavy metals. The most common technique is the constructed wetland system. This comprises:

- **a pond (or deep water zone):** open water that might have submerged plants, but with emergent macrophytes occurring around the fringe (littoral macrophytes), and
- **a wetland**: an area vegetated with emergent plants, with various vegetation zones being distinguished by depth, frequency and duration of inundation.

A pond can also be termed a water pollution control pond, a wet basin or a deep water zone. Ponds are commonly constructed upstream of a wetland, and can be contiguous within a wetland system. The pond and wetland may, however, be constructed separately to perform different functions

Sand filters may be constructed to include a media layer with an adsorption capacity (eg peat or humus). These could also be classified as a tertiary treatment measure.

Stormwater treatment measures and retarding basins should be located as close to the source as practical. This maximises the effect of managing stormwater quality and quantity throughout the length of the waterway, maximising benefits to downstream aquatic ecosystems, channel form and riparian vegetation. This approach will also eliminate the adverse environmental impacts that commonly occur when stormwater treatment measures are constructed on watercourses in the lower reaches of catchments. The risk of excessive pollutant loadings to receiving waters will also be reduced by this approach.

If a single, large treatment measure is relied on to achieve the desired reduction in pollutant loading, any failure will increase pollutant loadings. If a number of small treatment measures are distributed throughout the catchment, the failure of an individual treatment measure is unlikely to compromise the catchment's target pollution retention. Further, unless upstream flow and water quality controls are provided, restored aquatic habitats may require ongoing restoration.

3.4 Riparian vegetation management

The principal approaches to managing riparian vegetation are retention and replanting with appropriate indigenous species. It is, however, important that the causes of the initial degradation be addressed prior to undertaking replanting. This particularly applies to flow and water quality management and the possible need for structural bank protection works for eroding channels. Alternatively, the replanting could be designed to suit these changed conditions.

3.5 Watercourse and aquatic habitat management

Watercourse and aquatic habitat management activities include: maintaining existing valuable watercourses, rehabilitation of physically degraded waterways and designing "natural" channels in lieu of more conventional lined channels.

These activities can improve the ecological conditions of the waterway, and enhance recreation and aesthetic opportunities. As noted above, the causes of any degradation should be investigated and managed to minimise the impact of the cause prior to undertaking restoration, or the restoration should be designed for these changed conditions.

A range of techniques is available which can enhance the habitat characteristics of degraded watercourses for aquatic fauna. These techniques include: bank stabilisation, bank/armouring protection, and the installation of habitat structures (eg snags).

The design of "natural" channels is an extension of stream restoration. It involves the creation of channels with the attributes of natural watercourses, including:

- a meandering plan form in dynamic equilibrium with site characteristics;
- a main channel with a floodplain (principally in middle and lower reaches);
- a series of pools and riffle zones (rapids); and
- riparian and floodplain vegetation.

The location of stormwater discharge points to aquatic environments should also be carefully considered. Stormwater pipes discharging to tidal wetlands and estuarine environments with seagrasses can alter the salinity patterns by the discharge of "fresh" water. They can also effectively represent a "point source" of pollution to these areas. A similar situation can arise in sensitive freshwater environments such as wetlands. Appropriate energy dissipation should be undertaken for any stormwater pipes discharging to natural watercourses. This is to avoid a "jet" of stormwater causing erosion.

Maintenance of natural watercourses should be undertaken in a manner that is sensitive to the natural environment. This can include timing of maintenance activities to avoid the seasonal movement of any aquatic fauna.

3.6 Urban bushland management

Areas of urban bushland are frequently affected by the discharge of urban stormwater. This impact is caused by increased and more frequent stormwater flows, increased nutrient levels and weed seeds and propagules, leading to erosion of drainage lines and the establishing of weeds within bushland areas. To minimise these impacts, stormwater managers should:

- minimise the creation of new stormwater flow paths;
- control the velocity of stormwater flows entering bushland; and
- reduce the levels of stormwater pollutants discharged into bushland areas.

3.7 Bridges and culverts across waterways

A number of issues should be considered when designing bridges or culvert crossings of watercourses or estuaries to ensure their impacts are minimised. These include:

- designing the structure to enable any significant upstream and downstream movement of fish, aquatic insects and terrestrial fauna to occur;
- minimising scour downstream of the bridge or culvert. Higher downstream flow velocities may scour the channel, causing erosion and habitat loss;
- acknowledging that watercourses are in a state of "dynamic equilibrium" and can change their location and form under natural conditions. Waterway crossings may restrict this dynamic process or the crossing may be undermined; and
- providing an appropriate waterway area and geometry for estuary crossings, to minimise the impact on upstream tidal conditions. For example, box culverts can provide better flushing characteristics under these conditions than pipe culverts.

3.8 Water Sensitive Urban Design

New urban developments should be based on water sensitive urban design principles. These principles are based on minimising the impacts of development on the total water cycle and maximising the multiple use benefits of a stormwater system.

The overall goals of water sensitive urban design are:

- preservation of existing topographic and natural features, including watercourses and wetlands;
- protection of surface water and groundwater resources; and
- integration of public open space with stormwater drainage corridors, maximising public access, passive recreational activities and visual amenity.

The broad principles of water sensitive urban design include:

- minimising impervious areas;
- minimising use of formal drainage systems (eg pipes);
- encouraging infiltration (where appropriate); and
- encouraging stormwater reuse.

Water sensitive urban design principles can be adopted at a range of development scales, including:

- the overall extent of proposed development areas;
- the road and block layout within a development; and
- development forms on individual blocks.

Potential water sensitive design techniques include:

- inclusion of natural habitats (eg watercourses) within the development area, primarily within open space areas. This includes the provision of buffer zones adjacent to watercourses and other waterbodies;

- integration of major (above ground) stormwater systems as positive features within the urban design rather than purely functional elements to be 'hidden' (eg avoiding back fences adjacent to drainage reserves);
- adoption of water sensitive road development standards. These can include reduced pavement widths and the use of grass swales in place of kerb and gutter and piped stormwater drains;
- use of compact development forms. For example, reducing individual block sizes and increasing communal open space (and stormwater drainage) areas to achieve the same density as a standard residential development; and
- water sensitive car park design. This can include substitutes for impervious surfaces such as pavers or reinforced grass, particularly in infrequently used parking areas. Runoff can also be managed by grass swales instead of kerb and gutter and piped drainage systems. Infiltration of runoff can also be considered.

4 CHALLENGES TO IMPROVING STORMWATER MANAGEMENT

There are a range of financial, institutional, technical and management challenges that stormwater managers may need to recognise and address if the stormwater management objectives noted above are to be satisfied.

4.1 Institutional arrangements

Stormwater management is rarely the responsibility of one organisation within a catchment. Organisations that may play a role can include:

- a local council;
- a water authority;
- a road authority;
- a rail authority;
- catchment management bodies;
- a state or territory environment protection authority;
- a state or territory natural resources management authority;
- a state or territory planning authority;
- a national parks management authority; and
- land or property developers and builders.

The roles of some of these authorities may be undertaken by the private sector.

These organisations commonly have separate roles, responsibilities and management priorities. Stormwater management may be a core activity of only a few, if any of these organisations. Past experiences may influence the way that these stormwater managers make decisions. Achieving a common vision for all stormwater managers within a catchment can be a challenge.

The preparation of a Catchment Management Plan on a cooperative basis by all stormwater managers within a catchment can help address these institutional issues. The implementation of the plan could be guided by a steering committee, with representatives from all relevant managers. A catchment management body could also take a guiding role.

An additional challenge can occur in new developments. Land developers can install appropriate water quality controls during the construction phase of a development. These may then be removed when the responsibility for the land and stormwater systems is handed over to the local council. Often the building phase is not complete at this time, resulting in elevated pollution loads until building is complete. This highlights the need for appropriate management of the building phase by both builders and the local council.

4.2 Funding constraints

Funding for stormwater management by stormwater management authorities has often focused on the installation and maintenance of drainage infrastructure. Funding to broaden the current approach to stormwater management, and adopt a more environmentally-sensitive and ESD-based approach may not be readily available from existing revenue sources. Structural stormwater management controls tend to be relatively expensive, both in capital and operating costs. Non structural source controls tend to be lower cost.

Another funding challenge can arise when a downstream stormwater manager is required to pay for management practices that are necessary to manage the high flows and/or pollutant loads from upstream areas under the control of other stormwater managers.

There are two broad approaches that can be adopted to address this issue, separately or together:

- increase revenue, possibly by additional rates or levies. These are more likely to gain community support if the community has been closely involved in the stormwater planning process and can see where their money will be spent. Grant funding is an alternative income source; and
- re-allocation of existing funding. Local councils and other stormwater managers may have separate budgets that relate to broader stormwater management. These can include waste management, road maintenance, parks and garden maintenance, and community relations. A multi-disciplinary approach to stormwater management can draw on resources from these and other sources. Improved stormwater management practices can often be combined with existing programs at minimal cost.

Any special stormwater rates or levies could be based on a "generator pays" principle. Higher rates could apply to landholders generating higher runoff volumes or pollutant loads. This could be based on the impervious areas on a block of land. Rebates could be provided for the installation of rainwater tanks or blocks that minimise impervious areas connected to the drainage system. The distribution of costs should be equitable and legally sound.

Other options may include the development of catchment-based or regional stormwater management programs. This may include education campaigns or catchment audits of industrial or commercial premises. This can reduce the cost to the individual stormwater managers involved. A catchment management forum and focus can help here. It is unproductive to have one group repair the damage another group is causing as this does not lead to change in poor practices.

Preparing Stormwater Management Plans on a catchment basis through a co-operative process, involving all stormwater managers, can result in the identification of the most cost-effective and equitable management practices being implemented. It can enable a source control approach to be adopted, where stormwater is managed as close to the source as possible, reducing impacts on downstream managers.

4.3 Management skills

The shift to a more environmentally sensitive and integrated catchment approach has necessitated new and broader skills for managers, as stormwater management becomes an increasingly multi-disciplinary field. Some councils and other stormwater managers may not have the skill base, in both technical and managerial terms, to identify and successfully implement multiple-objective stormwater management programs.

Continuing education, the use of consultants, the use of other resources within a council (eg environmental and community relations officers), or sharing of technical resources between stormwater managers can help address this issue.

4.4 Uncertainty

A degree of uncertainty exists with many aspects of stormwater management, including:

- pollutant generation from different land uses;
- the response of waterways to pollutant loadings;
- aquatic ecosystem responses to changed water quality, flow and other conditions;
- the response of channel morphology to changed flow regimes;
- the effectiveness of stormwater treatment measures, community education programs and other management practices;
- water quality and hydrological modelling;
- uncertainty in estimating infrequent floods used in flood mitigation and any corresponding risk analysis;
- water quality monitoring (accurate and representative monitoring can be expensive, particularly as pollutant concentrations can vary over time); and
- climatic and seasonal variability.

Despite this uncertainty, there is ample evidence that urbanisation results in negative impacts on aquatic ecosystems. The current difficulties in quantifying these impacts should not prevent actions being implemented to minimise these impacts, in accordance with the precautionary principle of ESD. It is important that this uncertainty is accommodated within the stormwater management planning process.

Approaches to address this challenge may include:

- following an adaptive environmental management approach. This may involve implementing the best known solution to a problem, monitoring the effectiveness of the solution and refining it if necessary;
- undertaking or encouraging independent monitoring of stormwater treatment devices and disseminating the monitoring results; and
- including a monitoring component in stormwater projects. This can apply to both structural solutions and community education programs.

The NWQMS Guidelines such as the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (2000)* and *Guidelines for Water Quality Monitoring and Reporting (2000)* can assist in defining these aspects.

4.5 Public involvement

Community involvement in stormwater management is important to enable the community to have "ownership" of both the issues and the solutions. An approach where management solutions are developed in isolation from the community and then imposed "from above" is unlikely to be successful or sustainable.

Achieving effective community consultation in the stormwater management planning process can be a challenge. Holding a structured public meeting may be ineffective in reaching a significant section of the community. More "on-ground" consultation processes may be required (refer to the Community Education part of section 3.3 for further information).

Raising the profile of stormwater issues in the community is likely to encourage greater involvement in stormwater planning. Programs such as 'adopt-a-drain' for industries and schools or community involvement in simple stormwater monitoring programs can help in this regard.

There are also many situations where urban communities have been the primary source of the vision and impetus in recovering urban waterway values. Stormwater management agencies have provided an important technical information provision role in these situations.

4.6 Changing management framework

The management framework in which stormwater managers make decisions often changes over time. The policy and legal framework can change, as can community expectations. It is important that stormwater managers recognise this and adopt an adaptive approach to stormwater management.

4.7 Urban growth impacts

Growth of urban areas, increased urban density, industrial development, and failure of ageing sewers have commonly led to increased urban stormwater pollution of local and downstream ecosystems. Inadequate provision for stormwater drainage has led to flooding problems from increased peak flows, greater flow volumes and altered flow patterns.

It is important that the impacts of urban development be assessed as part of the land use planning process. This will enable the planning authority to make a more informed decision on the benefits and environmental costs of a proposed development.

The *Green Cities - Strategy Paper #3* (May 1995), published by the Department of Housing and Regional Development, discusses urban water quality problems and some directions for the future.

Increased nutrient and contaminant loadings lead to more apparent changes in ecosystem composition and structure. Cumulative loading of pollutants from catchments should be reduced to levels consistent with downstream sustainability. Development should be guided by a co-ordinated approach associated with:

- catchment based planning and management;
- integrated urban land use planning;
- integrated water cycle management; and
- infrastructure provision and management practices which reflect social, economic and environmental values.

5 CATCHMENT MANAGEMENT FRAMEWORK

5.1 Catchment management plans

Rarely does urban land use occupy the entire catchment. Consequently, there is a need to consider the role of diffuse discharges from a range of land use sectors, together with municipal, industrial and agricultural wastewater point source discharges, in securing the protection or restoration of downstream water quality and environmental values. This planning framework then provides the catchment context for the management of individual land use sectors, including urban land use, across the catchment.

5.1.1 Primary objective of catchment planning

The key objective of catchment planning is to achieve ecologically sustainable use and management of water and land resources across the catchment, and securing the physical, economic and social well being of communities within the catchment. The use of Catchment Management Plans have been adopted as a vehicle for:

- partnership of stakeholders in resource management decisions and action;
- integrated planning and management of water and related land resources;
- securing agreement on environmental and use values of waterways to be protected; and
- identification of collective actions required to meet a range of community physical, social and economic needs in a manner consistent with the protection of the agreed environmental and use values.

The development of Catchment Management Strategy Plans is encouraged under the NWQMS *Implementation Guidelines*(ANZECC & ARMCANZ, 1998) and the Council of Australian Governments Water Reforms (Council of Australian Governments Communique on Water Resource Policy, 1994).

5.1.2 Scope of Catchment Management Plan considerations

Catchment Management Plans do not replace the role of Local and Regional Plans in implementing a number of the strategies contained within the Catchment Management Plan. It is the basis for enabling stakeholders to collaborate in the identification of:

- the range of environmental and use values of waterways across the catchment to be protected (Section 7.2.4);
- the current flow and pollution issues and the management implications, across the range of land use sectors (including urban land use);
- the integrated catchment wide action necessary to secure a range of environmental, social and economic benefits in respect to waters across the catchment; and
- the principles guiding the implementation of the catchment actions relative to each of the land use sectors (including urban areas) and point source discharge categories across the catchment.

Decisions on land use, development form, landscaping, open space provision and location, and recreation facilities have a strong bearing on urban water management opportunities and constraints.

Consequently, in an integrated land and water based catchment approach, there are opportunities to secure substantial social, environmental and economic benefits as compared to a separate consideration of land and water aspects. A Catchment Management Plan can provide the instrument for this integration.

Plan development will focus on whole of catchment issues, comprise a broad range of objectives, and involve extensive community participation.

5.1.3 Administrative framework

State governments have adopted a range of administrative frameworks enabling the development of Catchment Management Plans, from legislation establishing catchment based water management agencies, to legislative or administrative requirements (and funding) for development of plans by local government authorities sharing catchments, to administrative provisions for establishment of catchment management advisory committees.

In addition, there are many examples where a local government authority, either independently in situations of sole occupation of a catchment, or in collaboration with adjoining authorities where a catchment is shared, has undertaken the development of Catchment Management Plans and best management practice guidelines. For example: Moreton Bay catchment, Port Phillip Bay catchment, Upper Murrumbidgee catchment (ACT and sub-region), coastal estuaries, Metropolitan Adelaide urban catchments, and Swan Canning and estuary catchment.

6 STORMWATER MANAGEMENT PLANS

6.1 Overview

The primary purpose of Stormwater Management Plans is to identify actions that will improve the environmental management of urban stormwater and protect the environmental values of receiving waters.

Urban stormwater is just one of a host of complex urban planning issues having broad social, economic and environmental implications for urban communities. Substantial urban planning, legislative and administrative frameworks are already in place, including community consultation, to deal with these issues.

There is a need to integrate urban stormwater management strategies into this urban planning and management framework. The recent growth in concerns about the provision and quality of urban open space, including drainage corridors, together with community concerns about the water quality impacts of urban stormwater, have highlighted the importance of urban stormwater strategies as part of urban planning. The Australian Model Code for Residential Development deals with stormwater as an integral part of urban design. The issues of urban water quality are described in the Department of Housing and Regional Development's *Green cities - Strategy paper #3 (1995).*

The planning and provision of urban stormwater infrastructure is largely the responsibility of local government. At times, these urban services are provided by the private sector. Planning controls, engineering standards and sub-catchment based drainage schemes are the principal instruments guiding the provision of these services.

Implementing urban Stormwater Management Plans is the key to improved quality of stormwater particularly in existing urban areas. These plans rely on the application of best management practices and the *Water Quality Guidelines* and the *Guidelines for Monitoring and Reporting (2000)* should inform their development.

6.2 Best practice

Stormwater Management Plans are a way of helping councils and other local authorities recognise the impacts of activities within their boundaries, and to develop best practice management strategies and programs.

Stormwater Management Plans reflect the obligation of every authority to adopt a best practice approach to the environmental management of urban stormwater. The achievement of best practice should ensure that (a) decisions in relation to new development (including redevelopment) are made with the implications for stormwater impacts on receiving waters taken into account rather than overlooked, and (b) remedial measures (both structural and non-structural) are undertaken in a cost-effective, integrated and coordinated manner. Best practice environmental management of urban stormwater requires the integration of a range of measures within a defined program, as pictured in **Figure 4**.

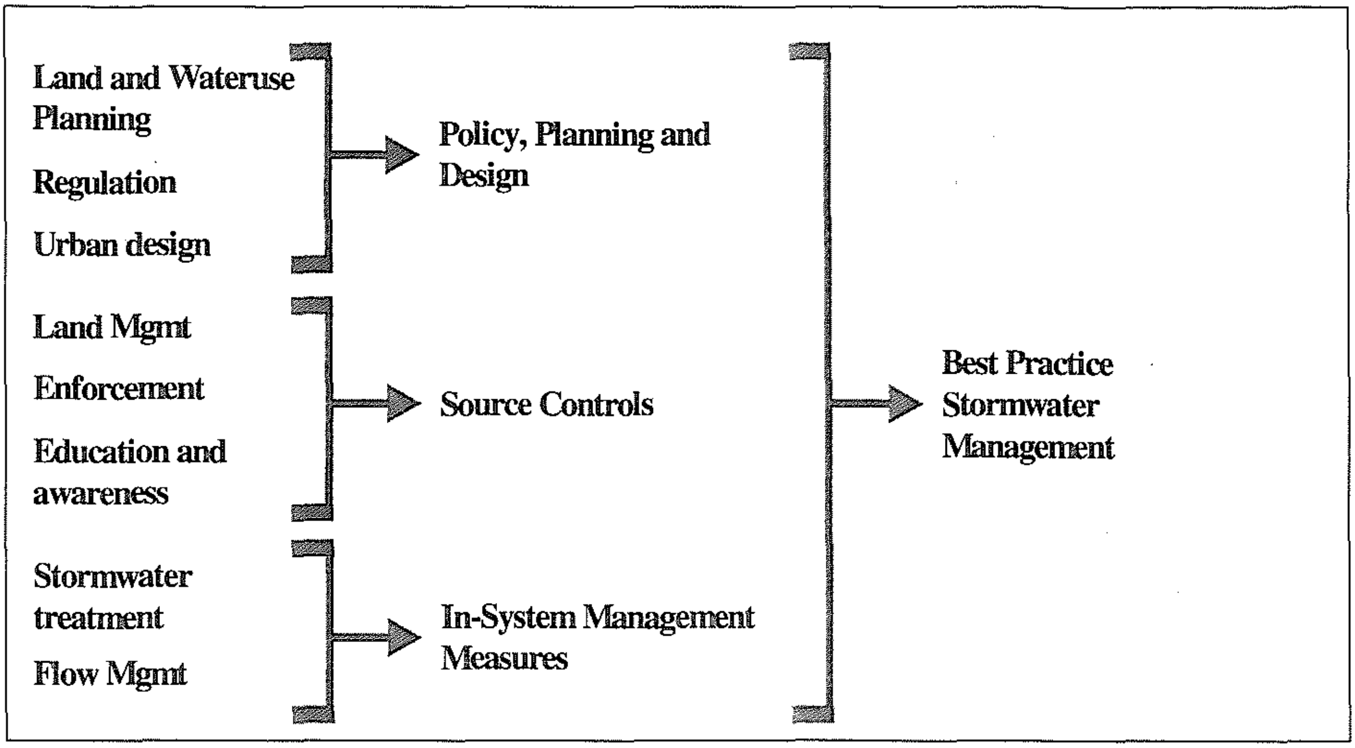

Figure 4 - Best practice environmental management of stormwater requires integration of a range of measures (Adapted from Victorian Stormwater Committee (1999))

These measures should increase the likelihood that:

- there is clear commitment to improved stormwater management;
- stormwater management objectives are incorporated into the statutory planning framework and other relevant plans, strategies and policies affecting land use and land management decisions;
- new urban infrastructure meets environmental performance objectives consistent with agreed sustainable load/concentration targets;
- relationships between agencies and local authorities are strengthened to deliver coordinated programs and ensure consistent priorities;
- the community is involved in stormwater management; and
- performance monitoring allows for feedback and improvement of the plan.

6.3 Adaptation to local circumstances

There is great variability in the physical, chemical and ecological processes which occur within and between catchments. Responsible authorities must deal with a range of management objectives, problems, issues and community expectations within catchments.

Development and implementation of Stormwater Management Plans must accommodate these circumstances as well as local legislative and administrative arrangements.

Each authority must make its own judgements about balancing priorities, conflicting objectives and allocating resources. Stormwater Management Plans should provide a framework for making these judgements, recognising the consequences of decisions and being accountable for performance.

6.4 Management objectives

The key objective in stormwater management is to identify a range of best practices for improving the environmental performance of urban stormwater systems that will assist in protecting the environmental values and beneficial uses of waterways and coastal waters. This objective may be secured by application of a range of actions, including:

- raising community awareness regarding stormwater management opportunities and benefits, and the provision of technical information guiding improved practice;
- the integrated planning, development and management of water and urban land on a catchment or sub-catchment basis;
- the partnership of stakeholders in resource management decisions and action; and
- identification of collective actions required to meet a range of community physical, social and economic needs in a manner consistent with the protection or restoration of the agreed environmental and use values, including the use of regulation and the provision of stormwater management infrastructure.

Where urban land use is the major land use across the catchment, the development of the Stormwater Management Plan may be undertaken integrally with the development of the Catchment Management Plan.

6.5 Management hierarchy

As noted in Section 3.1, stormwater management planning should be based on the following hierarchy:

1. **Retain and restore valuable ecosystems**: retaining or restoring (if degraded) existing valuable elements of the stormwater system, such as natural channels, wetlands and riparian vegetation;

2. **Source control: non-structural measures**: non-structural techniques for limiting changes to the quantity and quality of stormwater at the source;

3. **Source control: structural measures**: constructed management techniques installed at or near the source to manage stormwater quantity and quality; and

4. **In-system management measures**: constructed management techniques installed within stormwater systems to manage stormwater quantity and quality prior to discharge into receiving waters.

Best practice encourages an integrated approach incorporating these principles. Source controls can ideally prevent many of the pollutants from reaching the stormwater system, however, in practice a combination of source and structural controls are usually required to achieve an improvement in stormwater quality.

> Protecting or restoring the values and uses of urban water environments requires an integrated approach directed at managing the **volume and rate** of catchment run-off, the **quality** of the run-off, and the **habitats** necessary for supporting a healthy aquatic community.

Flood prevention and public safety remain as fundamental objectives of stormwater system planning and design. Stormwater quality measures should in no way compromise these objectives. In fact, many measures designed for stormwater quality control have inherent water quantity management functions (and vice versa).

6.6 Scope

Stormwater Management Plans should provide an integrated urban land use and drainage management strategy on a catchment or sub-catchment basis, which:

- describes the catchment or sub-catchment area
- identifies stakeholders and partnership mechanisms
- outlines agreed values, issues and management objectives
- identifies management strategies for:
  - land and water use and practices
  - land use and form
- addresses implementation instruments and programs, including:
  - education and training
  - planning
  - infrastructure provision
  - operation and maintenance
  - regulation
  - economic incentives
- addresses assessment and performance review, including:
  - monitoring of values and conditions
  - monitoring of strategy implementation
  - review timeframes

7 DEVELOPING STORMWATER MANAGEMENT PLANS

7.1 Process

Stormwater management planning should aim to:

- identify proposed management actions which will cost-effectively address the stormwater issues of a catchment or sub-catchment; and
- define mechanisms and arrangements for the implementation of these actions, including management, funding, performance review, monitoring, reporting and future revision of the plan.

Stormwater management planning should be based on the general model of resource management planning illustrated in **Figure 5**. The process of developing plans should:

- identify the values and conditions to be protected or restored;
- identify threats to these values and conditions, and management objectives addressing these threats;
- identify and assess management options to address management objectives or threats;
- adopt preferred management options, including management objectives and targets;
- identify means of implementing management options; and
- identify an implementation and performance review program.

This sequence of the planning process is important in ensuring management effort is effectively focussed on protection or restoration of the significant and priority catchment values. Attempting to address a long list of possible stormwater issues, without reference to how these issues affect achievement of objectives, is unlikely to be cost-effective.

It is important that the Stormwater Management Plans:

- encourage community involvement in stormwater management;
- encourage the preservation of valued existing elements of the water environment;
- maximise the control of stormwater runoff at source;
- identify and prioritise an appropriate mix of cost-effective stormwater management practices to suit the particular opportunities, constraints and requirements of a catchment; and
- incorporate monitoring procedures for feedback and improvement of the plan.

Identifying the values, management objectives, and key ecological/hydrological processes should be undertaken as part of the catchment planning process. Catchment Management Plans should identify the key uses and values across a catchment and establish water quality targets to sustain them. Urban stormwater is just one of many issues which may impact on catchment values and uses. Therefore, it should preferably be considered in context with these other issues.

In many areas, regional values, uses and water quality targets have not been established as part of a Catchment Management Plan or other planning process. Where these are not in place, the stormwater management planning process may need to incorporate an additional stage in order to identify these values and targets.

When setting specific water quality objectives for the identified environmental values, refer to the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (2000)*.

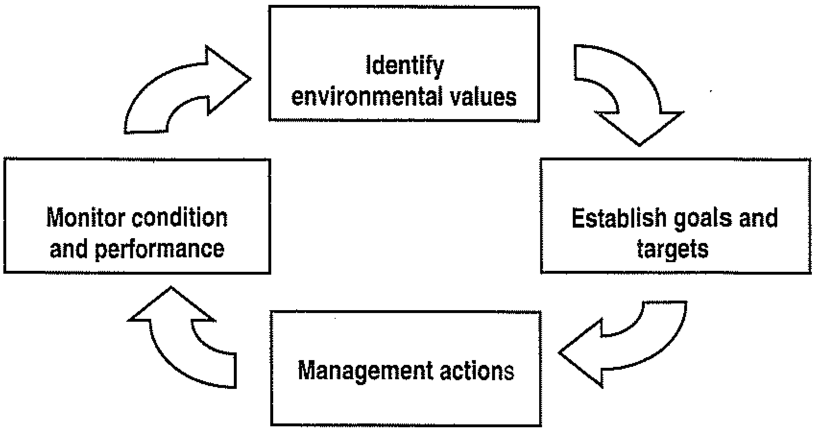

Figure 5 - Steps in resource management (adapted from *National Water Quality Management Strategy – Implementation Guidelines (1998)*

7.2 Essential elements in developing plan

7.2.1 Establish framework

The first task in the process can involve establishing the overall framework for the plan and the plan preparation process. This may include establishing:

- the purpose of the plan;
- the scope of the plan;
- responsibilities for stormwater management within the catchment;
- the boundaries for the plan (eg catchment/sub-catchment, municipality, individual township);
- public and other stakeholder consultation processes; and
- relevance of the findings or recommendations of any other relevant plan.

7.2.2 Identify stakeholders and partnership mechanisms

Lack of technical knowledge is only one obstacle to improved stormwater management. More often, the main constraint is a lack of agreement that improved environmental performance is important, or a lack of consensus on stormwater management priorities. 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 agencies and other stakeholders.

Commitment is achieved mostly through involvement of a wide cross section of authorities, key agency representatives, and other stakeholders in the planning process and in the assignment of accountabilities.

> It is important for those with a role in improving the environmental management of stormwater to share in the process of developing the plan. This means involving representatives from across functional areas of authorities, key agencies, and other stakeholders.

Many stakeholders have their own specific interests in decisions on urban drainage and drainage corridor management. Some examples of the types of stakeholders are listed in **Table 2**.

Table 2 - Possible stakeholders and their interests

Stakeholder type	Interest
Property owners adjacent to drainage corridors	Protection of property from flooding, local area amenity, and recreation opportunity, opportunities to incorporate stormwater treatment measures.
Environmental groups	Identification of environmental values, impacts of urban stormwater.
Drainage authorities	Efficient provision and operation of drainage services, drainage infrastructure standards, stormwater treatment, operation of the drainage system, receiving water management, risk and liability.
Sewerage authorities	Sewer overflows, treatment plant discharges, stormwater infiltration.
Environmental regulatory authorities	Designation of environmental values and uses, water quality targets. The licensing of discharges. Pollution prevention.
Natural resource management agencies	Protection of biota, habitat, natural communities and the balance and equitable use of natural resources.
Road authorities	Minimising pollution from roads and construction activities, ensuring road surfaces are quickly drained of stormwater.
Business	Adoption of best practice to minimise pollution.
Town planners	Land use planning, controls on land users, urban form, infrastructure requirements.
Infrastructure engineers	Engineering standards, minimisation of liability, risk and costs.
Operations	Service/maintenance standards, pollution response, enforcement, cost minimisation.

7.2.3 Identify activities and conditions

A critical stage in the planning process involves the gathering of information to support the rest of the planning process and ensuring the active involvement of the key participants.

During this inception stage, it is important to gain an understanding of the extent to which existing and potential future activities may threaten receiving environments, and how well existing management processes within local authorities and other agencies deal with stormwater issues. Examples of typical stormwater issues and their origins are listed in Appendix 3.

It is important to use the inception stage to establish how a review of management processes will be undertaken. The review should cover planning, regulation, education, enforcement and operations as well as any existing structural approaches to managing stormwater impacts as outlined below in **Table 3**. The relationship between the local authority and other agency activities should also be examined. This information will contribute to the formulation of management strategies later in the planning process.

Table 3 - Review of management processes

Planning	Planning scheme, planning policies, permit conditions
Operations	Specifications for service delivery (eg waste collections), asset maintenance activities (eg local roads), depot operations
Regulation	Integration between policy, planning controls, local laws and enforcement activities
Education	Programs aimed at those involved in activities with potential to affect the stormwater system
Structural measures	Incorporation of structural measures into buildings, roads and drainage systems to reduce environmental impacts

Document the nature of urban land use

It is important to compile an overall picture of land use activities. This is best represented by a plan of land use zones covering the area. However, local knowledge of differences between land use types must be applied. For example, to distinguish between old and new industrial areas which may differ in the types of industries and the quality or standard of associated infrastructure and therefore the level of impact on stormwater.

In addition to site specific activities there are a number of transient activities, such as building construction, which must be accounted for. Other examples include building maintenance activities, home car servicing and so on. Transient activities can be significant polluters and are difficult to control.

Document the stormwater system

It is also important to document the stormwater system. This is best presented as a map with physical features showing the catchments (main catchments and sub-catchments), the drainage system (main drains) and the receiving environments which might include open water courses, wetlands, water bodies and so on.

7.2.4 Identify values and objectives

Environmental values are particular values, or uses of the environment, that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution waste discharges and deposits.

There are a number of techniques available for assessing catchment and water body values that relate to stormwater management. A preliminary assessment of these values should be undertaken, which may be refined following receipt of additional information. It may be useful to establish these values by holding a stakeholder workshop to obtain community input into the identification of the values. These values may also be mapped over the catchment area.

Catchment values may include ecological values (aquatic fauna and flora, terrestrial fauna, urban bushland), social values (public health and safety, recreational use of waters, visual amenity) and economic values (water use, aquaculture, stormwater reuse etc).

Following identification of the values of a stormwater system and its catchment, management objectives can be developed to protect these values (refer to *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (2000)).* Stormwater management objectives aim to define the outcomes we seek to achieve in our management of stormwater to protect or restore the identified catchment or waterway values.

It is likely that three sets of objectives will be appropriate. The first may be long-term objectives (effectively a 'vision' for the catchment) and the second being more short term, quantifiable objectives. These short-term objectives can define what the plan should seek to achieve, and may be the basis for evaluating the performance of the plan at the end of a certain period (eg 3 years).

The third set of objectives relate to new development. The stormwater management objectives for new development aim to define the stormwater outcomes which will be required of new development within the catchment, including redevelopment of urban sites. These 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 at new development sites.

These objectives should be defined in terms of (and linked to) the catchment value(s) to which they relate. These objectives should be consistent with and incorporate the principles of ecologically sustainable development, as appropriate.

7.2.5 Identify threats to values, conditions and objectives

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

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

In arriving at a significance rating, consideration should be given to the magnitude and frequency of occurrence (eg quantity of pollutant load generated or severity of pollution spills and frequency) and the level of public concern about these. There will seldom be data available on the impact of these activities on receiving environments. However, an informed assessment can be based on professional judgement and experience as well as local knowledge, history of spills, complaints, age of infrastructure and so on.

7.2.6 Identify management strategies

A range of strategies and actions to manage urban stormwater threats to receiving water values should be considered. These should take into account local, regional or catchment-wide impacts and benefits, and will include a mix of strategies related to:

- at-source management strategies such as planning and design measures;
- in-transit structural controls; and

- receiving water management.

Chapter 3 identifies some of the responses that may be implemented as part of these strategies. These responses include a variety of planning, regulatory, infrastructure, source control, and educational approaches. The selection and design of any specific management approach will be strongly influenced by local conditions, such as sustainable load issues, runoff responses to land use change, receiving water responses to pollutants, and peakflow considerations. However, as noted in **Section 4.4 Uncertainty** managers may need to act on the basis of the precautionary principle as a degree of uncertainty exists with many aspects of stormwater management.

It may be necessary to undertake preliminary design of strategies as a basis for community assessment of options and to test their technical and administrative efficiency. Preliminary design should consider:

- protecting downstream environmental values via sustainable loadings or concentrations;
- allocating sustainable loadings across catchment sources, eg wastewater, urban stormwater, rural/agricultural runoff etc;
- determining best management practices;
- preliminary sizing and costing of components necessary to ensure compliance with sustainable loading allocated to stormwater runoff;
- local environmental quality issues; and
- changing community expectations and increased stringency of requirements.

7.3 Local area development plans

Local area development plans are a common requirement of State and Local Government Planning approval processes. Many jurisdictions require the consideration of utility services (drainage, sewerage, water supply) as part of these plans or as part of stormwater master plans. Some jurisdictions may require integrated and comprehensive treatment of bio-physical landscape components, along with the proposed land use change and design principles. Drainage authorities typically require that these plans are consistent with Stormwater Guidelines or drainage standards, which set out system design requirements, including major and minor flow pathways. These 'at-source' techniques are addressed as Best Management Practices (BMP) or Water Sensitive Urban Design Principles.

Integrated land and water planning at the local residential, commercial and industrial area offers opportunities for significant enhancement of block, streetscape, and precinct landscape and water use values, and a significant reduction in peak discharge and pollution emissions from the site.

Previously, drainage authorities undertook the development of a main drainage master plan, as the basis for meeting their service provision obligations. With the shift in role of the drainage corridors from single purpose 'drainage' function to multi-purpose use, a need for greater integration across related jurisdictions has occurred. Local development plans should identify opportunities to secure multiple water supply, open space, recreation and conservation benefits.

These plans are emerging as a critical tool to assist jurisdictions with shared responsibilities for service provision or management within drainage corridors to coordinate their planning.

Integrated land and water planning at the suburb or district level offers opportunities for significant enhancement of urban waterways as:

- corridors of significant open space and landscape values;
- people and wildlife movement corridors;
- attenuation of flows and interception of stormwater pollutants systems;
- creation of valuable recreation and conservation wetlands, ponds, lakes.

7.3.1 Development objectives

Requirements for development may be expressed as qualitative or quantitative performance objectives, service or infrastructure standards or guidelines. These may be contained in Catchment Management Plans usually as receiving water quality objectives or discharge requirements. Or they may be contained in a Stormwater Management Plan. The Development Plan should identify how these objectives or requirements will be achieved.

7.3.2 Administrative framework

There is a diverse array of administrative procedures bearing on this component. All States and Territories have planning structures prescribing procedures and standards to be incorporated into local government urban strategy or policy plans.

Local government authorities usually maintain urban strategy and policy plans and local area development plans as the basis for development approvals. There has been a significant shift away from prescribed management measures in recent years to a more strategic and guidelines focused approach. The development of *Australian Model Code for Residential Development* (AMCORD, 1995) is an example of this shift. The Code incorporates extensive material on integrated stormwater management practices.

Stormwater, landscape and recreation management groups within local government authorities maintain strategy and master plans as the basis for integration with land use planning, and the effective provision of services.

State environmental agencies may establish environment protection policies and requirements for management plans under State environmental legislation. Statutory environment policies are more often related to catchment plans than local development plans. So catchment plans and statutory environment protection policies may designate development requirements in terms of qualitative or quantitative performance objectives.

As noted above, there are many examples where a local government authority, either independently or in collaboration with adjoining authorities, has undertaken the development of Stormwater Management Plans and Best Management Practice guidelines. Some examples include:

- Stormwater Committee Victoria (1999), *Urban Stormwater: Best Practice Environmental Management Guidelines.*
- New South Wales EPA (1997), *Draft: Managing Urban Stormwater: Council Handbook.*
- Water and Rivers Commission (1998), *A Manual for Managing Urban Stormwater Quality in Western Australia.*
- Department of Natural Resources and Department of Environment (Queensland) (1998), *Stormwater Quality Control Guidelines for Local Government.*

7.4 Assessing alternatives and selecting preferred options

The achievement of 'best practice' will depend on the successful integration of a number of strategies and actions to protect stormwater quality across functional areas within the authority and coordination with other agencies and stakeholders.

Management options should be evaluated against criteria of cost, effectiveness in the long-term in protecting or enhancing values, opportunities for implementation, and capability of the authority or other agencies to implement. Acceptance by the community should also be considered.

7.4.1 Developing actions

Where particular management measures or options rate highly against the above criteria, detailed actions should be formulated. Where relevant, these actions should include:

- suggested changes to the land use planning framework, urban development guidelines, infrastructure standards, etc;
- suggested changes to specifications for service delivery;
- the type, location and indicative cost of structural treatment measures;
- target audiences for education and training programs or enforcement;
- specific locations for targeted programs (a particular industrial or commercial area or receiving environment);
- the need to further investigate the extent or nature of stormwater threats;
- the need for coordination with others;
- responsibility for leading implementation (ie council department, agency or other); and
- suggested performance measures and reporting framework.

There is also likely to be a need for a strategy to address the inclusion of general policies and objectives into an existing authority corporate plan and land use planning framework. This strategy should also deal with the integration of actions across functional areas within the authority, and any arrangements for coordination with other agencies.

Prepare and exhibit a draft plan

A draft Stormwater Management Plan should be prepared and made available for review by stakeholders including the community. An adequate exhibition period should be provided for the public to access and review the draft document.

Prepare final plan

Following receipt of comments from stakeholders on the draft plan, a final stormwater management plan can be prepared.

7.5 Implementing Stormwater Management Plans

Preparation of Stormwater Management Plans clearly constitutes only the first step towards the ultimate aim of improved environmental outcomes. It is essential for stormwater managers to also focus on the implementation of the plans.

It is important for Stormwater Management Plans to be viewed as 'live' documents, which are actively consulted, reviewed and revised. Stormwater managers should adopt a model of 'continuous improvement' in the progressive refinement of Stormwater Management Plans.

Stormwater managers should actively monitor the effectiveness of the plan, and report on the findings of that monitoring to the community. Such monitoring and reporting is considered to form an integral component of the 'continuous improvement' of Stormwater Management Plans.

The preparation of a Stormwater Management Plan can be considered as part of a stormwater management process (or system) for a catchment. This is illustrated in **Figure 6**. This management process can be based on the Environmental Management System approach outlined in the ISO 14000 series of standards.

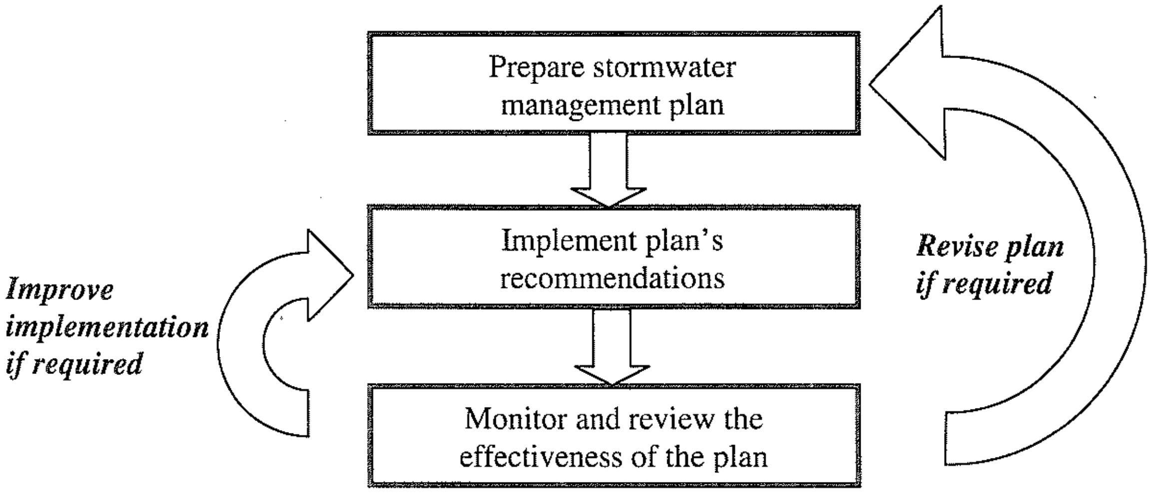

Figure 6 - The Stormwater management process

It is important to note that:

- the preparation of the plan is only one part of the process;
- the review of the implemented practices can lead to revisions to the plan; and
- the stormwater management planning process is never 'finished' (ie improvements can be made to the plan using the results of the monitoring and review process).

Public reporting can include both a progress report on the plan's implementation and reporting on the environmental outcomes achieved by the plan's actions. This reporting could be included in state-of-the-environment reports, regular newsletters, and/or on notice boards in public areas near watercourses. This public reporting is important if community support for the plan is to be maintained. Feedback from the public can also be requested through this process, which can assist in the monitoring and review of the plan.

8 PERFORMANCE REVIEW

Scientifically rigorous monitoring of stormwater discharge quality and pollutant loads is complex, requiring careful design, establishment of stream gauging and auto-samplers, and multiple sampling over a number of events. The *NWQMS Guidelines for Water Quality Monitoring and Reporting (2000)* provide information guiding the design of monitoring programs, selection of indicators, and location and frequency of sampling. The Guidelines include some low cost monitoring techniques capable of identifying impairment of biota and pollutant categories.

In view of the financial and technical resource demands of event based monitoring, and the broad uniformity for similar land uses and management practices regionally, consideration should be given to collaboration across local government areas and with State government agencies, in establishing joint monitoring programs.

As part of implementation of the Stormwater Management Plan, authorities should identify specific milestones and objectives which enable monitoring and review of the implementation process. These milestones should relate to:

- achieving improvements in specific receiving environment values which are currently threatened; or
- reductions in specific stormwater threats.

Performance in implementing the Stormwater Management Plan should be assessed annually and reported back to the community and stakeholders.

Where resources are available for long term scientific monitoring, programs should be carefully designed. There may be a need to review existing baseline data before developing a monitoring and review program. The plan should identify data deficiencies and monitoring requirements. This monitoring differs from the monitoring/auditing of the plan's implementation.

Monitoring enables review of:
- the plan's performance in reducing urban stormwater pollution;
- the water quality and ecology response of protected downstream waters; and
- community perception and acceptance of the strategy.

Three distinct monitoring categories are involved. These are:
- a broad characterisation of physical, chemical and biological components necessary to characterise the geomorphology, hydro-chemistry and ecology of systems, and determine their significance;
- analysis to identify trends in water quality and ecology of waters, and indicators of change in ecological composition and structure; and
- performance based monitoring to review specific policies or practices in modifying flow patterns and response processes to secure specific water quality or ecological objectives.

Appendix 4 outlines the scope of water quality and ecology data requirements.

9 A VIEW TO THE FUTURE

Many urban communities, local authorities and developers in Australia are now adopting a more integrated land and drainage approach to stormwater management, at the local sub-division, urban drain and waterway levels. The substantial social, economic and environmental benefits are driving communities towards this change.
Modified approaches and techniques being adopted by communities comprise:

- integration of rainwater management into architectural design for buildings and associated landscaping
  - ☆ applies to water supply, wastewater management and its recycling
- improved urban form and sub-division design which integrates stormwater management, greywater re-use and landscaping into the residential block and precinct levels (grey water re-use options need to be evaluated on a case-by-case basis)
- techniques used include infiltration, rainwater tanks, and grassed swales and wetlands in place of piped drains.
  - ☆ these are particularly attractive in situations of greenfield development and urban renewal
- retention of natural streams within the urban areas, or construction of vegetated waterways in place of large pipe or concrete channel main drains
  - ☆ as part of this approach, flood corridors are developed as open spaces and landscape features which can include wetland and flow detention facilities, ponds, riparian and flood way vegetation, with parklands and pedestrian and cycle pathways
  - ☆ waterways can also be used as a water supply distribution system for second class (stormwater) water supply purposes
- protection or restoration of regional waterways such as primary streams and their floodplains, or lakes or estuaries and their foreshore zones
  - ☆ in this approach, urban and regional waterways and their corridors are integrated as contiguous systems
  - ☆ benefits include effective drainage, protection of environmental and use values, people and wildlife movement corridors

This framework is illustrated in **Figure 7** - *Integrated framework guiding the development of management strategies.*

Such an integrated approach requires stormwater managers to select and apply measures which embrace a range of values (safety, water supply, open space and movement amenity, economy, sustainability, landscape, ecology and recreation). These measures need to be appropriate to the following nodes: buildings, terrain, local waterways and corridors and secondary and primary waterbodies.

Once selected, these nodes will then need to be interlinked so, for example:

- the terrain assessment addresses implications for local waterways and the primary water body;

- the local waterways assessment incorporates implications for the primary water body and feeds back to the terrain assessment; and
- the primary water body assessment feeds back to both the terrain and water body assessments.

For effective implementation of a truly integrated and systematic approach to stormwater management, managers must have a strong commitment to developing their knowledge and skills, so they are able to apply the best mix of tools or local problems. They must also be committed to understanding the role of education in stormwater management.

These *Urban Stormwater Guidelines* encourage managers to apply best drainage and pollution management practices to protect basic environmental and use values of downstream waters. They encourage a more integrated approach to urban land and water planning and management and this integrated framework defines our long-term objective in Integrated Catchment Management - where we want to get to.

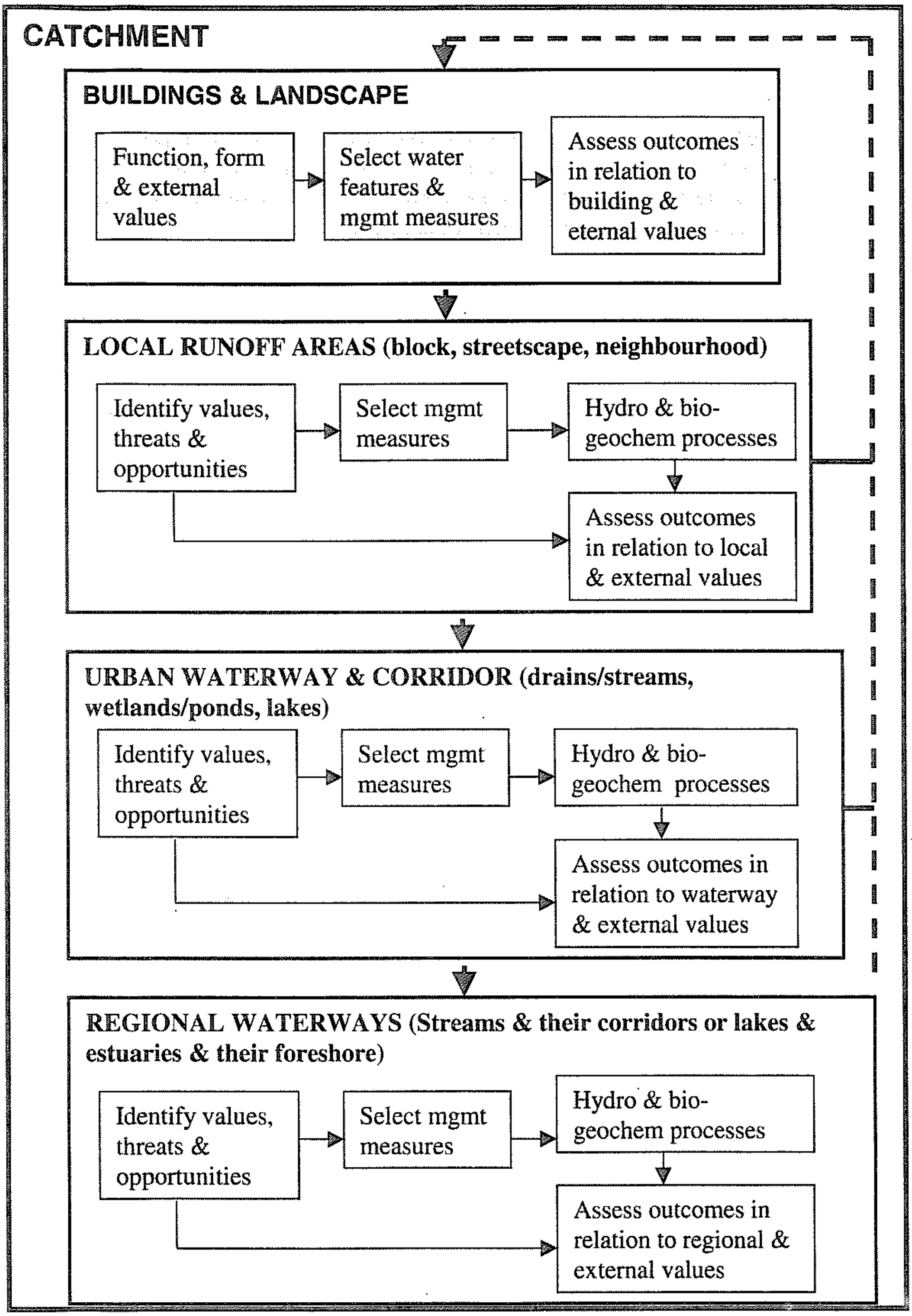

Figure 7 - Integrated framework guiding the development of management strategies

APPENDIX 1: NWQMS GUIDELINE DOCUMENTS

Paper No.	Title
Policies and Process for Water Quality Management	
1	Water Quality Management - An Outline of the Policies
2	Policies and Principles - A Reference Document
3	Implementation Guidelines
Water Quality Benchmarks	
4	Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters
4a	An Introduction to the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters
5	Australian Drinking Water Guidelines - Summary
6	Australian Drinking Water Guidelines
7	Australian Guidelines for Water Quality Monitoring and Reporting
7a	Australian Guidelines for Water Quality Monitoring and Reporting - Summary
Groundwater Management	
8	Guidelines for Groundwater Protection in Australia
Guidelines for Diffuse and Point Sources	
9	Rural Land Uses and Water Quality - A Community Resource Document
10	Guidelines for Urban Stormwater Management
11	Guidelines for Sewerage Systems - Effluent Management
12	Guidelines for Sewerage Systems - Acceptance of Trade Waste (Industrial Waste)
13	Guidelines for Sewerage Systems - Sludge (Biosolids) Management (draft)
14	Guidelines for Sewerage Systems - Use of Reclaimed Water (draft)
15	Guidelines for Sewerage Systems - Sewerage System Overflows (draft)
16a	Effluent Management Guidelines for Dairy Sheds
16b	Effluent Management Guidelines for Dairy Processing Plants
17	Effluent Management Guidelines for Intensive Piggeries
18	Effluent Management Guidelines for Aqueous Wool Scouring and Carbonising
19	Effluent Management Guidelines for Tanning and Related Industries
20	Effluent Management Guidelines for Wineries and Distilleries

APPENDIX 2: IMPACTS OF URBANISATION ON THE STORMWATER ENVIRONMENT

It is important for managers to have an understanding of the many, often interacting impacts of urban stormwater, as a consequence of urbanisation activities, on human and ecosystem health. This will help to:

- base management decisions on ESD;
- make cost-effective decisions which target the cause of a problem, not the symptom;
- develop actions that benefit aquatic ecosystem health; and
- develop management actions tailored to a particular catchment to minimise impacts – there are no simple generic solutions.

Urbanisation will generate significant changes within a catchment including changes to its hydrology, water quality, waterway channels, riparian vegetation, and aquatic habitats.

HYDROLOGY

Runoff from non-urban catchments is influenced by factors such as:

- **rainfall** – rainfall intensity, duration and the period between rainfall events all influence runoff rates and volumes;
- **evaporation** – direct evaporation from water bodies and evapotranspiration from soil and vegetation reduces runoff;
- **soils, particularly soil permeability** – runoff volumes tend to be higher from catchments with low permeability soils. Soil moisture levels can vary across catchments, influenced by both topography and rainfall. Soils with high moisture levels generate higher runoff;
- **vegetation** – this influences evapotranspiration rates and groundwater characteristics. Runoff volumes and rates are generally higher from a rural catchment than from a forested catchment;
- **topography** – runoff rates tend to be higher from steeper catchments; and
- **watercourse characteristics** – flow rates from catchments with steep, narrow watercourses are higher than those from flat, wide watercourses.

Runoff characteristics from non-urban catchments can therefore be highly variable. For example, two adjacent catchments could have different runoff responses to the same rainfall event, due to different topography, soils and vegetation.

Urbanisation results in large impervious areas being constructed within a catchment. These can range from 25-50% of a standard residential catchment. Higher impervious areas occur in high-density, industrial or commercial areas. These impervious areas decrease rainfall infiltration and evapotranspiration across a catchment. This increases runoff volumes and accelerates overland flow velocities.

The stormwater "transport systems" in urban areas (pipes and lined channels) tends to be more hydraulically efficient than natural watercourses. This further increases flow rates.

Stormwater runoff in urban catchments is often from impervious surfaces such as roads and paved areas. As such, soil characteristics, topography and vegetation generally have a minor effect on urban runoff rates. Urban runoff is commonly less variable from under non-urban catchments.

These changes can have a number of effects on the streamflow regime, including:

- increased frequency of runoff events. Runoff will occur for almost all rainfall events, rather than only large events for rural or forested catchments;
- higher volumes, peak flows, flow velocities, bed shear stress. This can cause channel erosion and widening, resulting in increased turbidity and sedimentation;
- more rapid rate of water level rise and fall during floods;
- more frequent inundation of floodplains;
- decreased groundwater flow due to reduced rainfall infiltration; and
- reduced base flows in watercourses, caused by lower groundwater discharges. Excess garden watering and leakage from water pipes may compensate for this.

The greatest difference between peak flows from non-urban and urban catchments commonly occurs for frequent flood events. This often occurs for events with an average recurrence interval of 2 to 5 years. It is caused by the pervious areas only contributing runoff from these larger events. **Figure 8** illustrates this change.

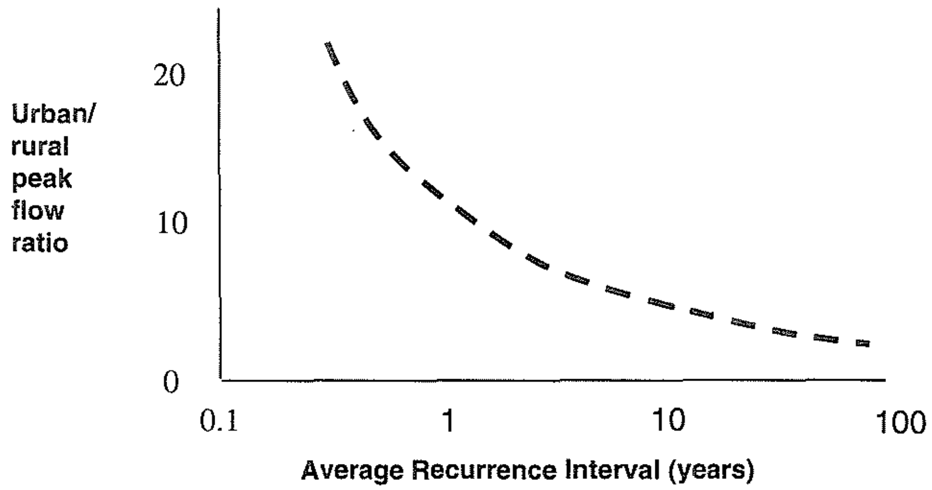

Figure 8 - Indicative ratio of peak flows from urban and rural catchments
(after Codner et al 1988)

Changes to flow patterns after urbanisation can result in a range of environmental impacts, including:

- public safety, direct and indirect property and infrastructure damage. This is caused by the higher flow rates and velocities;
- altered channel form and increased sediment transport. Scouring of channels by higher flows can widen and deepen watercourses. The scoured sediments can be deposited in downstream waterbodies;

- uprooting of riparian and aquatic vegetation by the higher flows. There can also be a shorter period for these plants to re-establish between floods;
- the more frequent runoff events cause more frequent pollutant inputs to waterways. Greater runoff volumes also generate higher pollutant loadings;
- the wetting and drying cycles in freshwater wetlands can be altered by the increased runoff. This can impact on the wetland's vegetation and fauna;
- altered tidal conditions in estuaries. The salinity patterns in estuaries and estuarine wetlands can be altered by the higher runoff; and
- more frequent floods increase the frequency of disturbance to aquatic ecosystems. This is likely to reduce the diversity of aquatic fauna. The movement of aquatic fauna may be hindered by the altered flow conditions.

WATER QUALITY

Many substances present in water that are often called "pollutants" are essential to the function of aquatic ecosystems. These include:

- **suspended solids** - these solids can contain organic matter for processing by aquatic insects and micro-organisms. They also provide a home for certain insects and "soil" for aquatic plants;
- **nutrients** - are used by aquatic plants and algae; and
- **leaves** - provide a food source for aquatic insects and bacteria.

Table 4 lists commons sources of pollutants in stormwater. Typical instantaneous concentrations of a number of pollutants are presented in **Table 5**.

In non-urban catchments, factors influencing water quality include the geochemistry of the underlying bedrock and the catchment's soils. Riparian and catchment vegetation are also influencers. Agricultural land use also affects water quality in rural areas. Pollutant concentrations therefore vary, both within and between these catchments.

Table 4 – Common sources of pollutants in stormwater

Pollutant	Common source
Sediment	Soil erosion during land development, building Stream bed/bank erosion Particulates from pavement and vehicle wear Re-suspension of previously sedimented material Atmospheric deposition of particulates Spillage/illegal discharge of particulates Discharge of organic matter (eg leaf litter, grass) Particulates from car washing Particulates from the weathering of buildings/structures
Nutrients	Weathering of bedrock Erosion of soils having adsorbed nutrients Release from sediments as a result of decomposition of organic material Washoff of fertiliser Sewer overflows/septic tank leaks Animal/bird faeces emissions and washoff Detergents from car washing Spillage/illegal discharge Atmospheric deposition
Oxygen demanding substances	Washoff of organic matter from urban landscape & agriculture Atmospheric deposition Sewer overflows/septic tank leaks, sewage effluent discharge Animal/bird faeces emissions & washoff Spillage/illegal discharges
pH (acidity)	Atmospheric deposition (acid rain) Industrial spillage/illegal discharge Washoff of organic material & decomposition Erosion of roofing material Mobilisation of acid sulfate soils as a result of urban drainage or soil stripping
Micro-organisms (including pathogens)	Animal/bird faeces emissions & washoff Sewer overflows/septic tank leaks, sewage effluent discharge Washoff of organic material & decomposition
Toxic organics	Washoff, drift of pesticides, erosion of soil having adsorbed pesticides Washoff, leakage of herbicides, erosion of soil having adsorbed herbicides Spillage/illegal discharge Sewer overflows/septic tank leaks, sewage effluent discharges
Heavy metals	Atmospheric deposition of particulates Particulates from vehicle wear and emissions Sewer overflows/septic tank leaks, sewage effluent discharge Particulates from weathering of buildings/structures Release from sediments as a result of decomposition of organic material Industrial spillage/illegal discharge
Gross pollutants (litter and debris)	Pedestrians and vehicle emissions, wear, littering Spills from waste collection systems Leaf-fall from trees Disposal of lawn clippings Spills and accidents
Oils and surfactants	Weathering of asphalt pavements, release from sediments, spillage/illegal discharges, emissions, leaks from vehicles, surfactants from car washing Discharge of organic matter high in natural oils Organic matter
Increased water temperature Runoff from impervious surfaces Salinity	Removal of riparian vegetation Discharge of groundwater high in salinity as a result of drainage, or elevation of groundwater level as a result of urbanisation. Wastewater effluent discharges.

Table 5 – Range of typical pollutant concentrations in stormwater

Pollutant	Dry weather concentrations			Wet weather event mean concentrations		
	Forest	Rural	Urban	Forest	Rural	Urban
Suspended solids (mg/L)	1-20	3-270	1-350	1-140	4-200	20-1000
Nutrients (mg/L): Total phosphorus Total nitrogen	 0.006-0.24 0.04-1.2	 0.008-0.81 0.12-4.2	 0.001-2.2 0.1-11.6	 0.01-0.42 0.27-0.66	 0.03-1.3 0.23-5.1	 0.12-1.6 0.6-8.6
Micro-organisms: Faecal coliforms (cfu/100mL)	0-200	10-100	40-40,000	260-4,000	700-3,000	4,000-200,000
Increased water temperature (°C)	n/a		5	n/a		

(Source: after Simeoni et al (1994), Ferguson et al (1994), Sharpin (1995b, c))

Urbanisation of a catchment introduces a range of new pollutant sources. In addition, the higher runoff volumes, combined with elevated pollutant levels, increases pollutant loadings. **Table 6** outlines a range of the potential environmental impacts which result from urban stormwater pollution.

Table 6 - Potential environmental impacts of urban stormwater quality

Pollutant	Potential impact
Suspended solids	deposited sediment affects aquatic insect habitats
Turbidity	reduces water clarity, impacting on fish and aquatic plants
Phosphorus and nitrogen	stimulates growth of algae and undesirable aquatic plants
Ammonia, metals and pesticides	toxic to fish and aquatic insects at high levels
Organic material (BOD)	reduces dissolved oxygen levels, impacting on fish and aquatic insects, and may transform pollutants into more bio-available and toxic forms.
Gross pollutants / litter	visually unattractive, decomposing leaves reduce dissolved oxygen levels
Increased temperature	affects life cycles of aquatic fauna, depresses dissolved oxygen levels, encourages growth of undesirable aquatic plants
Micro-organisms (eg pathogens)	cause disease in humans in contact with stormwater (eg swimming, boating)

CHANNEL FORM

Natural watercourses commonly have three zones:

- upland reaches: these tend to be steep, narrow, fast flowing, relatively straight and have erosion-resistant beds;
- middle reaches: these commonly have moderate slopes, channel widths and flow velocities. They tend to be more sinuous with moderately erosive channel beds; and
- lower reaches: commonly these reaches have low bed slopes and flow velocities. They tend to be wide, sinuous and have floodplains and sediment beds.

These natural channel systems are in a state of dynamic equilibrium, often changing form with large floods. The most significant changes to stream geometry occur when the flow exceeds the bank-full flow rate. In Australia, the bank-full flow rate is often between the 1.5 year and 5 year average recurrence interval flood event. These changes occur largely in the lower and to a lesser extent the middle reaches.

Riparian vegetation plays a major role in stabilising the banks of watercourses and floodplains. During urban development, this vegetation is commonly removed, possibly replaced by exotic vegetation. The channel geometry may also be physically altered.

Increased flows after urbanisation can have a significant impact on channel form. This is particularly the case in the lower reaches. Higher flow velocities are more erosive than pre-development. These flows can dislodge riparian vegetation. Higher sediment loads from upstream urban catchments are deposited in these reaches. The frequency of bank-full flow rates also increases. This often causes widening of channels.

Overall, the impacts on channel form may not be evident for some distance downstream of an urban area. They may also be superimposed on any previous impacts caused by rural land uses.

Sediment transport patterns vary with location along watercourses. Upper reaches tend to be sediment source zones, middle reaches sediment transport zones and lower reaches sediment deposition zones. Estuaries and beaches are also sediment deposition zones. In a "natural" system, flow rates and sediment transport are in a state of dynamic equilibrium.

Following urbanisation, both flow rates and sediment loads can increase, potentially altering this state. This can result in channel erosion and increased sediment deposition in lower reaches and estuaries.

Management practices that are designed to trap coarse sediment (eg gross pollutant traps) can cause downstream erosion problems due to sediment starvation. Sediment loads may be reduced to or below pre-development levels. The sediment conveying capacity of floodwaters may not be met by the reduced sediment loads, resulting in bank erosion. Starving of coastal beaches of sand caused by reduced sediment loads may also occur.

RIPARIAN VEGETATION

Riparian vegetation plays a number of important roles in the water environment. These include:

- shading, lowering water temperatures and reducing light penetration;
- leaves and branches providing a source of organic carbon and nutrients;
- stabilising channel banks;
- logs and tree roots providing an important habitat for aquatic fauna;
- providing a habitat for terrestrial fauna, including insects that are a food source for fish;
- pollution control, trapping pollutants in overland flow; and
- weed control, as native vegetation can inhibit the growth of noxious weeds.

The removal of riparian vegetation and its possible replacement with exotic species is a common pattern in rural and urban land areas. Higher flow velocities after urbanisation can also dislodge riparian vegetation.

The environmental impacts caused by removing riparian vegetation can include:

- higher water temperatures;
- loss of organic matter inputs or replacement with unsuitable leaf litter from exotic plants;
- loss of aquatic and terrestrial habitats;
- decreased bank stability;
- increased pollutant loads; and
- exotic weed invasion.

AQUATIC HABITATS

In-stream objects in watercourses provide important aquatic habitats. They provide aquatic insects and fish with shelter from high flows, shade, refuge areas and spawning sites. They fall into three main groups:

- bed material (eg rocks and gravel) and variations in bed shape (eg pools and rapids);
- fallen trees and branches (snags); and
- aquatic plants.

Wetlands and floodplains are also important aquatic habitats. These habitats are often partially or totally destroyed in urban areas. Physical changes, high flow rates and sedimentation can cause this. The loss of habitat results in higher and less variable flows, loss of refuge areas and spawning sites. This commonly reduces the diversity and abundance of aquatic fauna and flora.

WATERCOURSE BARRIERS AND CONSTRICTIONS

Bridges, culverts, weirs, drop structures and other structures are commonly built on watercourses in urban areas. These barriers can:

- alter flow patterns in watercourses, increasing flow velocities;
- impact on the movement of aquatic insects and fish;
- change sediment transport patterns, resulting in sediment deposition or scouring in unexpected areas; and
- culverts and bridges across estuaries can reduce upstream tidal flushing and increase tidal velocities in the vicinity of the construction.

APPENDIX 3: STORMWATER ISSUES

The following list of major physical and chemical stressors are based on the eight major issues identified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARCANZ, 2000a). **Table 7** relates these stressors or conditions to the range of stormwater related sources, impacts and related stressors.

Table 7 – Major physical and chemical stressors

Environmental impairment issues	Typical Sources	Impacts	Related stressors & modifiers
Impact of pathogens on health	Sullage, sewer overflows, septic, animals	Closure of beaches, human infection, illness and disease	Faecal coliforms, bacteria, viruses, retention time
Impact of oxygen depletion	Sullage, sewer overflows, septic animal waste, grass and leaf litter	Low dissolved oxygen, smells, stress to aquatic life	Organic matter, ammonia, mixing, temperature, nitrate
Impact of toxicants including metals and pesticides	Cars, car parks, roads, processing industries, spills, atmospheric deposition.	Bio-accumulation, death of aquatic life	Pesticides, herbicides, lead, zinc, suspended solids, sulphate, organic mat'l, pH
Impact of particulate matter	Roads, urban land use, construction sites, modified drainage	Smothering of aquatic plants & animals, impact on feeding, impact on light	Silt, sand, gravel, clays, retention time
Impact of floating debris and surface scums	Commercial areas, fast food outlets, plant debris	Mainly visual, interferes with aquatic life	Paper, plastic, leaves, dead vegetation, algal scums, oil
Nuisance plant growth	Sullage, septic, sewer overflows, animals, STP discharges, leaves	Promotes plant and algal growth, blue green algal blooms	Phosphorus, nitrogen, organic matter, mixing, retention time, temp
Impact of changes in flow regimes, increased stormwater runoff.	Changes in catchment land use & vegetation, changes in drainage morphology	Pattern of particulate deposition & re-suspension, washout of biota – succession processes, DO regimes.	Volume, frequency, velocity
Changes in physical habitat		Loss of riparian vegetation, change in substrate	Modification to channel morphology, change in flow & frequency

APPENDIX 4: DESIGN OF MONITORING PROGRAMS

Table 8 builds on defining the issues, and the information requirements, of good monitoring design practice outlined in the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARCANZ, 2000b). It addresses the most common issues and information need categories arising in stormwater management.

Table 8 – Common issues and information need categories arising in stormwater management

Management Issues	Information requirements	Monitoring category
Identification of environmental values	Current uses of water bodies. Ecological significance of ecosystems	Characterisation of prevailing water quality and ecology
Outline of problems and issues	Areas of exceedence of water quality criteria and constituents having a potential to impact on the health or viability of the ecosystem or uses	Characterisation of prevailing water quality and ecology, characterisation of water quality and ecological processes, trend analysis of changes in water quality and ecology, analysis of changes in processes.
Determination of sustainable loading	Sustainable loading of key runoff constituents consistent with maintaining key water quality criteria and composition and structure of ecosystem	Characterisation of water quality and ecological processes
Determination of existing or future loading	Estimation of cumulative loads on critical downstream nodes associated with land uses and management practices across the catchment	Characterisation of rainfall - runoff and constituent exports as a function of land uses and management practices
Evaluation of export reduction for management strategies	Estimation of level of constituent interception or immobilisation for different management practices	Characterisation of water quality and ecological processes. Performance monitoring for a range of management practices
Review of the performance of the strategy and its components	Evaluate reduction in exports and changes in water quality and ecology in relation to objectives	Performance monitoring of overall system, performance monitoring of components, trend analysis

APPENDIX 5: BIBLIOGRAPHY

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APPENDIX 6: GLOSSARY AND COMMON TERMS

For the purposes of this document these terms have the following meaning:

Abatement
Action to reduce the level or intensity of peak discharge or pollutant concentration or loads discharged in storm events.

Abiotic
The non-living components of a system.

Adsorption
Bonding of metal and nutrients onto the surfaces of suspended particles, by way of physical, chemical and biological processes, and their removal by a process of sedimentation of the suspended particles.

Aeration
The injection of air through diffusers into water bodies, or rapid mechanical mixing of the surface of water bodies to promote entrainment of atmospheric air into the water column. A treatment process adopted in situations of high loading of oxygen demanding substances.

Aerobic or oxic zone
An environment in which there is free oxygen.

Anaerobic or anoxic zone
An environment devoid of oxygen

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.

Atmospheric deposition
Pollutants accumulating across urban surfaces as a result of deposition of fine air borne solids. Vehicle and industrial air emissions may constitute a significant contribution to levels of lead and nitrates across urban areas

Attenuation
The reduction in the magnitude of flows, concentrations or loads of pollutants.

Average Recurrence Interval (ARI)
Average time between events of a given value.

Bankfull flow
The flow rate at which a stream or channel will run full. The frequency of bankfull conditions is commonly adopted as the criteria for maintaining the channel cross section and freedom from sedimentation in the longer term. This frequency will vary according to climatic regions.

Bank stabilisation
(Refer to Armouring or stabilisation)

Baseflow
The underlying flow rate that cannot be directly attributed to storm events.

Basket
A simple steel mesh collection device placed in pits of gross pollutant traps to collect debris and rubbish.

Bed trap
A structure designed to intercept and retain sediment carried in flow by means of bed load processes.

Best Management Practice (BMP)
Structural measures used to store or treat urban stormwater runoff to reduce flooding, remove pollution or to provide other amenities.

Bio-accumulation
The process in which substances are accumulated by organisms, from water directly or by consumption of food containing the substances.

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).

Bio-diversity
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 includes:

(a) diversity within species and between species; and

(b) diversity of ecosystems.

Biofilm
A gelatinous sheath of algae and micro-organisms, including benthic algae and bacteria, formed on gravel and sediment surfaces and surfaces of large plants.

Bio-monitoring
Surveys of the biodiversity of selected biological groups or families, and comparison to a reference site for a similar ecosystem, as a measure of ecosystem health.

Biota
Living organisms in streams.

Buffer zones
A vegetated strip between the edge of a stream or drainage channel and a land use activity, designed to trap the lateral overland flow borne pollutants.

Catchment
A topographically defined area drained by a stream such that all outflow is directed to a single point.

Channel
The bed and banks of a stream or constructed drain.

Colloids
Fine abiotic and biotic particles of typically 0.1 μm to 1 nm in diameter.

Critical downstream nodes
The most sensitive downstream water bodies in respect to sustainable pollutant loads, which dictate land use and management practice requirements across their catchment.

Denitrification
The reduction of nitrate or nitrite to nitrogen gas, in the absence of oxygen.

Detention (dry) basins
A basin designed to temporarily detain storm or flood waters, to attenuate peak flows downstream to acceptable levels.

Discharge
The volume of flow passing a predetermined section in a unit time.

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.

Dissolved Oxygen (DO)
The level of dissolved oxygen in streams is a critical property sustaining aquatic biota, and in determining the risk of occurrence of anoxic conditions.

Drainage network
The system of channels and pipes and overland flow pathways which drain a catchment area. Networks typically comprise a main drain, branch drains, and collector drains.

Easement (right of way)
A corridor of land over which the drainage function is the primary role.

Effluent
Sanitary, industrial or agricultural discharge from wastewater treatment plants or treatment lagoons.

Event
A single precipitation and associated runoff occurrence.

Event Mean Concentration
The average concentration of a pollutant 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.

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 of groundwater or discharge to a drain.

Floodway
Corridor of land identified as a major stormwater flow path, often is association with a minor (pipe or channel) flow path.

Flow retardation
See Detention Basins

Frequency
(Refer to Average Recurrence Interval)

Geomorphology
Processes of weathering, flow and sediment transport which determine the pattern of drainage features across a catchment, and the equilibrium between sediment accumulation in channels and sediment re-suspension.

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.

Grain size distribution
The statistical distribution of grain (by weight) passing a range of sieve sizes.

Grey water
Non-potable water derived from other household uses, suitable (with or without treatment) for other uses such as toilet flushing, garden watering.

Gross Pollutant Trap (GPTs)
A trap designed to intercept coarse particulate material (by sedimentation) and trash and debris (by screens or booms). GPTs may be incorporated into the inlet pits, collector drains or main drains.

Gully pot, inlet pit
A roadside inlet pit, designed to collect stormwater runoff washed from paved surfaces and to intercept sediment and litter prior to entry into the drainage network.

Impermeable or impervious surface
The part of the catchment surfaced with materials which prevent infiltration of rainwater into the underlying soil and groundwater.

Indirect drainage
The breaking of the direct connection of roof downpipes to stormwater drains, and impervious area washoff to inlets and drains, by their discharge to pervious areas or infiltration devices, and ultimate overland or subsoil interception at the property boundary by the stormwater network.

Infiltration pit, trench, basin
A stone filled pit, trench or detention basin designed to enhance runoff infiltration into the subsoil and groundwater zones.

Integrated catchment management
Managing natural resources within a 'whole of system' approach. In a stormwater context, it requires a whole of catchment and total urban water cycle based design and management approach, with integral consideration of land and water processes and values.

Loading
The total mass of a pollutant discharged during a storm event. The term may also be used to describe the mass of pollutant intercepted (g/sq metre) by a device during a storm event, or on an annual basis.

Multiple use
Facilities meeting a range of functions eg urban waterways accommodating drainage, pollution interception, landscape, recreation and water supply functions.

Off-line and on-line
Off-line facilities are located adjacent to but off the drain or major flow pathway, such as to treat low flows or the discharge of a branch drain. On-line or in-line facilities are located within the drain or major flow pathway such as to treat event flows.

On-site and off-site
On-site facilities are located on individual residential or development blocks so as to enhance local detention and interception of runoff and pollutants. Off-site facilities are located on drainage networks to provide area wide detention and interception of runoff and pollutants.

Oil trap or separators
A stilling tank configured to separate lighter oily matter, scums and hydrocarbons from stormwater.

On-site stormwater detention (OSD)
A requirement for developers of land to compensate for increased runoff due to increases in imperviousness on blocks.

Overland flow
The component of rainfall (excess) which is not removed by infiltration and discharges down the slope as surface flow.

Permeable (porous) pavement
Pavements comprising materials which facilitate infiltration of rainwater and transfer to the underlying sub-soil.

Point source and non-point source pollution
Point source is any discernible confined and discrete conveyance, including pipes, channels, conduits. Non-point source is a diffuse pollution source without a single point of origin or specific discharge point.

Pollutant retention
The proportion of pollutant load intercepted and retained by a device, either on an event or annual basis.

Pollution Control Ponds
A shallow pool of water, characterised by areas of emergent aquatic plants and open water, designed to intercept event discharges and enable adsorption and sedimentation of pollutants, and to support a diverse range of micro-organisms and plants associated with the breakdown of organic material and uptake of nutrients. The detention of event flows and settling of suspended particles and associated pollutants is a key component of pond pollutant interception processes.

Recycled water
Treated stormwater, greywater or black water suitable for a range of uses eg. toilet flushing, irrigation, industrial processing or other suitable applications.

Remobilisation
The transformation of sedimented pollutants by microbial or chemical processes into a dissolved form and transfer by diffusion from the sediment pore water into the water column.

Re-suspension
The physical entrainment of sedimented particles by elevated flows, or as a result of sediment bio-turbation.

Retarding or Retention Basin
See Detention Basin

Roughness coefficient
A factor describing the roughness (irregularities) of surfaces related to flow energy loss.

Runoff
The portion of precipitation on a drainage area or surface that is discharged from the drainage area to drainage.

Sediment trap
A structure designed to intercept and retain sediment transported by the flow.

Sedimentation
The physical process of settling of suspended particulates under forces of gravity. The sedimentation efficiency is a function of eddy forces in the settling basin, and the period of detention of flow in the basin.

Sewer overflow
The discharge of sewage to surface water or stormwater drainage as a result of sewage flow exceeding the sewer capacity (infiltration of rainwater), or sewer blockage.

Stormwater
Water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment.

Stormwater Quality Interception Devices (SQIDs)
See *Best Management Practices*

Stormwater Treatment Measures (STMs)
See *Best Management Practices*

Street sweeping
The removal of particulates and litter from street surfaces by sweeping or vacuuming.

Sub-catchment
A topographically defined area drained by a tributary or branch drain of a primary stream or main drain draining a catchment.

Subsurface drain
A drain designed to intercept sub-soil water and thereby lower the soil water table.

Swales
A grassed open channel, designed to intercept and convey surface runoff to a drainage network inlet, promote infiltration, promote interception of particulate material by the vegetation, and to provide a landscape element.

Swirl separator
A device which uses the flow energy to create a vortex, enhancing the separation by gravity of water and particulate materials.

Total Catchment Management (TCM)
See *Integrated Catchment Management*

Total urban water cycle based management
The integrated management of all components of the hydrological cycle within urban areas (surface water, soil interflow, groundwater, water supply and recycled wastewater) and the landscape to secure a range of social, economic and environmental benefits.

Water Sensitive Urban Design
Design of subdivisions, buildings and landscape which enhances the opportunities for at-source conservation of water, rainfall detention and use, infiltration, and interception of pollutants in surface runoff from the block.

Wetlands (artificial)
A shallow pool of water, characterised by extensive areas of emergent aquatic plants, designed to support a diverse range of micro-organisms and plants associated with the breakdown of organic material and uptake of nutrients. Wetlands may be designed as permanent wet basins (perennial), or alternating between dry and wet basins (ephemeral), or combining these two systems (extended detention).

Wet basin
See Pollution Control Ponds