11.00 Environmental considerations

11.01 Introduction

The National framework for the management of water quality, including stormwater management, is presented within the National Water Quality Management Strategy (NWQMS).

A legal cornerstone for the environmentally responsible management of stormwater within Queensland is the "general environmental duty" as presented within the *Environmental Protection Act 1994*, that being:

> 'A person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.'

It is recognised that there is still a significant degree of uncertainty associated with many of the environmental aspects of stormwater management, including:

- pollution loading generated from different land uses in different regions;
- the response of receiving waters to pollutant loadings;
- the geomorphological response of waterways to changes in catchment hydrology;
- the effectiveness of different stormwater treatment measures within different geographical regions, flow regimes and catchment conditions;
- the relationship between the predictions of water quality models and real world outcomes.

In addition to the above, there are the ongoing hydrologic uncertainties associated with:

- rainfall prediction;
- long-term hydrologic changes (e.g. climate change);
- errors associated with the simplified numerical modelling of rainfall and runoff;
- errors associated with the simplified numerical modelling of complex waterway hydraulics; and
- data collection and monitoring errors.

Despite these uncertainties, stormwater managers must take all reasonable and practicable measures to prevent or minimise potential environmental harm caused by stormwater runoff and the construction and operation of stormwater management systems. Specifically, consideration must be given to potential adverse impacts resulting from changes to the natural water cycle, water quality and the volume, rate, velocity, duration and frequency of stormwater runoff.

In circumstances where these uncertainties are significant, or where significant questions arise regarding the suitability of a proposed stormwater management system, consideration should be given to the following:

(i) A lack of understanding, or the degree of uncertainty associated with an action or response, should not be used in <u>isolation</u> as an excuse to avoid the incorporation of current best management practice within stormwater design.

(ii) It is the responsibility of the stormwater designer to be aware of what is considered "current best management practice".

(iii) The preferred design outcome should be one that retains sufficient space and capabilities (to the best estimate of the designer) within a stormwater catchment for the future upgrading of the stormwater treatment system once a better understanding of the treatment system and/or the catchment's needs has been achieved. It is noted that retro-fitting drainage layouts and treatment systems is very difficult when "space" becomes the major site constraint. Also refer to Section 7.01 of this Manual.

(iv) Wherever practical, stormwater treatment systems within a catchment or sub-catchment should not rely on a single treatment system or product, but should incorporate diversity ie. the "treatment train" approach.

11.02 Waterway management

11.02.1 General

The following discussion focuses on the potential impacts of stormwater management systems on the physical aspects of urban waterways. For the purpose of this discussion, reference is made only to vegetated waterways including creeks, rivers, estuaries and constructed channels having a natural appearance.

11.02.2 Waterway integrity

Significant changes can occur to the structural integrity of urban waterways following a change in the catchment hydrology. The degree of change primarily depends on the type and degree of changes to the catchment's runoff characteristics. These changes may result from the full or partial urbanisation or de-forestation of the catchment.

Land clearing, even if replaced by vegetative surfaces such as grass or crops, can significantly alter the runoff characteristics of a catchment, and as a result cause long-term changes to downstream waterways. Specifically, de-forestation has the potential to:

- (i) reduce initial rainfall losses;
- (ii) significantly increase the total annual runoff volume;
- (iii) increase the frequency at which previous low ARI runoff discharges are generated;
- (iv) reduce the effective *time of concentration* of stream flows;
- (v) initiate gully erosion;
- (vi) alter downstream waterway morphology.

Even though erosion is a natural aspect of all waterways, the basic aim is to avoid an un-natural acceleration or deceleration of this erosion. Stream flows at or near the bankfull flow rate are normally considered to have the greatest influence on channel erosion; however, once significant vegetation loss has occurred within a waterway, regular bed and bank erosion can be initiated by much smaller flows.

The impacts of land clearing and urbanisation are more likely to affect minor waterways such as creeks. There are generally four types of creek systems: clay-based, sand-based, gravel-based and spilling (rocky) creeks. Each of these creek systems will respond differently to changes in catchment hydrology.

It is not possible to *accurately* predict the response of a natural, earth-lined waterway to changes in catchment hydrology. Past history has shown that in the absence of major flow control systems (i.e. dams and retention basins) creeks located within traditional urban areas typically expand from around a 1 to 2 year ARI bankfull capacity to around a 5 to 10 year ARI bankfull capacity following full urbanisation. There are of course many exceptions to this generalised statement.

Changes to a waterway cross-section can result in many adverse effects, including:

(a) Channel expansion causes significant amounts of coarse sediment to be released into the waterway. This sediment smothers aquatic habitats, harms the ecological benefits of riffle systems, in-fills pools, smothers essential bed vegetation, increases the potential for weed growth within the channel, and initiates bank erosion caused by the excessive growth of reeds within the settled bed sediments.

(b) Loss of useable land by adjacent landowners.

(c) Damage to both private and public assets located immediately adjacent an expanding urban waterway, and the public and private expense of stabilising these waterways to prevent further damage. Often these stabilisation works involve the use of hard-engineering measures which can further harm aquatic and riparian ecosystems.

(d) Lateral movement of the waterway channel within a floodplain caused by the expanding radius of channel bends. It is noted that the radius of a channel bend is usually dependent on the top width of the channel.

(e) Conversion of some sections of "closed-canopy" creeks into "open-canopy" creeks. Such changes can significantly change bed and bank vegetation, increase low-flow water temperatures, and alter the ecological balance within the affected reach of the waterway.

(f) Potential changes to the cultural and spiritual values of the waterway. For example, excess sedimentation may alter the traditional use of water holes. All instream works (construction and maintenance) need to comply with the *Aboriginal Cultural Heritage Act 2003*. The main purpose of the act is to provide effective recognition, protection and conservation of Aboriginal cultural heritage.

Where necessary, steps should be taken to minimise those changes to catchment hydrology that are likely to cause undesirable changes to downstream waterways. Issues to be considered include:

(i) What types of waterways are susceptible to undesirable physical change?

(ii) What land use activities and stormwater management practices are likely to significantly contribute to undesirable physical change?

(iii) What changes in catchment hydrology (i.e. volume, rate, velocity, frequency and duration of runoff) will most likely cause undesirable physical change?

(iv) What stormwater management practices will most likely minimise the potential for undesirable physical change?

The above questions are discussed in more detail in the following section. However, it should be noted that the greatest single *action* that can be taken by a stormwater designer to minimise changes in downstream waterways is to minimise changes to the natural water cycle.

The types of waterways that are most susceptible to physical change caused by changes in catchment hydrology include:

(i) natural creek systems;

(ii) constructed, vegetated channels of natural appearance.

The types of waterways that are usually not susceptible to undesirable physical change caused by changes in catchment hydrology include:

(i) rocky gorges;

(ii) modified or constructed channels heavily stabilised with rock or hard-engineering measures;

(iii) concrete-lined channels;

(iv) constructed, grass-lined channels.

Large waterways, such as river systems, are rarely physically altered as a result of the hydrological changes resulting from urbanisation. Large waterways are more susceptible to hydrologic changes resulting from the introduction of major storage reservoirs, or changes in land use over a significant proportion of the catchment such as farming and de-forestation.

11.02.3 Effects of changes in tidal exchange

Flood mitigation works often involve increasing the channel capacity of waterways. If these works occur within a tidal reach of the waterway, then there is the potential for these works to increase the volume of tidal exchange. Designers need to investigate and address potential problems including the following issues:

(i) scour problems resulting from changes in channel velocity and the redistribution of flows within the waterway;

(ii) flooding issues associated with increased mangrove growth within upstream waterways and drainage channels;

(iii) ecological problems resulting from a change in tidal flow, including changes in water quality, water salinity, and the extent of tidal flow;

(iv) changes to the tidal exchange within tidal wetlands, or the introduction of tidal exchange within freshwater wetlands;

(v) encroachment of saline water into fresh environments can also impact on concrete structures as well as vegetation. Damage to pipes, culverts, bridges, etc. can affect flooding, public safety and the local environment.

11.02.4 Cause and effect of changes in catchment hydrology

Table 11.02.1 summarises the possible causes of changes in waterway characteristics.

Table 11.02.2 summarises likely impacts of land use change on catchment hydrology and waterway characteristics.

Table 11.02.3 summarises likely impacts of various stormwater management practices on catchment hydrology and waterway characteristics.

Table 11.02.4 summarises likely benefits of various stormwater management practices on catchment hydrology and waterway characteristics.

Table 11.02.1 Possible causes of changes in waterway characteristics

Change in Waterway	Possible Causes of Changes in Waterway Characteristics
Creek erosion	• Increase in the duration or frequency of near-bankfull flows, typically the 1 in 1 year to 1 in 10 year ARI events. • Increase in channel flow velocity (possibly caused by an increase in channel grade, straightening of the channel, decrease in channel roughness, or a lowering of downstream water levels).
Stress to aquatic habitats and ecosystems	• Increase in the duration, velocity or frequency of low flows (i.e. the runoff from regular minor storms less than the 1 in 1 year ARI event). • Deterioration in the water quality of low flows within creeks and minor waterways. The critical flows are the dry weather base flows and those extended low flows that occur for days or weeks after wet weather. • Deterioration in the water quality of major flows within lakes, wetlands, rivers and other major waterways. • Inflow of coarse sediment (during any storm event). • An increase in the area of impervious surfaces directly connected to an impervious drainage system.
Deterioration of water quality	• Urbanisation of the catchment and the consequent higher pollutant loading. • Inadequate erosion and sediment control measures applied on building and construction activities. • Long-term damage to grassed surfaces (e.g. parks and road verges) causing ongoing soil erosion.
Weed infestation of banks and riparian zones	• Urbanisation of the catchment and the consequent higher nutrient loading. • Removal of canopy cover from urban waterways. • Direct connection of drainage systems to the waterway. • Inappropriate selection of street trees. • Plant and seed infestation originating from private property.
Weed/reed infestation of channel bed	• Removal of canopy cover from urban waterways. • Direct connection of drainage systems to the waterways. • Inflow of coarse sediment (during any storm event). • Accelerated creek erosion resulting in an increased channel top width, loss of canopy cover, and increased bed load sediment.

Table 11.02.2 Likely impacts of land use change on catchment hydrology and waterway characteristics

Land Use Change	Likely Changes
Changes in the fire management of bushland, including management of fuel load	• Increase or decrease in volume of runoff. • Reduced initial loss rates. • Increased frequency of minor flows. • Possible increase in frequency and duration of bankfull flows. • Increased peak discharge rates. • Increased erosion and sediment flow within alluvial streams (e.g. sand-based and gravel-based creeks). • Channel expansion within well-vegetated, clay-based creeks.
De-forestation for the development of grasslands, including farming and rural-residential development	• Significant increase in runoff volume. • Reduced initial loss rates. • Increased frequency and duration of channel flows. • Increased frequency and duration of over-bank flows. • Increased peak discharge rates for all but extreme flood events. • Significant increase in erosion and sediment flow within alluvial streams with a resulting increase in channel depth and/or width. • Channel expansion within well-vegetated, clay-based creeks, and possibly a significant increase in sediment flow. • Gully erosion extending laterally from existing creeks.
Urbanisation of farmland or grassland	• Significant increase in runoff volume. • Reduced initial loss rates. • Significant increase in frequency and duration of in-bank flows. • Increased peak discharge rates for all but extreme flood events. • Possible increase in average recurrence interval (ARI) of bankfull flows. • Significant increase in erosion and sediment flow within minor waterways (ie. creeks) with a resulting increase in channel depth and/or width.
Urbanisation of bushland	• Significant increase in runoff volume. • Significant reduction in initial loss rates. • Significant increase in frequency and duration of in-bank flows. • Significant increases in peak discharge rates. • Significant increase in the average recurrence interval (ARI) of bankfull flows. • Significant increase in erosion and sediment flow within minor waterways (ie. creeks) with a resulting increase in channel depth and/or width. • Development of open-canopy, weed-infested creek systems.

Table 11.02.3 Likely impacts of various stormwater management practices on catchment hydrology and waterway characteristics

Stormwater Practice	Likely Changes in Catchment Hydrology and Waterway Characteristics
Adoption of rainwater tanks and/or stormwater harvesting systems	• Slight decrease in annual volume of runoff. • Potential increase in the duration of the "critical storm". • Slight decrease in the volume, rate, frequency and duration of minor flows. • Increase or decrease in dry weather base flows depending on whether the stormwater is used for garden watering. • Altered flow conditions possibly affecting aquatic biota.
Establishment of a piped drainage system throughout the catchment	• Significant decrease in the duration of the "critical storm". • Significant increase in peak flows. • Increase in the frequency of in-bank flows. • Decrease in dry weather base flows. • Significant erosion and expansion of natural creeks.
Channelisation of minor creeks and overland flow paths	• Significant decrease in the duration of the "critical storm". • Significant increase in peak flows. • Increase in the frequency of in-bank flows. • Significant erosion and expansion of downstream creeks. • Decline in biodiversity and ecosystem values.
Adoption of on-site detention (OSD) in association with a piped drainage system and/or channelisation of overland flow paths and creeks	• Increase in flood flows can still occur downstream of the piped drainage and channelised flow paths. • Decrease in peak flows from minor storms. • Potential increase in the duration of channel flows. • Significant erosion and expansion of medium to large creeks, but possibly little change in minor creeks (i.e. the benefits of OSD decrease with increasing catchment area).
Use of regional detention and retention basins sized for flood control only	• Possible increase or decrease in "critical storm duration" compared to the undeveloped catchment. • Significant increase in the duration of in-bank and bankfull flows. • Significant erosion and expansion of creek channels.
Use of extended detention basins	• Possible increase or decrease in "critical storm duration" compared to the undeveloped catchment. • Significant increase in the duration of post-storm flows. • Possible minor erosion of creek channels.
Adoption of Water Sensitive Urban Design	• Possible increase in annual volume of runoff, although less than for traditional urban developments. • An increase in stress to aquatic biota may still occur. • Possible minor erosion of creek channels.

Table 11.02.4 Likely benefits of various stormwater management practices on catchment hydrology and waterway characteristics

Stormwater Practice	Likely Benefits Compared to Traditional Stormwater Management Systems
Water Sensitive Urban Design (WSUD)	• Reduced changes to the volume, rate, frequency and duration of runoff as a result of urbanisation. • Reduced changes to pollutant runoff. • Improved low-flow water quality. • Reduced impact of development on instream ecological values and biodiversity. • Reduced likelihood of waterway erosion/expansion.
Stormwater designs based on minimal changes in runoff volume	• Reduced changes to the frequency, rate and duration of runoff. • Reduced changes to pollutant runoff. • Reduced likelihood of waterway erosion/expansion.
Use of extended detention basins	• Reduced changes to the rate and duration of high-flows, but an increase in the duration of low-flows. • Improved water quality of instream pools through the provision of prolonged post-storm low-flows. • Reduced likelihood of waterway erosion/expansion.
Use of detention basins sized for low-flow discharge	• Reduced changes to the rate and duration of bankfull flows, but increase in the duration of low-flows. • Reduced likelihood of waterway erosion/expansion.
Replacement of traditional piped drainage with swales, vegetated drainage channels and the preservation of natural waterways	• Increase in effective *time of concentration* relative to a traditional piped catchment. • Reduced changes in rate of runoff. • Reduced changes to pollutant runoff. • Improved low-flow water quality. • Preservation of instream ecological values and biodiversity. • Reduced likelihood of waterway erosion/expansion.
Use of Natural Channel Design for constructed drainage channels	• Increase in effective *time of concentration* relative to a piped or channelised catchment. • Slightly reduced changes in rate of runoff. • Improved low-flow water temperature and habitat value.

11.02.5 Fauna issues

Fauna issues need to be considered in the design of many waterway structures as summarised in Table 11.02.5.

Table 11.02.5 Incorporation of fauna issues into waterway structures

Structure Type	Fauna Issues
Bridges, and culverts	• Detailed discussion and design guidelines on fauna passage are provided in Sections 9.07.3, 9.07.4, 10.04.13 and 10.04.14.
Channel stabilisation works	• Detailed discussion on habitat impacts of various bed and bank stabilisation methods is provided in Chapter B2 of Brisbane City Council (1997).
Constructed wetlands and treatment ponds	• The provision of suitable fish passage conditions both into and out of a wetland can significantly improve mosquito control. • Constructed wetlands can provide excellent bird habitat; however, the impact of bird life on water-borne pathogen levels must be considered.
Gross pollutant traps and trash racks	• If it is necessary to place a trash rack within an aquatic habitat, consider the use of overlapping, partial width screens that allow unrestricted aquatic passage between the two screens. • GPTs placed downstream of urban lakes should incorporate coarse vertical bar screens suitable for fish passage.
Lakes	• Constructed instream lakes typically provide significant restrictions to fish passage resulting from upstream and downstream water level controls. • Urban lakes can cause a significant discontinuity in terrestrial movement corridors. Where possible, a riparian zone should be established along at least one side of the lake.
Snag management within urban waterways	• The retention of snags in urban waterways may cause adverse water quality conditions due to the high nutrient loadings expected within urban runoff (refer to Table 9.06.1). • Though essential within natural catchments for aquatic biota habitat, the retention of snags within urban waterways should be assessed on a case-by-case basis.
Vegetated drainage channels	• Detailed discussion and design guidelines on fauna passage are provided in Chapter 9 and in Brisbane City Council (2000).
Waterway corridors	• Urban waterway corridors often act as the primary terrestrial wildlife corridor. • The development of a council-wide Wildlife Corridor Plan that identifies linkages between terrestrial and riparian corridors can provide a valuable planning tool for urban development.
Weirs and grade control structures (eg, drop structures, riffles, chutes, rock weirs)	• Potential restriction to aquatic passage. • Limit fall height to 0.5 metres (maximum) wherever practical within aquatic habitats, otherwise the structure should incorporate an appropriate fishway. • Fish "ladders" should not be used on bed control structures.

11.03 Stormwater quality management

11.03.1 Planning issues

The long-term success of water sensitive urban developments depends largely on the appropriate planning of the development layout. The following guidelines may assist in the successful planning of water sensitive residential and commercial developments.

Step 1: Consider soil properties

(i) The selection of the preferred stormwater treatment and conveyance measures should reflect the soil infiltration capacity.

(ii) Stormwater infiltration measures should be given priority when working in soil regions with a high infiltration capacity (e.g. sandy soils).

(iii) In clayey soil areas, many stormwater treatment measures will require the establishment of a subsoil drainage system. It is essential for this subsoil drainage system to be allowed to drain freely into either a stormwater pipe or open channel.

(iv) Soil properties can have a significant bearing on the long-term outcomes of urban lakes. The existence of dispersive soils may result in urban lakes having a permanent "brown" colour. The expected social acceptance of a lake's colour should be given appropriate consideration during the planning phase.

Step 2: Consider opportunities for stormwater infiltration

(i) The promotion of stormwater infiltration is desirable in most cases, even on clayey soils; however, potential problems must be considered.

(ii) Promoting stormwater infiltration can result in permanent seepage problems along boulder/retaining walls in terraced estates unless adequate subsoil drainage provisions are included. Infiltration systems need to be sustainable without causing disputes between neighbouring properties.

(iii) The promotion of stormwater infiltration may also cause or aggravate salinity problems further down the slope or catchment. Such problems can occur well away from the property being developed.

(iv) The promotion of stormwater infiltration does not necessarily mean the use of grass swales. It can also be achieved through the use of bio-filtration systems and rubble pits.

(v) Appropriate landscaping is critical for the long-term success of most infiltration systems.

Step 3: Look for natural "opportunities" available within the catchment

(i) Look for "opportunities" to use the natural features of the catchment to optimise the cost-effectiveness and efficiency of the stormwater management system.

(ii) Identify those areas of land with topographic features best suited to specific stormwater treatment systems (e.g natural detention areas for wetland placement, and highly porous soils for infiltration systems).

Step 4: Consider the maintenance capabilities of the land owner

(i) Avoid using stormwater treatment techniques that require maintenance funding or equipment that is beyond the capabilities of the asset manager.

(ii) Stormwater treatment systems that require the access of personnel into confined spaces (e.g. some OSD systems) should not be incorporated into residential or commercial properties unless supported by a risk assessment study. A detailed maintenance manual that clearly identifies maintenance risks, issues and procedures must be prepared to the satisfaction of the local government.

Step 5: Review conditions for the retention of natural waterways and the adoption of Natural Channel Design drainage systems

(i) Guidelines for the retention of natural waterways are provided in Section 9.02 (b) of this Manual.

(ii) Guidelines for the adoption of Natural Channel Design are provided in Section 9.06 of this Manual.

Step 6: Look at the needs of receiving waters

(i) Certain stormwater treatment systems are preferred adjacent to certain receiving waters (refer to Table 11.05.6).

(ii) As a general guide, large water bodies such as lakes and rivers are adversely affected more by fine sediments generally less than 100µm (i.e. turbidity) than coarse sediments, and thus requires good management of clayey soils. Conversely, minor water bodies, such as creeks and wetlands, experience greater physical change as a result of the inflow of coarse sediments. Note, this does <u>not</u> imply that large water bodies do not experience problems resulting from coarse sediment, or that small water bodies do not experience problems resulting from turbidity.

(iii) The groundwater can be a "receiving water" for significant quantities of stormwater. It is important that *planners* clearly identify the environmental values of groundwater replenishment (e.g. the use of groundwater as a water supply, or for maintaining dry weather flows into urban streams) and any associated water quality issues. If groundwater quality issues are critical, then *designers* may need to modify the detail design of WSUD features to prevent polluted runoff from entering the groundwater system.

11.03.2 Water sensitive urban design

Water Sensitive Urban Design (WSUD) involves the integration of urban stormwater, water supply, and wastewater issues during the planning and design of urban developments in a manner that uses water in a resource-sensitive and ecologically sustainable manner.

Water Sensitive Urban Design seeks to:

- Preserve the existing topography and features of the natural drainage system including waterways and water bodies.
- Integrate public open space with stormwater drainage corridors to maximise public access, passive recreation activities and visual amenity, while preserving essential waterway habitats and wildlife movement corridors.
- Preserve the natural water cycle including minimising changes to the natural frequency, duration, volume, velocity and peak discharge of urban stormwater runoff.
- Utilise surface water and groundwater as a valued resource.
- Protect surface water and groundwater quality.
- Minimise the capital and maintenance costs of stormwater infrastructure.

It is recommended that the principles of WSUD are applied wherever practical to greenfield urban developments as well as infill developments and urban redevelopment programs. Recommended reference documents on WSUD are presented in Section 11.07.

11.03.3 Water sensitive road design

Water Sensitive Road Design (WSRD) focuses on water-sensitive stormwater management within car parks and road reserves. The principles can be applied to both urban and rural roads.

Basic design tools incorporated into WSRD are:

- minimising the extent of impervious surfaces;
- stormwater detention/retention;
- stormwater treatment systems;
- pollution containment systems;
- the concepts of indirectly connected impervious surface area;
- appropriate street landscaping.

Design features of Water Sensitive Road Design include the following:

(a) Minimising the extent of impervious surfaces

(i) Use of narrow, single crossfall residential roads incorporating road drainage along only one side of the roadway.

(ii) Provision of adequate formal on-street and/or off-street parking to prevent vehicular damage to roadway verge and other grassed areas. It is noted that vehicle damage often leads to soil compaction, loss of grass cover and ongoing soil erosion (water quality) problems.

(iii) Use of permeable pavements, wherever practical, for car parks and pedestrian areas (e.g. CBD and community areas).

(iv) Incorporation of a footpath along only one side of the road reserve.

(b) Stormwater detention and retention

(i) Incorporation of stormwater detention and water quality treatment into roundabouts (primarily used along sub-arterial and arterial roads).

(ii) Incorporation of stormwater detention and water quality treatment into the median of dual-carriageways. This can include dual-carriageway sub-arterial roads entering large residential estates.

(iii) Incorporation of low-velocity drainage swales along sub-arterial and arterial roads.

(c) Stormwater treatment systems

(i) Priority given to the treatment of road runoff from areas where there is a high concentration of vehicle braking and turning (i.e. roundabouts, intersections and off-ramps).

(ii) Incorporation of grassed swales (where appropriate) to reduce total pollutant loadings to receiving waters.

(iii) Incorporation of water treatment systems into roadway features such as bio-retention filters into traffic calming devices.

(iv) Incorporation of litter collection systems into the car parks and surrounding roadways of shopping centres, takeaway food centres, community areas, entertainment facilities and sporting fields.

(v) Incorporation of public education messages onto the face of stormwater inlet lintels (e.g. PROTECT OUR WATERWAYS – FLOWS TO CREEK).

(vi) In rural areas, the retention of sediment basins—established during the construction of the road—as permanent pollution containment systems (see (d) below) or stormwater treatment devices.

(d) Pollution containment systems

Pollution containment systems are different from traditional stormwater treatment devices in that they are primarily designed to capture pollutant runoff from isolated incidents such as traffic accidents. The pollution is collected after the incident and removed from the site for treatment and disposal.

(i) Use of pollution containment systems at critical locations including: freeway off-ramps; roadways where there is a high risk of traffic accidents particularly involving industrial transport vehicles; roadways immediately up-slope of critical waterway habitats; high risk industrial estates.

(ii) Roadside detention/retention basin outlet structures modified to allow Emergency Services (e.g. EPA, councils, fire service) to temporarily shut-off the basin's outlet system to allow the containment and later removal of pollutant spills. This typically involves the use of a gate or stop board system.

(iii) The incorporation of oil skimmers into the outlet structures of roadside retardation basins and constructed wetlands.

(iv) The incorporation of oil skimmers, or other appropriate hydrocarbon treatment systems, into long-term or high volume car parks (e.g. large shopping centres, airports, bus interchanges and railway stations).

(e) Indirectly connected impervious surface areas

(i) Minimising the direct drainage of road and car park surfaces to impervious drainage systems.

(ii) Allowing stormwater runoff from roads and car parks to discharge as "sheet flow" across adjacent grassed surfaces prior to entering the formal drainage system.

(f) Appropriate street landscaping

(i) Appropriate selection of street trees to reduce leaf fall and the resulting stormwater passage of organic matter into receiving waters.

(ii) Appropriate selection of street trees, especially in cyclone prone areas, to reduce the discharge of organic matter into receiving waters.

11.04 Stormwater treatment techniques

11.04.1 General

The National Water Quality Management Strategy (ARMCANZ & ANZECC, 2000) has established the following hierarchy for the management of stormwater quality:

1. Retain, restore, or rehabilitate valuable ecosystems.
2. Source control through non-structural measures.
3. Source control through structural measures.
4. Regional instream treatment measures.

This hierarchy places a priority on the establishment of non-structural source controls over the adoption of structural source controls and regional instream treatment measures. However, this does not mean that structural or regional controls should not be adopted until after all non-structural source controls have been implemented.

For most urban land uses it is unlikely that non-structural source controls alone will achieve the required water quality objectives, thus for the time being, structural stormwater treatment measures will remain an integral part of the urban landscape.

11.04.2 Non-structural source controls

Non-structural source controls principally rely on pollution prevention through the use of community education and appropriate work place management practices.

(a) State Government

State Government activities that support stormwater pollution prevention include:

(i) Active enforcement of the *Environmental Protection Act*, *1994* and its associated *Environmental Protection Policies*.

(ii) Provision of a leadership role in the adoption of best management practice stormwater management on State works.

(iii) Provision of a leadership role in the adoption of best management practice Erosion & Sediment Control on State construction projects.

(iv) Cooperation with local governments, industry groups and professional bodies in the development of Best Management Practice guidelines.

(v) Encouragement and support for best management practice technology transfer between local and interstate authorities, industry groups and professional bodies.

(vi) Training of emergency services in the operation of “shut-down” systems on stormwater treatment devices and pollution containment systems.

(vii) Promotion of litter and nutrient reduction campaigns.

(b) Local government

Detailed discussion on municipal activities is provided in Victoria Stormwater Committee (1999).

Municipal activities that support stormwater pollution prevention include:

(i) Active enforcement of the *Environmental Protection Act*, *1994* and its associated *Environmental Protection Policies*.

(ii) Adoption of best management practice stormwater management and treatment measures on council works.

(iii) Adoption of best management practice Erosion & Sediment Control on council construction projects.

(iv) Development of Stormwater Management Plans in accordance with the requirements of the *Environmental Protection Act, 1994*.

(v) Establishment of local Water Quality Objectives (WQOs) and waterway Environmental Values.

(vi) Development and adoption of local planning policies and development regulations that support best management practice stormwater management, including WSUD.

(vii) Development and implementation of Asset Maintenance Plans (Section 2.09 (e)) for existing stormwater treatment systems.

(viii) Development and promotion of public education activities.

(ix) Investigation and control of illegal dumping, including the disposal of garden waste within parks and along waterways corridors.

(x) Integration of the planning and management of sewer overflows into catchment management planning.

(xi) Establishment of best management practice plant and equipment maintenance and wash-down facilities within council depots, including covered parking and chemical storage, stormwater runoff isolation areas in association with oil and grit traps.

(xii) Promotion of an environmentally sensitive septic tank replacement program.

(xiii) Establishment of local laws on the containment of dog faeces within public areas.

(xiv) Staff training and awareness programs.

(xv) Town planning protection of natural waterways and the rehabilitation of hard-lined drainage channels.

Street cleaning:

- Adoption of only suction-type sweeper units.
- Focusing street cleaning on critical areas including: the central business district (night sweeping), commercial areas, public activity and sporting areas, areas of high building activity, and residential streets following heavy winds.
- Reviewing night time parking restriction in high risk areas to improve the efficiency of street sweeping activities, otherwise conduct street sweeping during periods of daytime parking restriction.
- Adoption of wind-proof community litter bins.

Domestic waste collection:

- Establishing green waste collection facilities.
- Introducing community clean-up and waste collection prior to cyclone season.

Management of road shoulders:

Unsealed road shoulders can represent a significant source of coarse and fine sediments, and metals.

- Sealing or otherwise stabilising road shoulders wherever practical.
- Considering the use of grassed "structural soils" in areas where normal grassing or single coat bitumen seal is not practical.

(c) Business unit operations

Business activities that support stormwater pollution prevention include:

(i) Active enforcement of the *Environmental Protection Act*, *1994* and its associated *Environmental Protection Policies* within business activities.

(ii) Adopting alternative water sensitive practices relating to start-of-day and end-of-day "wash-down" and "clean-up" procedures, with preference given to portable sweeper/suction devices.

(iii) Establishment of best management practice plant and equipment maintenance and wash-down facilities, including covered parking and chemical storage, stormwater runoff isolation areas in association with oil and grit traps.

(iv) Development of industry-based stormwater management "codes of practice" for industries such as: fast food outlets, roof/house cleaning, carpet cleaning, mobile dog washing, building industry, construction industry, driveway/pavement stencilling, salt water pool maintenance.

(v) Site and local areas litter and debris collection.

(vi) Staff training and awareness programs.

(d) Public activities and education programs

Community attitudes and values greatly influence the selection and ranking of environmental values. Activities such as the *Clean-Up Australia* campaign have greatly influenced community's attitudes to gross pollutants, even though these attitudes may not necessarily be ecologically based. Stormwater managers have a responsibility to both identify and understand community values, and to assist in the education and guidance of the community in a manner that will assist in the protection of both existing and anticipated future environmental values.

The benefits of community participation are outlined in ARMCANZ & ANZECC (2000).

Community education programs can incorporate the following features:

- Development of fact sheets, brochures, booklets and videos.
- Stormwater guidelines for the community (e.g. Environmental Protection Authority SA, 1997).
- Development of community-based guidelines on: the management of green waste, operation of fresh and salt water swimming pools, use of garden fertilisers and pesticides, car washing, building site erosion and sediment control.
- Promotion of environmentally sensitive septic tank maintenance and adoption of replacement systems.
- Community awareness campaigns such as the "Adopt A Lake", "Adopt A Waterway" schemes, Clean-Up Australia campaign, and stormwater lintel messages (e.g. PROTECT OUR WATERWAYS – FLOWS TO CREEK).

Community education programs should reinforce key issues such as:

(i) Potential impacts of increased impervious surface area within residential homes on the quantity and quality of stormwater runoff and downstream ecosystems.

(ii) Impact of waste organic matter (e.g. garden waste and grass cuttings) on stream water quality.

(iii) The importance of a complete vegetative cover over all earth surfaces, including the footpath regions of road reserves.

(iv) The ecological importance of maintaining high quality stormwater runoff.

(v) The financial cost to ratepayers for litter collection within residential areas (e.g. street sweeping), parks and waterways (e.g. construction and maintenance of various end-of-pipe stormwater treatment systems).

11.04.3 Structural controls

Treatment levels for structural controls can be graded into Primary, Secondary and Tertiary (polishing) treatment in a manner aligned with the classifications adopted for wastewater treatment. The various treatment levels are outlined in Table 11.04.1 to 11.04.3.

Table 11.04.1 Primary treatment classifications

Mechanics	Description	Target Pollutants
Screening	Physical separation of solids from a liquid passing through a screen. Promoted by fine screen opening.	Solids, litter, debris
Isolation	Physical entrapment of substances. Promoted by storage volume and flow control barrier.	Hydrocarbons, chemicals, toxicants
Separation	Physical isolation of two collective substances by an impervious barrier. Promoted by low turbulence and depth of surface skimmer.	Hydrocarbons, floating litter and debris
Settling (sedimentation and oil separation)	The separation or layering of substances according to their relative mass. Promoted by low turbulence.	Solids, BOD, pathogens, particulates, COD, nutrients (particulates), hydrocarbons (if skimmer is used)

Table 11.04.2 Secondary treatment classifications

Mechanics	Description	Target Pollutants
Adsorption	The attachment of a substance to the surface of a solid by virtue of forces arising from molecular attraction. Promoted by high soil Al, Fe; high soil organics; circumneutral pH.	Dissolved P, nutrients (N, P), metals, synthetic organics
Filtration	Physical retention of particles on surface of the filter or within the filter medium. Promoted by fine, dense herbaceous plants; or fine, homogeneous porous medium (e.g. sand with uniform grain size)	Solids, BOD, pathogens, particulates, COD, nutrients (particulates)
Flocculation	The process by which suspended colloidal or very fine particles coalesce and agglomerate into well-defined hydrated floccules of sufficient size to settle rapidly. Promoted by flocculating agent and low turbulence.	Turbidity, fine sediments, metals, nutrients (particulates)
Infiltration	The movement of water into the soil. Promoted by highly porous soils.	As for filtration

Table 11.04.3 Tertiary treatment classifications

Mechanics	Description	Target Pollutants
Aeration	The combining of oxygen from the atmosphere with the water body.	Oxygen demanding substances, process resulting in low DO water
Biological decomposition	To separate or resolve into constituent parts or elements through biological activity. Promoted by high plant surface area and soil organics.	BOD, COD, organic matter, petroleum hydrocarbons, synthetic organics
Biological uptake	A process by which materials are absorbed and incorporated into organic matter. Promoted by high plant activity and surface area; soil pH (variable depending on substance).	Nutrients (P, N) and metals
Disinfection	Destruction of pathogens (eg. bacteria) by ultra-violet light. Promoted by high light, shallow water depth, low turbidity.	Pathogens
Fixation	Fixation of atmospheric nitrogen to ammonia by microbial organisms and chemical fixation.	Nitrogen
Nitrification & denitrification	Microbial conversion of ammonia to nitrite, then to nitrate; and the reduction of nitrate or nitrite to nitrogen gas, in the absence of oxygen. Promoted by variable oxygen levels, circumneutral pH, low toxicants, water temperature > 15°C.	Nitrogen
Oxidation	The combination of oxygen with a substance. Promoted by aerobic conditions.	COD, nutrients (N, P), petroleum hydrocarbons, synthetic organics
Solar treatment (volatilisation & disinfection)	Destruction of pathogens (eg. bacteria) and the breakdown of hydrocarbons by ultra-violet light. Promoted by high light, shallow water depth, low turbidity.	Pathogens, hydrocarbons
Volatilisation	The conversion of a chemical substance from a liquid or solid to a gaseous or vapour state. Promoted by high temperature and air movement.	Mercury, volatile petroleum hydrocarbons and synthetic organics

Unless otherwise specified, stormwater treatment systems should be designed for the equivalent of the 3-month peak design storm flow. This is usually (in 2007) adopted as a fraction of the 1 year ARI design storm, typically 0.5 to 0.6 times the peak 1 in 1 year ARI discharge.

11.05 Selection of treatment techniques

Various design procedures may be followed depending on the existence of local or regional Stormwater Management Plans (SMPs) or Water Quality Objectives (WQOs). Six design procedures are presented in Table 11.05.1 representing the typical range of procedures adopted around Australia. Over time it is expected that only one or two of these procedures will be commonly used within Queensland.

Priority is generally given to Methodology 4 wherever practical within large catchments or critical waterway habitats where the added costs of such scientific investigations can be justified. Otherwise, for urban development and large land use changes, the local government should identify their requirements for numerical water quality modelling based on Methodologies 1, 2 or 3. Design Methodologies 5 and 6 should only be used where it is not considered practical to establish a numerical water quality model of the site, such as minor council road works.

There are numerous arrangements of treatment measures that can "numerically" (i.e. through computer modelling) satisfy the required Water Quality Objectives (WQOs). The treatment train should not be selected with the sole aim of achieving these WQOs, but should show due consideration towards the following factors:

(i) an understanding of the pollutant runoff characteristics of different land uses;
(ii) an understanding of the benefits of different treatment techniques;
(iii) an understanding of the needs of different downstream waters and ecosystems.

To provide the best and most robust stormwater treatment system, all waterway catchments should ideally incorporate an array of primary, secondary and tertiary treatment measures.

The *selection* of treatment techniques should give appropriate consideration to numerous factors including the following:

(i) aims of a relevant Stormwater Management Plan;
(ii) site and catchment conditions and target pollutants;
(iii) cost-effectiveness of each treatment method or device, including life cycle costs;
(iv) capability of the asset manager to operate and maintain the treatment measure;
(v) opportunities provided by the particular land use, land area and soil type;
(vi) the potential for stormwater management infrastructure to enhance urban amenity.

Wherever practical, the *design* of stormwater treatment measures must consider the following issues on a site-by-site basis:

- topography – land area and slope;
- soil type – porosity, erosivity, depth to bedrock;
- groundwater issues – watertable level, risk of contamination, rising salinity problems;
- ecology issues – habitats, vegetation, waterways etc;
- land ownership;
- cultural heritage considerations;
- provision of services (power and water);
- flooding issues;
- public safety;
- maintenance equipment and access;
- proximity of residents;
- potential odour problems;
- visual impacts;
- possible long-term site contamination;
- health problems relating to mosquitoes and vermin.

Note: *The information presented in Tables 11.05.2 to 11.05.8 has been provided as a general guide only. The suitability of a treatment system to a particular catchment location is governed by numerous factors that can significantly alter its benefit, function, efficiency, suitability and ranking. The information presented within these tables should not supersede site specific investigation, modelling or design.*

Table 11.05.1 Various design procedures

Design methodology	Design steps
Methodology 1. Design to achieve a given water quality	• Obtain local or regional Water Quality Objectives from relevant regulating authority. • Model post-development stormwater runoff conditions.
Methodology 2. Design to achieve a % reduction in pollutant runoff	• Obtain local or regional pollution reduction standard from relevant regulating authority. • Model post-development stormwater runoff conditions.
Methodology 3. Design to achieve pre-development catchment discharge quality	• Obtain existing water quality conditions (if available). • Model stormwater runoff conditions for pre and post development.
Methodology 4. Design to protect a given downstream environment	• Consult State government and local authority for terms of reference for study. • Identify environmental values. • Conduct scientific research/study (if study has not already occurred). • Develop water quality model of research area, including downstream waters. • Establish WQOs to either protect, restore or secure the environmental values as defined by the National Water Quality Management Strategy. • Where appropriate, develop an Urban Stormwater Quality Management Plan (Section 2.06). • Adopt Methodology 1 or 2 (above) depending on the type of WQOs determined from scientific study.
Methodology 5. Selecting BMPs based on a given critical receiving water	• Use Tables 11.05.2 and 11.05.3 to select a short list of techniques most appropriate for the given catchment area and soil porosity. These tables should not be viewed as prescriptive, but as a general guide. • Use Tables 11.05.4 to 11.05.6 to further refine this short list of treatment measures based on the receiving waters.
Methodology 6. Selecting BMPs based on land use activities	• Use Tables 11.05.2 and 11.05.3 to select a short list of techniques most appropriate for the given catchment area and soil porosity. These tables should not be viewed as prescriptive, but as a general guide. • Use Tables 11.05.7 and 11.05.8 to further refine this short list of treatment measures based on the land use category.

Table 11.05.2 Typical optimum catchment area for treatment techniques

	Catchment Area (hectares)								
	1	**2**	**5**	**10**	**20**	**50**	**100**	**500**	**>500**
Primary Treatment									
Grate inlet screens	✓								
Side entry pit traps	✓								
Litter baskets	✓	✓	✓	✓	✓	✓			
Outlet litter cages	✓	✓	✓	✓	✓	✓			
Release nets	✓	✓	✓	✓	✓	✓			
Enclosed GPTs	✓	✓	✓	✓	✓	✓			
Oil & grit separators	✓								
Open GPTs				✓	✓	✓	✓		
Trash racks			✓	✓	✓	✓	✓	✓	✓
Floating booms							✓	✓	✓
Floating GPT							✓	✓	✓
Sedimentation basins				✓	✓	✓	✓	✓	
Roadside pollution containment systems	✓								
Secondary Treatment									
Porous pavements	✓								
Filter strips	✓								
Grass swales	✓	✓	?						
Bio-retention cells	✓	✓							
Infiltration trenches	✓	?	?						
Infiltration basins		✓	✓	?	?				
Exfiltration systems	✓	?	?						
Extended detention			✓	✓	✓	✓	✓		
Sand filters	✓	?							
Filter basins		?	✓	✓	✓	✓	✓		
Mini wetlands	?	✓	✓	✓	?				
Tertiary Treatment									
Ponds			?	✓	✓	✓	✓	✓	✓
Constructed wetlands				?	✓	✓	✓	✓	✓

Note: " ✓ " means that the technique is likely to be suitable for catchment area

" **?** " means the suitability of the technique to the given catchment area is questionable.

Table 11.05.3 Optimum soil permeability for various treatment systems [1]

	Sand **210 mm/hr**	**Loam sand** **54 mm/hr**	**Sandy loam** **26 mm/hr**	**Loam** **13.2 mm/hr**	**Silt loam** **6.9 mm/hr**	**Clay loam** **2.3 mm/hr**	**Clay** **0.5 mm/hr**
Secondary Treatment							
Porous pavements	✓	✓	✓	✓	Use subsoil drainage		
Filter strips	✓	✓	✓	✓	✓	[2]	
Grass swales	✓	✓	✓	✓	Use subsoil drainage		
Bio-retention cells	Use swale or infiltration			✓	✓	✓	✓
Infiltration trenches	✓	✓	✓	✓			
Infiltration basins	✓	✓	✓	✓			
Exfiltration systems	✓	✓	✓	✓			
Extended detention	✓	✓	✓	✓	✓	[3]	
Sand filters	Use infiltration systems			✓	✓	✓	✓
Filter basins	Use infiltration systems			✓	✓	✓	✓
Mini wetlands		[4]		✓	✓	✓	✓
Tertiary Treatment							
Ponds		[4]		✓	✓	✓	✓
Wetlands		[4]		✓	✓	✓	✓

Notes:

[1] Consideration should be given to the likely long-term soil permeability (i.e. during normal operating conditions) taking appropriate consideration of long-term maintenance and possibly ongoing replacement of the filtration system.

[2] Water quality benefits decrease with decreasing soil porosity. Likely maintenance mowing problems during wet season due to soil saturation.

[3] Runoff detention benefits still achieved, but water quality benefits are reduced due to limited infiltration.

[4] Possible plant sustainability problems due to low soil water levels. Consider design of sub-surface flow wetland or melaleuca wetland.

Table 11.05.4 Typical pollutant removal efficiencies of treatment systems

Benefit Ranking: L = Low benefit M = Medium benefit H = High benefit	Litter & Debris	Coarse Sediment	Fine Sediment	Nutrients		Metals	Hydrocarbons	Oxygen Demanding Substances	Pathogens
				Dissolved	Particulate				
Primary Treatment									
Grate inlet screens	L								
Side entry pit traps	L-M							L	
Litter baskets	L-M							L	
Outlet litter cages	H							M-H	
Release nets	H							L-M	
Enclosed GPTs	H	H	L		L	L	L	L-M	
Oil & grit separators	L	H	L		L	L	M		
Open GPTs	M-H	M-H	L		L	L		L-M	
Trash racks [1]	M-H	L						L-M	
Floating booms	L						M		
Floating GPT	L						L		
Sedimentation basins	L	M-H	L-M		L	L	L	L	L
Roadside pollution containment system [2]							H		
Street sweeping	H-M	M						L	
Secondary Treatment									
Porous pavements		L-M	L-M	L	M	M	M	L	M
Filter strips	L	M	L-M	L	L-M	L-M	L	L	M
Grass swales	L	M-H	L-M	L	L-M	L-M	L	[3]	L-M
Bio-retention cells	L	M-H	M	L	M	M	L-M	L-M	L-M
Infiltration trenches	L	M-H	M	L-M	M	M	M	M	M
Infiltration basins	L-M	H	M-H	L-M	M-H	M-H	M-H	M-H	M-H
Exfiltration systems	H	H	M-H	L	M-H	M-H	M-H	M-H	M
Extended detention	M	H	L-M	L	M	M	L	L	M
Sand filters	L-M	H	M	L	M-H	M-H	M-H	M-H	M
Filter basins	L-M	H	M-H	L	M-H	M-H	M-H	M-H	M-H
Mini wetlands	M	H	L	M	M-H	M	L	L	L
Tertiary Treatment									
Ponds	M-H	H	M	M	M-H	M	L	L	[4]
Constructed wetlands	M-H	H	M	H	H	M-H	M	L	[4]

Notes (Table 11.05.4):

[1] Benefits depend on maintenance frequency and whether trapped organics remain wet or dry between storms.

[2] Target pollutant is usually hydrocarbons and liquid chemicals released from spills and traffic accidents.

[3] Grass swales can generate large volumes of cut grass that, if not collected, can be washed into receiving waters.

[4] Pathogen level may be increased due to resident bird life.

Table 11.05.5 Potential ecological impact of pollutants on waterways [1]

		Ephemeral Creeks	Perennial Creeks	Freshwater Rivers	Lakes	Natural Wetlands	Canals	Saline Rivers & Estuaries	Bays	Ocean
Gross Pollutants	Litter [2]	L	L	L	M	M	M	M-H	H	H
	Organic Debris	H	H	M	M-H	L	H	L-M	L	L
	Coarse Sediment	H	H	M	L-M	H	L-M	L	L	L
Fine Sediment		M-H	H	H	H	M	M	M	M	L
Nutrients		H	H	H	H	M	H	H	H	L
Metals		H	H	H	H	M	H	H	H	H
Hydrocarbons [3]		H	H	H	H	H	M-H	M	M	M
Oxygen Demanding Substances		H	H	M	H	M	M-H	L-M	L-M	L
Pathogens [4]		M	M	H	H	L	M-H	M	M	M

Notes:

[1] Potential impacts are highly variable and site specific. Values provided are only a guide to typical ecological impacts. Consideration has not been given to safety, social or economic impacts.

[2] Litter impact on coastal water is high due to potential digestion of litter (plastic bags, etc.) by large marine life.

[3] Reference is made to minor quantities of hydrocarbons, not to major oil or fuel spills.

[4] Reference is made to potential impact on human and aquatic health.

Table 11.05.6 Typical benefits of treatment systems on waterways

Benefit Ranking: L = Low benefit M = Medium benefit H = High benefit	**Ephemeral Creeks**	**Perennial Creeks**	**Freshwater Rivers**	**Lakes**	**Natural Wetlands**	**Canals**	**Saline Rivers & Estuaries**	**Bays**	**Ocean**
Primary Treatment									
Grate inlet screens	L	L	L	L	L	L	L	M	M
Side entry pit traps	L	L	L	L	L	M	M	M	M
Litter baskets	L	L	L	L	L	M	M	M	M
Outlet litter cages	L	L	L	L	L	M	M	M	M
Release nets	L	L	L	L	L	M	M	M	M
Enclosed GPTs	M-H	M-H	M	M-H	M	M-H	M	M	M
Oil & grit separators	M-H	M-H	M	M	M	L-M	L	L	L
Open GPTs	M-H	M-H	M	M-H	L-M	M-H	M	M	M
Trash racks	M	M-H	L	M	L	M	M	M	M
Floating booms	[redacted]	[redacted]	L	M	[redacted]	[redacted]	M	M	M
Floating GPT	[redacted]	[redacted]	L	L	[redacted]	[redacted]	M	M	M
Sedimentation basins	M-H	M-H	L-M	L	L-M	L	L-M	L	L
Roadside pollution containment systems	H	H	H	H	H	H	H	H	H
Street sweeping	M	M	L	L	L-M	M	H	H	H
Secondary Treatment									
Porous pavements	M-H	M-H	M	M	L	M	M	L	L
Filter strips	M	M	L-M	L	L	M	M	M	M
Grass swales	M-H	M-H	M	M	L	M	M	M	L-M
Bio-retention cells	H	H	M-H	H	M	M-H	M-H	M-H	M-H
Infiltration trenches	H	H	H	H	H	H	H	H	H
Infiltration basins	H	H	H	H	H	H	H	H	H
Exfiltration systems	H	H	H	H	H	H	H	H	H
Extended detention	M-H	M-H	L-M	L-M	L-M	L-M	L-M	L	L
Sand filters	H	H	M-H	H	H	M-H	M-H	M	M
Filter basins	H	H	H	H	H	H	H	M	M
Mini wetlands	H	H	M	M-H	L-M	M	M	M	M
Tertiary Treatment									
Ponds	H	H	H	H	H	H	H	M-H	M
Constructed wetlands	H	H	H	H	H	H	H	M-H	M

Table 11.05.7 Suitability of treatment systems to various land uses [1]

	Car Parks	Shopping Centres	Sporting & Public Areas	Rural Roads	Residential Roads	Arterial Roads	Coastal Roads	Road Intersections
Primary Treatment								
Grate inlet screens	L	L	L			L	L	
Side entry pit traps	M	H	M		L	L	M	L
Litter baskets	M	H	M			L	M	L
Outlet litter cages		M	M			L	H	
Release nets		M	M			L	H	
Enclosed GPTs	M	H	H		L	M	H	
Roadside pollution containment systems						H	M	M
Secondary Treatment								
Porous pavements	H	H	H					
Filter strips	M	M	M	M	L	L	L	L
Grass swales	M	M	M	M	M	M	M	M
Bio-retention cells	H	H	H		H	H	M	H
Infiltration trenches	H	H	H			H	M	M
Infiltration basins		H						
Exfiltration systems	H	H						
Extended detention	L	M						
Sand filters	H	H	H					
Filter basins		H						
Mini wetlands	M	M	M	M	M	M	M	M

Note:

[1] This table is provided as a general guide only. The suitability of a treatment system to a particular land use is governed by numerous factors which can significantly alter its function, efficiency and overall suitability. The indicated "suitability" of a treatment system to a given land use has been based on the likely integration of the system into the land use, and the ability of the system to capture and/or treat the type of pollutants most commonly associated with the land use activity. The information presented in these tables should not supersede site specific investigation, modelling or design.

Table 11.05.8 Suitability of treatment systems to various land uses [1]

	Parks & Open Space	Rural Residential	Low Density Residential	Medium Density Residential	High Density Residential	Commercial Areas	Industrial Areas	Central Business Districts
Primary Treatment								
Grate inlet screens						L	L	L
Side entry pit traps					L	L	M	M
Litter baskets				L	L	M	M	M
Outlet litter cages				M	M	M	M	M
Release nets				M	M	M	M	M
Enclosed GPTs				M	M	M	M	M
Open GPTs				M	M	M	M	M
Roadside pollution containment systems				L	L		M	
Secondary Treatment								
Porous pavements	L	L	M	L	L	L	L	
Filter strips	L	M	M	L	L	L	L	
Grass swales	M	M	M	M	M	M	M	M
Bio-retention cells	M	M	H	H	H	H	H	H
Infiltration trenches				H	H	H	H	H
Infiltration basins				H		H	H	
Exfiltration systems					H	H	H	H
Extended detention				M	M	M	M	
Sand filters					H	H	H	
Filter basins					H	H	H	
Mini wetlands	M	M	M	M	M	M	M	M

Note:

[1] This table is provided as a general guide only. The suitability of a treatment system to a particular land use is governed by numerous factors which can significantly alter its function, efficiency and overall suitability. The indicated "suitability" of a treatment system to a given land use has been based on the likely integration of the system into the land use, and the ability of the system to capture and/or treat the type of pollutants most commonly associated with the land use activity. The information presented in these tables should not supersede site specific investigation, modelling or design.

11.06 Stormwater management plans

11.06.1 General

Stormwater Management Plans set out the proposed management of activities within a catchment which are likely to:

(i) alter stormwater runoff volume, rate, duration and frequency; or

(ii) adversely affect the environmental values of receiving waters, including groundwater, downstream water and coastal water.

Stormwater Management Plans should identify the proposed protection, treatment and management of the identified waterways and water bodies within the catchment with respect to:

(i) the impact of stormwater on these features and their ecosystems; and

(ii) the impact of these features on stormwater.

There are two forms of Stormwater Management Plans:

(i) Urban Stormwater Quality Management Plans;

(ii) Site-based Stormwater Management Plans.

A brief description of catchment-based Urban Stormwater Quality Management Plans is presented in Section 2.06 of this Manual.

11.06.2 Site-based stormwater management plans

Site-based Stormwater Management Plans are normally developed by an applicant as part of a development application for approval under the *Integrated Planning Act, 1997*.

These plans are prepared for urban developments to provide a set of guidelines to control soil erosion and pollutant transport during the construction phase, post-construction maintenance phase, and ongoing operational phases of the development.

Site-based SMPs must be consistent with any current catchment-based Urban Stormwater Quality Management Plan or Catchment Management Plan.

Three separate SMPs may need to be produced dealing with the Construction Phase, Post-construction Maintenance Phase, and the Operational Phase. The Operational Phase SMP is prepared as a guide for the long-term management and maintenance of the various stormwater management systems installed within the development.

(a) Erosion and sediment control

Erosion and sediment control requirements during the construction phase of a development may be incorporated into, or otherwise linked to, the site-based SMP.

Sediment, in all its forms—sand, silt, clay, earth and mud—constitutes a "pollutant" if it exceeds an undesirable or environmentally damaging concentration or deposition quantity. Thus the removal and transportation of sediment by rainfall and stormwater runoff must be appropriately managed.

Erosion and Sediment Control Plans (ESCPs) should be developed for the building/construction phase of all significant land disturbances, whether or not the land disturbance is regulated by an external authority. A significant land disturbance would include any soil disturbances that occurs over a period exceeding 24 hours during which time rainfall is possible, or any soil disturbance exceeding 100 square metres that will remain unprotected during a period in which rainfall is possible.

The degree of complexity and detail provided in the ESCP shall depend on the extent and complexity of the works, and the potential for environmental harm resulting from the works. Guidelines on the preparation of ESCPs can be found in the latest version of the Engineers Australia ESC guidelines, or other regional or local government ESC guideline.

(b) Site-based stormwater management plans – construction phase

Issues to be addressed within the SMP (Construction) include:
- site constraints;
- water quality objectives and indicators;
- statement of who is responsible for each task;
- erosion and sediment control (submission of plan, review and monitoring of plan, amendment and re-submission of plan)
- management of trapped fauna;
- management/protection of permanent stormwater treatment systems during the construction phase;
- management of changing weather and site conditions;
- treatment of acid sulfate and dispersive soils;
- on-site chemical and fuel storage;
- waste and litter receptors;
- maintenance procedures (ESC and waste)
- clean-up of pollution spills/deposition (on-site and off-site);
- clean-up after storm events;
- water quality monitoring requirements (location and testing);
- site inspection and monitoring;
- procedures for recording and addressing external complaints;
- incident reporting;
- reporting procedures.

The management of wastes and chemicals on building and construction sites should incorporate appropriate storage, handling and disposal of any material or pollutant that may be incorporated into, or transported by, stormwater, whether or not such material was initially displaced by rain, flowing water, wind or mechanically by construction practices. These management practices should ensure:

(i) chemicals and fuels are stored, handled and disposed of in a manner which ensures that no pollutants are discharged to stormwater;

(ii) wastewater from construction and building activities (e.g. equipment clean-up and site wash-down water, and cooling water from material cutting) to be contained on-site; and

(iii) litter and building waste to be adequately stored and disposed of.

(c) Site-based stormwater management plans – post-construction maintenance phase

Where necessary, a separate SMP may be required for the post-construction maintenance phase that addresses the following issues:

- water quality objectives and indicators;
- statement of who is responsible for each task;
- management and maintenance of permanent stormwater treatment systems;
- maintenance of retained ESC measures
- water quality monitoring requirements (location and testing);
- site inspection and monitoring;
- incident reporting;
- reporting procedures.

Specifically, instructions should be provided on the necessary site conditions that should exist prior to commissioning each stormwater treatment system.

(d) Site-based stormwater management plans – operational phase

Where necessary, a separate SMP may be required for the operational phase that addresses the following issues:

- water quality objectives and indicators;
- short-term (e.g. weekly, monthly, annual, biannual) maintenance requirements for various stormwater treatment systems;
- long-term (e.g. 5, 10, 20-year plan) maintenance requirements and procedures for various stormwater treatment systems;
- water quality monitoring requirements (location and testing).

11.07 Related guidelines

(a) Erosion and sediment control:

1. Brisbane City Council 2001, Sediment *Basin Design, Construction and Maintenance Guidelines.* Brisbane City Council, Brisbane.
2. Brisbane City Council, *Instream Sediment Control Guidelines – Draft 3.* Brisbane City Council (internal document, unpublished).
3. Gold Coast City Council & Brisbane City Council 1998, *Best Practice Guidelines for the Control of Stormwater Pollution from Building Sites.* Brisbane City and Gold Coast City Councils, Brisbane.
4. Institution of Engineers, Australia 1996, *Soil Erosion and Sediment Control – Engineering Guidelines for Queensland Construction Sites.* The Institution of Engineers, Australia, Queensland Branch, Brisbane.
5. Landcom 2004, *Managing Urban Stormwater: Soils and Construction.* Landcom, New South Wales Government. ISBN 0-9752030-3-7.

(b) Catchment hydrology:

1. Carey, B. 2004, *Soil Conservation Measures – Design Manual for Queensland.* Queensland Department of Natural Resources and Mines, Brisbane.
2. Institution of Engineers, Australia 1998, *Australian Rainfall and Runoff – A Guide to Flood Estimation.* Revised Edition, The Institution of Engineers, Australia, Barton, ACT. ISBN 085825 434 4.

(c) Creek engineering:

1. Brisbane City Council 1997, *Erosion Treatment for Urban Creeks – Guidelines for Selecting Remedial Works.* Brisbane City Council, Brisbane.
2. Brisbane City Council 2000, *Natural Channel Design Guidelines.* Brisbane City Council, Brisbane.
3. Brisbane City Council 2002, *Stormwater Outlets in Parks and Waterways.* Brisbane City Council, Queensland.
4. Fairfull, S., Witheridge, G. 2003, *Why Do Fish Need to Cross the Road? – Fish Passage Requirements for Waterway Crossings.* NSW Fisheries, Cronulla.
5. Witheridge, G.M. 2002, *Fish Passage Requirements at Waterway Crossings – Engineering Guidelines.* Catchments & Creeks Pty Ltd, Brisbane.

(d) Farm drainage and soil conservation:

1. Carey, B. 2004, *Soil Conservation Measures – Design Manual for Queensland.* Queensland Department of Natural Resources and Mines, Brisbane.

(e) Stormwater management plans:

1. Ahern, C.R., Ahern, M.R. and Powell, B. 1998, *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland.* QASSIT, Department of Natural Resources, Resources Sciences Centre, Indooroopilly, Queensland.
2. ARMCANZ & ANZECC 2000, *Australian Guidelines for Urban Stormwater Management.* National Water Quality Management Strategy, prepared by Agriculture and Resources Management Council of Australia and New Zealand & Australian and New Zealand Environment and Conservation Council, Canberra. ISBN 0 642 24465 0.
3. CIRIA 1992, *Scope for Control of Urban Runoff – Volume 1: Overview.* Report 123, Ed. A.D. Maskell. Construction Industry Research and Information Association (CIRIA) London.
4. Brisbane City Council 2000, *Water Quality Management Guidelines.* Version 1, Brisbane City Council, Brisbane.
5. Department of Environment 1997, *User's Guide to Queensland Environmental Protection (Water) Policy 1997.* Department of Environment, Queensland. ISBN 0 7242 6396 9.
6. Department of Environment 1997, *Environmental Protection (Water) Policy 1997.* Department of Environment, Queensland.
7. Environmental Protection Agency 2001, *"Model Urban Stormwater Quality Management Plans and Guidelines".* Environmental Protection Agency, Queensland Government, Brisbane.

(f) Stormwater reuse:

1. Environmental Protection Agency 2005, *Queensland Water Recycling Guidelines.* Environmental Protection Agency, Brisbane.
2. NSW Department of Environment and Conservation 2006, *Managing Urban Stormwater Harvesting and Reuse.* NSW Department of Environment and Conservation, Sydney.

(g) Stormwater treatment:

1. Brisbane City Council 1999, *Design Guidelines for Stormwater Quality Improvement Devices.* Final Draft, November 1999, prepared by Geo-Eng Australia and City Design – Brisbane City Council, Brisbane.
2. Engineers Australia 2005, *Australian Runoff Quality – A Guide to Water Sensitive Urban Design*, Engineers Australia, Canberra.
3. Environmental Protection Authority 1997, *Stormwater Pollution Prevention – Code of Practice for the Community*. Environmental Protection Authority, Department of Environment and Natural Resources, South Australia, Adelaide. ISBN 0 7308 0211 6

4. Livingston, E.H., Shaver, E., Skupien, J.J. 1997, *Operation, Maintenance and Management of Stormwater Management Systems.* Watershed Management Institute, Inc. Maryland, USA.

5. Victoria Stormwater Committee 1999, *Urban Stormwater – Best Practice Environmental Management Guidelines.* CSIRO Publishing, Collingwood, Victoria. ISBN 0 643 06453 2.

(h) Water sensitive urban design

1. Brisbane City Council 2003, *Water Sensitive Road Design Guidelines.* Release 2 (CD-ROM), Brisbane City Council, Brisbane.

2. Brisbane City Council 2005, *Draft Water Sensitive Urban Design – Engineering Guidelines*. Brisbane City Council, Brisbane.

3. Engineers Australia 2005, *Australian Runoff Quality – A Guide to Water Sensitive Urban Design*, Engineers Australia, Canberra.

4. Healthy Waterways Partnership 2006, *WSUD Technical Design Guidelines for South East Queensland,* Version 1, June 2006.

(i) Waterway structures

1. Austroads 1994, *Waterway Design – A Guide to the Hydraulic Design of Bridges, Culverts and Floodways.* Austroads, Sydney.

2. AUSTROADS 2005, *Guide to Bridge Technology*, AUSTROADS, N.S.W.

3. Fairfull, S., Witheridge, G. 2003, *Why Do Fish Need to Cross the Road? – Fish Passage Requirements for Waterway Crossings.* NSW Fisheries, Cronulla.

4. Witheridge, G.M. 2002, *Fish Passage Requirements at Waterway Crossings – Engineering Guidelines.* Catchments & Creeks Pty Ltd, Brisbane.

(j) Wetland design

1. Department of Land and Water Conservation 1998, *The Constructed Wetlands Manual.* New South Wales Department of Land and Water Conservation, NSW. ISBN 0 7313 1329 6.

2. Engineers Australia 2005, *Australian Runoff Quality – A Guide to Water Sensitive Urban Design*, Engineers Australia, Canberra.

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Brisbane City Council 2000, *Natural Channel Design Guidelines.* Brisbane City Council, Brisbane. ISBN 187609 141X

Environmental Protection Authority 1997, *Stormwater Pollution Prevention – Code of Practice for the Community*. Environmental Protection Authority, Department of Environment and Natural Resources, South Australia, Adelaide. ISBN 0 7308 0211 6

Standards Australia 1993, *The storage and handling of flammable and combustible liquids*. AS1940–1993. Standards Australia, Homebush NSW. ISBN 0 7262 8545 5

Victoria Stormwater Committee 1999, *Urban Stormwater – Best Practice Environmental Management Guidelines.* CSIRO Publishing, Collingwood, Victoria. ISBN 0 643 06453 2

Witheridge, G.M. 2002, *Fish Passage Requirements at Waterway Crossings – Engineering Guidelines.* Catchments & Creeks Pty Ltd, Brisbane.