10 CHOICE OF MANAGEMENT OPTIONS

10.1 INTRODUCTION

This chapter provides guidance for the selection of various stormwater management system facilities across a catchment. The selection of options will normally be made as part of the Master planning process described in the previous chapter.

(a) Constraints Imposed by Landuse Planning

The prior existence of Landuse or Structure Plans will have an impact on the choice of stormwater management options. For that reason, it is highly desirable that landuse planning be carried out in conjunction with stormwater planning. The relevant Authorities should establish formal mechanisms to ensure coordinated landuse and stormwater management planning.

(b) Economics and Community Expectations

Ultimately it is the public that bears the cost of a stormwater system. Irrespective of whether it is built by a private developer or a government authority, these costs will ultimately be passed on to the community in the form of house prices and/or government charges.

The economic value of a drainage and stormwater management system should be assessed as the *total lifecycle cost* of the system to the community. The designer should aim to minimise the total cost of the system, within practical, social, environmental and legislative constraints. For example, lined/piped drains occupy less land area but are relatively more expensive to construct than open waterways systems. Poorly designed drains may have a low capital cost but this is offset by high ongoing maintenance costs. Therefore, when evaluating alternatives the total lifecycle cost must be considered.

The process of stormwater management system planning should involve the costing and economic evaluation of a number of options, as described in Chapter 9. The guidelines set out in this Chapter will assist engineers and planners to select suitable options for particular applications. These options should then be evaluated from both economic and social perspectives, to determine the best solution for the particular location.

10.2 QUANTITY CONTROL FACILITIES

10.2.1 Objectives

Detention and/or retention facilities are normally planned for inclusion in urban stormwater management systems for one of the following purposes:

- to remedy a situation where some part of the downstream drainage system is undersized, and cannot be enlarged conveniently or inexpensively;
- to reduce flows from a developing area, so that the flows from the fully urbanised catchment are no greater than those which would occur under present conditions, or for the catchment in its natural state; or
- to develop the most cost-effective drainage system possible, by reducing the sizes and cost of downstream pipes and channels, or as long as this reduces the overall net cost of the total drainage works

10.2.2 The Needs of Flow Reduction

(a) Restriction of Flows to Capacity of Downstream Flow Facility

This is the simplest situation to analyse. The objective is to reduce flows at a critical point downstream to the capacity of some existing conduit or facility. These flows must be related to an ARI (see Chapter 4) in keeping with the severity of the damage and inconvenience which would result when downstream flooding occurs.

The problem point may be a section of pressurised pipe or open channel, a feature such as a junction or bend, or a culvert or bridge crossing. The critical flowrate will be the safe capacity of the facility, allowing for flowrates, velocities, and acceptable freeboards.

The downstream facility may be undersized due to:

- inadequate planning schemes, allowing encroachment of development on natural drainage paths and providing insufficient room for drainage system overflows and backwaters
- errors or deficiencies in original design concepts or calculations (improved methods, such as computer models, can show up inadequacies in previous calculations)
- changes in upstream landuse producing greater amounts of stormwater runoff than originally intended (this may be due to re-zoning, alteration of drainage systems and catchment boundaries, development of large facilities such as shopping centres, or piecemeal development on many upstream facilities)
- the facility may have deteriorated, or have been damaged in such a way that its capacity is diminished (e.g. a culvert pipe may crack under earth loads, and require insertion of a liner)
- the design standard may be increased, so that a formerly adequate facility may now be unsatisfactory (social attitudes may also change, bringing new requirements not envisaged by the original designers)

It will be necessary to design a storage, or a system of storages, to reduce flows to the available downstream capacity.

(b) Restriction of Developed Urban Flows to Rural Rates

As an area is urbanised, its surface is covered and its natural drainage system is replaced by lined drains. This has the following effects:

- runoff rates are increased, due to reduced infiltration and faster overland and channel travel times (surface runoff responds much faster than interflow or groundwater, and faster travel times concentrate flows from different parts of catchment);
- runoff volumes are increased; and
- incidental effects occur such as alteration of catchment boundaries, increased erosion of land surfaces and streams, and impacts on flora and fauna

The degree of increase depends on the nature of the original catchment, and the exact pattern of urbanisation. The impact of urbanisation will be greater for frequent storms than for rarer ones, as catchments are likely to be more thoroughly saturated in high ARI events.

Controlling authorities in many countries require developers to restrict flowrates from their development site so that none exceed the flows produced with the cathment in its present state, or in its natural state. However difficulty may be experienced in assessing what was the 'natural' state of a catchment. Sometimes it is stipulated that developed catchment flows of a certain ARI must not exceed pre-development flows of a higher ARI, to account for increases in flow volumes as well as peaks.

The process of urbanisation can be modelled reasonably by available computer software. If only one storm has to be considered, the process is simple. However, depending on the type of development under consideration, it may be necessary to consider several storm durations and ARIs.

(c) Reduction of Flows to Optimise Costs of Drainage System

This is perhaps the most difficult case, as the objective is more nebulous than in the cases discussed in the two previous sub-sections.

The measure for success of detention/retention systems in this case is the saving in expenditure they can provide over the costs of alternatives. The best way to approach this situation is to prepare a concept design of a drainage system without storages and to cost this approximately. Storages can then be introduced, analysed and the downstream drainage waterways reduced in size. The changes in costs are then evaluated. Introducing storage will involve increased costs of land acquisition, earthwork, etc., but there will be lower costs and land acquisition requirements along the waterway easement. If the total cost is reduced, the storage is worthwhile. It may also be necessary to consider intangibles, such as recreation opportunities and amenity provided by a detention basin.

As a general rule, storage sites in the upper half of the catchment are often beneficial in reducing the total cost of a drainage system. Sites further downstream in the catchment are less beneficial – although they may have other merits, such as for water quality control.

(d) Detention Planning Considerations

Town planning plays a large part in setting the form of basins, by setting restrictions on the available land, by locating features such as roads near basins, and by influencing additional uses of land reserved for drainage, such as recreation.

Good planning can greatly enhance drainage facilities and make the engineer’s job easy; while bad planning can obstruct and restrict drainage works and other infrastructure.

Some designers may assign storage to various places in a catchment area, putting so much here and so much there. The effectiveness of storage depends on a number of factors:

- the size of the storage, with a larger storage being generally more effective than two or more smaller storages with the same total volume
- the relation of storages to the stream system layout (a storage near the lower end of a catchment may actually *increase* peaks, by delaying the peak on a tributary so that it coincides with a peak on the mainstream, instead of running ahead of it)
- the exact storage discharge relations of the storages, which can influence when outflow peaks occur, as well as their magnitudes (this timing is important when considering a system of basins).

The flow reducing effect of a storage is greatest immediately below a storage. Further downstream and as tributary flows enter, the relative effect of the storage diminishes. In a large system storages throughout the basin may only have a small effect on flows at the outlet .

10.2.3 Choice of Detention/Retention Facilities

(a) New Development and Redevelopment

New development or redevelopment of existing sites, should implement detention and/or retention in accordance with the Strategic Plan for the catchment. If there is no Strategic Plan, the development/redevelopment should be required to comply with the Master Plan guidelines in Chapter 9. The principles and details of runoff quantity control works are set out in Part E of this Manual.

- On-site detention or retention is provided to reduce the peak discharge in small storms, up to the minor system design ARI.

- Community detention or retention should be provided to reduce peak discharges in major storms, generally up to 100 year ARI.
- Detention storage can be designed to include a permanent wet pond for water quality control. The wet pond/ detention storage can be included within the development's open space contribution, subject to the conditions set out in Chapter 9.

(b) Existing Urban Areas

It is often difficult and expensive to retro-fit on-site detention or retention measures to existing development. If excessive peak discharges from existing urban areas are a problem, community/regional detention or retention may be a viable approach if sufficient open space is available. These facilities are discussed in Chapters 20 and 22.

(c) Other Locating Principles

These include:

- Community detention or retention facilities can be located in any suitable existing open space area in the catchment. Often, the options for locating these facilities are very limited in existing areas.
- Detention storage can be designed to include a permanent wet pond for water quality control.
- Detention storage should ideally be located near the centre of the catchment, so that advantage can be taken of the storage to reduce the downstream conveyance system sizes. Permanent wet ponds should ideally be located at the bottom end of the catchment. As these two requirements are in conflict, compromise solutions are usually necessary.
- Site constraints may limit the size of the detention facility. It is still worthwhile to use available sites even if they are smaller than the theoretical guidelines. In that case, the amount of flow reduction should be calculated for the actual size of the facility using the routing procedures given in Chapter 14.
- Retention facilities should be protected from high sediment loadings, or pollutant contamination. Established residential areas on pervious soils are the most suitable areas to be treated by retention.

10.3 CONVEYANCE FACILITIES

10.3.1 Choice of Piped or Open Drain

Past drainage design practice in Malaysia has predominantly used open drains. Open drains have distinct advantages under heavy tropical rainfalls, in that they are less likely to be affected by blockage. Open drains are preferred for maintenance reasons in areas with high sediment, debris or rubbish load. They are also easier to design. However they are unsightly and are hazardous to people unless they are fenced.

Piped drainage is suitable mainly for high-density, high-value residential development where the land supply is limited or costly. Pipes are also recommended in areas of high pedestrian usage, such as in city centres. Pipes or enclosed culverts give a better appearance and safety than open drains.

The design of pipe drainage is generally more complex, requiring detailed consideration of inlet pits and hydraulic grade lines. With appropriate training and the use of computer design aids this is no longer a significant drawback.

The maximum economic limit for pipes depends on the manufacturing process, and is usually between 1200 mm and 1500 mm diameter. Very large pipes may create problems with clearance to other services, such as sewers. If calculations show that a larger size is required, multiple pipes, open drains or engineered waterways should be used.

Engineered waterways are used when the design flow exceeds the economic limits for pipes or open drains. Typically, this will occur when the catchment area exceeds 40 to 80 hectares.

Engineered waterways have a bigger land reserve requirement than other conveyance types. Part or all of the engineered waterway can be included within the development's open space contribution, subject to the conditions set out in Chapter 9.

10.3.2 Choice of Channel

This section assumes that a choice has been made to provide an open channel, rather than a pipe drain.

The choice of channel types available to the designer is almost infinite, depending only upon good hydraulic practices, environmental design, sociological impact, and basic project requirements. However, from a practical standpoint, the basic choice to be made initially is whether or not the channel is to be a hard-lined one for higher velocities, a grassed floodway, or a natural channel already existing.

(a) Types

The following types of channel are generally used in urban areas:

Natural Channels : Drainageways carved or shaped by natural forces before urbanisation occurs. They often, but not always, have mild slopes and are reasonably stable in the natural state. As the channel's tributary catchment becomes urbanised, natural channels often experience severe erosion and they may need grade control checks and localised bank protection to stabilise. Stabilisation of natural waterways is discussed in Chapter 43.

Grass-lined Channels : Among various type of constructed or modified drainageways, grass lined channels are most desirable. They provide channel storage, lower velocities, attractive appearance and multiple use benefits. Low flow areas may need to be partly concrete or rock lined to minimise erosion and maintenance problems.

Wetland Bottom Channels : A subset of grass lined channels that are designed to encourage the development of wetland or certain types of riparian vegetation in the channel bottom. In low flow areas the banks need rock lining to protect against undermining.

Concrete Lined Channels : Concrete lined channels are high velocity, formalised drainageways that should not be encouraged in urban areas. However, and where right-of-way is limited, concrete channels may be the only practical type of drainage system.

Rock Lined Channels : Rock riprap lined channels offer a compromise between a grass lined channel and a concrete lined channel. They can reduce right-of-way needs, but are more difficult to keep clean than other types and are recommended for consideration only in retrofit situations where existing urban flooding problems are being addressed.

Other Channel Liners : A variety of artificial channel liners are available; all intended to protect the channel walls and bottom from erosion at higher velocities. These include gabions, interlocked concrete blocks, concrete revetment mats formed by injecting concrete into double layer fabric forms., and various types of synthetic fibre liners. As with rock or concrete liners, all of these type are best considered for helping to solve existing urban flooding problems and are not recommended for new developments. Each type of liner has to be scrutinised for its merits, applicability, how it meets other community needs, its long term integrity, and maintenance needs and costs.

(b) Factors

The actual choice must be based upon a variety of multi-disciplinary factors and complex considerations which include, among others:

Hydraulic:

- channel slope
- drainage reserve width
- capacity needs
- basin sediment yield
- topography
- ability to drain adjacent lands

Structural:

- cost
- availability of material
- areas for placing surplus fill
- seepage and uplift forces
- shear stresses
- pressures and pressure fluctuations
- momentum transfer

Environmental:

- neighbourhood character
- neighbourhood aesthetic requirements
- need for new 'green' areas
- street and traffic patterns
- municipal, state and national policies
- wetland preservation
- wildlife habitat
- water quality enhancement

Sociological:

- neighbourhood social patterns
- neighbourhood children population
- pedestrian traffic
- recreational traffic
- recreational needs

Maintenance:

- life expectancy
- repair and reconstruction needs
- ease of maintenance
- accessibility

(c) Selection Process

Prior to choosing the waterway type, the planner should consult with experts in related fields in order that the waterway chosen will create the greatest overall benefits. Whenever practical, the waterway should have slow flow characteristics, be wide and shallow, and be natural in its appearance and functioning.

To assist with selection of type of channel or drainage improvements to be used, the flow chart in Figure 10.1 can be used. Numerical threshold values given are for guidance only: they will vary in each situation according to rainfall IDF relationships, topography, landuse, social and economic considerations.

The first step is to determine if channelisation is needed or desired. In many cases a well-established natural waterway and its associated floodplain can be preserved and protected from erosion damage. However the flood-affected land will not be suitable for development. Constructing an improved channel may provide additional flow capacity and release more land for development.

Before deciding to channelise, the designer should consider if the value of land 'reclaimed' in this way will justify the cost of channelisation and whether the new channel provides greater community and environmental benefit than provided by the existing waterway.

If the decision is to not channelise or rechannelise an existing waterway, the next step is to investigate the stability of the natural waterway and its banks, and selectively stabilise the longitudinal grade and banks.

If the decision is to channelise, then determine if the existing natural waterway has a perennial flow, evidence of wetland vegetation, or if it is a well established ephemeral channel. If any of these are present, then the project may be subject to environmental requirements. It is the responsibility of the proponent to comply with all applicable Federal and State environmental laws and regulations.

The channel will need to be lined if the velocity in the design flow exceeds the safe limiting velocities to avoid erosion. Channel lining greatly increases the cost of a drainage channel.

If the decision is made to provide a lined channel the usual choice is to select the most hydraulically efficient and cost-effective cross-section, in order to minimise costs. It can be shown from hydraulic principles that the cross-section with the least wetted perimeter is the most hydraulically efficient. The most efficient cross-section is a semi-circle, but it is rarely used because of the difficulty of construction. The most efficient polygonal cross-section is a half hexagon (see, for example, Daugherty and Franzini, 1977).

Unlined channels can be used if the velocity in the design flow is less than the limiting velocity for erosion. If this is the case, design decisions still need to be made on whether or not to provide a lined low-flow invert. Design principles for engineered waterways are given in Chapter 28.

Composite grass/ lined channel cross-sections can also be used. With this type of channel a small lined section is provided for frequent flows, with a grassed section to cater for additional flows up to the magnitude of the design flow. Composite cross-sections combine some of the advantages of both lined and unlined channels.

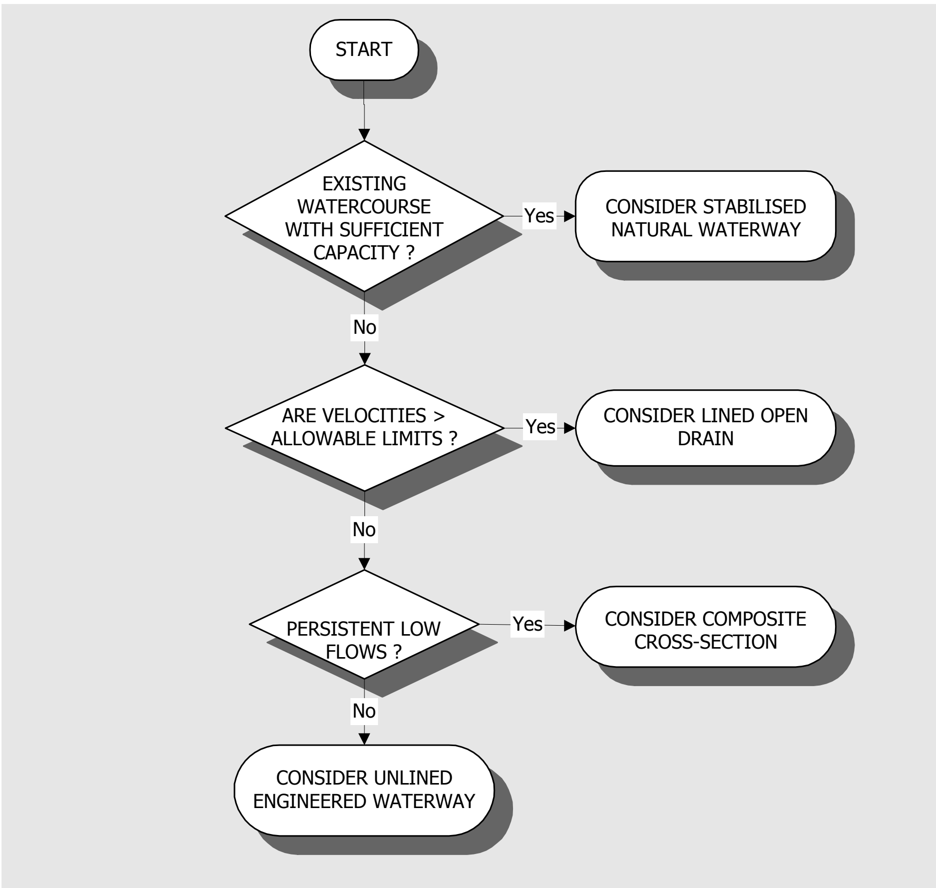

Figure 10.1 Flow Chart for Selecting Channel Type

10.4 QUALITY TREATMENT FACILITIES

This section provides guidance for the selection of a stormwater treatment system. This system will generally comprise several water quality control Best Management Practices(BMPs). A number of BMPs are available and they should be carefully selected based on site-specific conditions and the overall management objectives of the catchment.

The selection process has the following aspects:

- identification of problems and treatment objectives
- familiarisation with capabilities of the alternative treatment devices and treatment mechanisms
- familiarisation with constraints on use of various treatment devices
- cost considerations

In this Chapter the treatment objectives and treatment mechanisms are introduced. The advantages or disadvantages of each device, constraints on use and some factors likely to affect cost are summarised. Additional design detail on the main types of measures is given in the subsequent chapters in Part G. Guidelines on Good Practice for the location of quality control devices are given in Section 10.4.6.

10.4.1 Overview

Source control should be a central theme of stormwater management. Treatment or structural solutions to stormwater management are expensive and the devices listed in this Chapter will be more effective if combined with source controls.

For stormwater management to be effective, BMPs must be applied throughout the catchment. Nonetheless, the increase in pollutant loads from urban areas is typically so large that, even with the use of BMPs, it is difficult to reduce pollutant loads to pre-development levels.

10.4.2 Economic Benefits of Stormwater Quality Control

Considerable expenditure has occurred in providing stormwater quality control measure sin overseas countries in recent years. In the past the assumption has been that these measures provide aesthetic and environmental benefits, but that any economic benefits are difficult to quantify.

In an unpublished study referring to Canberra, Australia, Lawrence (1998) analysed the economic benefits of providing stormwater quality control measures in two new urban developments. This study is quoted as an example to show that in fact, modified stormwater management systems can have large economic benefits including reduced construction costs and increased land values.

"In approaching the planning for the new town of Gungahlin, the performance of previous lined channel and piped drainage systems was reviewed and compared with a system (that used) detention basins and natural waterways. Economic analysis of the stormwater options indicated that the natural channel option, after adjustment for additional landtake, yielded a 60% reduction in cost compared to conventional stormwater drainage and had a benefit/cost ratio of 2.6."

"Water quality modelling in the case of Tuggeranong indicated that without (stormwater quality) controls, severe water quality degradation would occur within Lake Tuggeranong and the Murrumbidgee River, significantly impacting on their recreational value, and on the value of properties in the area. . . The economic analysis yields a benefit-cost ratio of 6.0 for the pollution control and landscaping measures (GPTs, wetlandsand ponds)."

No comparable studies are yet available for Malaysia, but it is expected that the findings would be similar.

10.4.3 Types of Devices

This Chapter does not represent a complete list of all stormwater pollution treatment devices. It does however represent some of the more readily available units currently in use around the world. It is to be expected that new and improved devices will be developed and the designer should keep up to date with these in the future.

The discussion of BMPs in this Part focuses on the water quality benefits of various mitigation measures, including:

- biofiltration swales and vegetative filter strips
- infiltration devices
- filtration devices
- oil separators
- gross pollutant traps
- ponds and wetlands

(a) Biofiltration Swales and Vegetative Filter Strips

Several types of vegetative BMPs can be used to convey and filter runoff. They take advantage of biological processes (see Section 10.4.5) to improve pollutant removal. Biological controls are typically cheaper and more aethestic than structural controls, but may involve more maintenance and landtake. Biofiltration devices are described in Chapter 31.

(b) Infiltration Devices

Infiltration devices can take a number of structural forms including pits, trenches, or basins. All of these devices work by storing stormwater flow and promoting infiltration into the soil. They typically reduce peak flows as well as removing soluble and fine materials from stormwater. Infiltration devices are discussed in Chapter 32.

(c) Filtration Devices

These devices use a filtering action to remove pollutants, mainly particulate material. Two types of filtration are used in stormwater: biofiltration, using biological methods, and media filtration through porous media such as sand.

The application of these devices is generally restricted to areas of suitably porous soil, such as aquifers. Filtration devices are discussed in Chapter 31.

(d) Oil Separators

As the name suggests, these devices remove oil and grease which may be a significant pollutant in situations where hydrocarbons such as fuel or lubricating oil can be released to the environment. Oil separators are discussed in Chapter 33.

(e) Gross Pollutant Traps

Gross pollutant traps (GPTs) remove gross litter, which comprises litter and sediment. Gross Pollutant Traps are discussed in Chapter 34.

(f) Constructed Ponds and Wetlands

Ponds have a beneficial effect on stormwater by controlling the volume of runoff and providing treatment by gravity settling, biological stabilisation of solubles such as nutrients, adsorption and decomposition of biodegradable pollutants such as BOD and light oils. They can also be used as detention storage for flood control, as described in Chapter 20.

Constructed wetlands are similar to ponds except that areas of active vegetation growth are the main component, instead of areas of open water. This promotes biological action in preference to sedimentation. In practice, most constructed ponds contain wetland areas and vice versa so that it is convenient to consider the two types together. Constructed ponds and wetlands are discussed in Chapter 35.

10.4.4 Treatment Objectives

The primary objective of the treatment devices in this manual (with the exception of oil separators) is to remove suspended sediment and sediment-bound compounds. Removal of sediment will result in the removal of many of the contaminants of concern, including:

- particulate trace metals
- particulate nutrients
- oil and grease on sediments

The overall objective of removing 80% of the sediment load (on a long-term average basis) in a catchment has been adopted in this Manual (refer Chapter 4). A higher degree of removal would require a large increase in treatment device size and cost. In some retrofitting cases in older developed catchments, it may not be possible to meet the 80% removal objectives due to space limitations. For oil and grease removal from services station and fuel areas, the objective of treating over 90% of the total annual runoff is proposed.

An important parameter for BMP design is the runoff volume to be treated. Some of the designs in Table 10.2 are best suited to treating the first-flush runoff. This first flush often carries higher non-point source pollution loads. In this Manual, the first flush is taken to be the first 10 mm of runoff.

10.4.5 Treatment Mechanisms

To create effective treatment devices, the designer should be aware of the following treatment mechanisms:

(a) Sedimentation

Particles settle to the bottom of the device or collector surface. Particles in stormwater consist of a variety of sizes which settle at different rates. Sediment that is coarser than medium silt settles rapidly. Longer settling times are required to settle out fine silt and clay particles.

(b) Filtration and Sorption to Filter Material

As particles pass through a filter bed or through soil, they are removed by the following processes:

- settling into crevices
- enmeshment in interstices (sieving)
- for some media types, impingement onto filter particles followed by "sticking" onto particles (by electrostatic or other bonding)

Dissolved substances can be removed by:

- sorption to filter material
- uptake by micro-organisms in the filter material.

(c) Gravity Flotation

Oil and litter float to the water surface where they are collected (like an inverted sedimentation device).

(d) Attachment to Plant Material

Contaminants may adhere to plant surfaces or be absorbed into vegetation, thus removing them from the water column. This is one of the benefits of maintaining plants in treatment devices.

10.4.6 General BMP Selection Guidance

(a) Basic Principles

For large developments or where the expected impacts are particularly severe, local regulatory authorities should set standards in terms of pollutant removal targets. Targets should be set as a result of a Stormwater Management Planning process, as described in Chapters 8 and 9. These targets should ideally be based on ecological and other water quality indicators.

(b) Interim Guidelines

Although it is desirable to tie in the selection of treatment devices to predicted outcomes in the receiving waterway, this is difficult to achieve in practice. In any case the required studies will take a long time to complete. Chapter 8 of this Manual therefore allows for the setting up of *Interim Guidelines*. Most regulatory agencies throughout the world have adopted a similar approach.

Local Authorities can adopt Interim Stormwater Management Guidelines which specify particular *best management practices* for non-point source pollutant control. This approach should be seen as an interim measure, pending the development of ecologically-based stormwater management policies. This Manual provides guidance to developers in selecting, installing and operating suitable measures to achieve those targets.

Table 10.1 provides information on the characteristics of various types of BMPs. This table can be used to select suitable treatment devices to remove particular target pollutants.

Table 10.2 provides a comparative analysis of pollutant removal for various types of BMPs. Generally, the BMPs provide high pollutant removal for non-soluble particulate pollutants such as gross solids, suspended sediment and trace metals. Much lower removal rates are achieved for soluble pollutants such as phosphorus and nitrogen.

Where pollutant removal targets have been set by a regulatory authority, Table 10.2 can be used as a guide to choose suitable stormwater treatment devices to meet those targets.

10.4.7 Treatment Train/Locating Strategy

Many stormwater treatment devices work best in combination with other devices. Such a combination, which provides a sequence of treatment, is called a *treatment train*.

The planning approach described in Chapters 8 and 9 of this Manual should include the assessment of treatment trains. Stormwater Management Master Plans will generally prescribe suitable treatment trains for a particular site. Typically, the Master Plan will set performance requirements for the devices which are part of the treatment train.

However, if no Master Plan is available the designer should still investigate options for providing treatment trains in order to achieve the project objectives.

Often, the components of a treatment train are intended to treat different pollutants. An example is a GPT to treat coarse sediment and litter, combined with a wet pond to treat fine sediment and dissolved nutrients. In this case, each device can be sized according to its own sizing guidelines and ignoring any pollutant removal provided by the other device. The resulting design is likely to be conservative.

(a) Determining Strategy and Locating Measures

It will usually be necessary to provide some stormwater quality treatment measures, even with the use of source quality controls. Sites for potential facilities such as swales, gross pollutant traps, detention/retention storages (ponds or wetlands) should be identified based on the site plan and preliminary assessments made of the likely benefits. These preliminary assessments should be based upon the area "commanded" by each measure as a proportion of the total area of urban development, and on the potential surface area/ catchment area ratio.

The location of regional detention storages and major water quality control ponds is very much governed by site characteristics. The following general principles apply:

- source controls should be towards the top end of the catchment.
- infiltration basins, of course, require suitable soils.
- treatment measures such as GPTs or ponds are best located towards the bottom of the urban catchment, in order to control as much of the urban catchment area as possible.
- locations where most of the flow comes from natural catchments are unnecessary.
- all works should be located for ease of access.

More specific location guidelines for each type of control measure are given in Part G.

(b) Locating Guidelines

The following gives some general guidelines for the location of devices in a treatment train:

- vegetative filter strips, and biofiltration swales can only serve small areas and therefore need to be located near the top of a catchment.
- oil separators are only likely to be required for stormwater runoff from high-risk sites such as petrol stations or automotive workshops.

Table 10.1 Summary of Characteristics of Stormwater Treatment Devices (Auckland Regional Council, 1992)

Device	Description	Landuse considerations	Hydrologic performance	Visual appeal, community acceptance	Maintenance
Biofiltration swales	Vegetated channel for runoff	Replaces lined drains. Low density development, slope 1% to 4%	Provides some flow retardation	Moderate to high visual appeal	Regular mowing
Vegetative filter zones	Area of dense vegetation	Catchments < 2ha, slopes <5%	Provides limited flow retardation	Moderate to high visual appeal	Requires some maintenance
Filter devices	Tank or pond with porous media	Catchments < 3ha, requires a head drop	Provides limited flow retardation	Variable	Requires intensive maintenance
Porous pavements	Coarse graded asphalt, concrete	Carparks, low-traffic roads	Reduces runoff	Improved traffic safety	Requires sweeping
Infiltration trench or basin	Storage and flow spreading to promote infiltration	Only for suitable soil and groundwater conditions	Reduces runoff	Little or no visual impact	Susceptible to clogging, difficult to maintain
Oil separators	Structures to trap floating oil	Used at sites with high potential for oil spill	None	Usually underground, no impact	Requires regular maintenance
Inlet control pits	Modified pits to trap sediment	Not suitable for open drains	Increased risk of clogging	No impact	Requires regular maintenance
Litter control devices/ trash racks	Structures to trap rubbish	All	None	Generally unsightly	Requires regular maintenance
Sediment traps	Pond or tank to trap coarse sediment	Used upstream of a pond or wetland	None	Variable	Requires regular maintenance
Gross pollutant traps	Structure to trap rubbish and coarse sediment	Used upstream of a pond or wetland	None	Unsightly if above-ground	Requires regular maintenance
Extended detention ponds	Wetland, no permanent pond	Can be used with high water table or impervious soils	Limited flow retardation	Limited value, mosquitoes are a concern	Moderate maintenance
Wet ponds	Permanently full pond	Can use existing ponds	Can include flood storage/ retardation	High aesthetic appeal, mosquito concern	Moderate to high maintenance
Wetlands	Permanently full shallow wetland with vegetation	Can use existing ponds or low-lying areas	Moderate flow retardation	High aesthetic appeal, mosquito concern	Moderate to high maintenance

For pollutant removal efficiency see Table 10.2

Table 10.2 Relative Effectiveness of Stormwater Treatment Devices (CRCFE,1998, based on Lawrence et al, 1996)

Device	Pollutant Removal							
	Rubbish	Solids	P	N	BOD	Metals	Oil and Grease	Bacteria
Biofiltration swales	*Note*	√	√	√	√	x	*Note*	√
Vegetative filter zones	*Note*	x	√	√	√	x	*Note*	x
Filter devices	*Note*	√	x	x	x	x	*Note*	x
Porous pavements	√	x	√	√	√	√		√
Infiltration trench or basin	*Note*	√√	√√	√√	√√	√√√		√√
Oil separators							√√√	
Inlet control pits	√√√	√	x	x	√	x		x
Litter control devices, trash racks	√√√							
Sediment traps	√	√	√	√	√	√		√
Gross pollutant traps	√√√	√√	x	x	√	x	√	x
Dry detention ponds	*Note*	√	x	x	x	x		x
Extended detention ponds	*Note*	√√√	√	√	√√	√√		√
Wet ponds	*Note*	√√√√	√√√	√√√	√√	√√	*Note*	√√√√
Wetlands	*Note*	√√√	√√√	√√√	√√	√√	*Note*	√√√

1. The number of ticks indicates relative effectiveness:
   √ √ √ √ > 80%   √ √ √ 60-80%   √ √ 40-60%   √ 20-40%   x 0-20%
2. NA indicates not applicable.
3. *Note* indicates that rubbish, solids, or oil and grease will degrade performance and should be excluded by providing a suitable upstream control measure.

- inlet control pits are only suitable for piped drains.
- infiltration trenches or basins require suitable soils and large land areas, relative to other devices.
- infiltration trenches or basins must be protected from high sediment loads which would otherwise clog the basin. They should either be restricted to areas of low sediment load (eg residential), or be protected by an upstream GPT.
- sediment traps on their own, are not desirable in urban areas because of the litter problem and GPTs should be used instead.
- there is a wide range of types and sizes of GPTs available. Further discussion of GPTs is provided in Chapter 34.
- no significant benefit is gained by locating similar types of devices in series, one downstream of another. However it is beneficial to locate similar devices in parallel, such as on different tributaries of a drain.
- GPTs should be located on all drain outlets leading to ponds or wetlands.
- if both ponds and wetlands are used, either the pond should be upstream of the wetland or the wetland should be off-line.

As a general principle it is not economic to provide more than one type of device in series for the same pollutant. However, it is worthwhile to provide similar devices in parallel if they command different sub-catchments within the overall catchment. Examples of locating devices in series and parallel are shown in Figure 10.2.

10.4.8 Handling Excess Runoff

(a) Bypass

Stormwater treatment devices are almost always located on the minor drainage system. This is because they need to collect the small, frequent flows.

Chapters 13 and 15 demonstrated that over 90% of the annual runoff occurs in storms of 3 month ARI or less. For this reason, the *water quality design storm* is recommended to be 3 month ARI.

However the minor drainage system is usually designed for an event of between 2 and 10 year ARI. Therefore, with almost all types of devices it is necessary to provide some form of bypass for flows in excess of the water quality design storm. Furthermore, the bypass should not cause excessive head loss as this will affect the hydraulic gradient in the minor system.

Bypass and storage requirements for the different types of water quality treatment devices are listed in Table 10.3.

Bypassing can be accomplished by providing a flow diversion structure, such as a weir, in a manhole upstream of the treatment device. Flow diversion structures are described in Chapter 29 of this Manual under Special Structures.

Bypassing can also be achieved by allowing the minor system flows in excess of the water quality design storm, to surcharge or be diverted at a point upstream of the structure. This method requires detailed hydraulic analysis in order to achieve the correct flow behaviour. Usually, a detailed computer model would be required.

It is, of course, necessary to consider what happens to the bypassed flow. This flow should be contained within the minor drainage system, and conveyed to a point downstream of the treatment device.

(b) Balancing Storage

Most stormwater treatment devices function best at a constant flow rate. However, the inflow rate from a stormwater drainage system is usually highly variable as it is a function of rainfall intensity.

For this reason many stormwater treatment devices would benefit from the inclusion of a *balancing storage* upstream of the device. This would be designed to temporarily store peak inflows, and release flow at a lower, steady rate to the treatment device. Balancing storage, if provided, should be located downstream of the high flow bypass.

The sizing principles for a balancing storage are similar to those for on-site detention (see Chapter 19).

Table 10.3 lists the typical requirements for high-flow bypassing and/or balancing storage for each main type of treatment device.

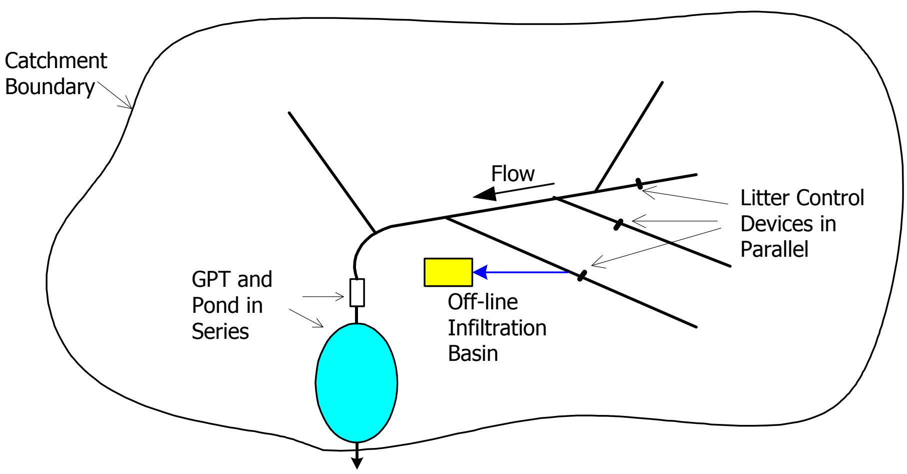

Figure 10.2 Typical Configurations of Stormwater Treatment Measures

Table 10.3 Bypass and Storage Reqirements for Stormwater Treatment Measures

Device	High-flow Bypass	Balancing Storage
Biofiltration swales	No	No
Vegetative filter zones	No	No
Filter devices	No	*Desirable*
Porous pavements	No	No
Infiltration trench or basin	*Required*	*Desirable*
Oil separators	*Required*	*Highly desirable*
Inlet control pits	No – excess flow can divert to next pit	No
Litter control devices, trash racks	Bypass by overtopping or upstream surcharge	No
Sediment traps	*Required*	No (trap provides some storage)
Gross pollutant traps	*Desirable. Some proprietary devices incorporate a bypass*	No (GPT provides some storage)
Dry detention ponds	*Required*	No – pond provides storage
Extended detention ponds	*Required*	No – provides storage
Wet ponds	No	No – pond provides storage
Wetlands	*Required if on-line*	No