Chapter 4
Choosing stormwater management devices

4.1 Introduction

Stormwater management involves controlling either or both the quantity and quality of runoff. Quantity control practices regulate the peak flow rate and, depending on the practice, the total volume of runoff. Water quality control practices prevent the initial release of contaminants into receiving systems, or once they are released, reduce the quantities that enter surface or groundwaters. Completely recapturing released contaminants is impossible, and there is a pronounced diminishing of the rate of return on higher levels of capture. Prevention is more efficient and cost-effective. This Chapter will discuss runoff quantity and quality control and show how a number of different practices achieve these.

It is important to realise that stormwater practices do <u>not</u> all perform the same functions. A pond may be excellent at reduction in suspended solids, but and not as effective at capturing hydrocarbons. It is important to recognise the potential effectiveness of different stormwater practices on the contaminants generated on a specific site. As such, land uses and their associated contaminants are an important consideration in determining which stormwater practice or practices are appropriate for a given site.

4.2 Regulatory objectives

Stormwater management regulatory requirements can be categorised in a number of ways. A simple way is to define what purpose the practice is serving. For this manual, there are three broad regulatory categories which define the stormwater management universe:

- Water quantity control,
- Water quality control, and
- Aquatic ecosystem protection.

All three categories will not necessarily be addressed on each site, but rather they shall be used as needed. Examples could include:

- Discharge to tidewater (saline water) will not generally require peak control. The main focus will be water quality treatment.
- Discharge into a concrete (open or enclosed) system having adequate capacity for additional flows will only be considered for water quality treatment as the conveyance system is sized to handle peak flows.
- A project in the top part of a catchment not having downstream flooding problems will have to consider control of the 2 and 10 year storm, storage and release of the first 34.5 mm of rainfall over a 24 hour period, and 75% reduction in suspended solids.

<u>4.2.1 Water quantity control</u>

Water quantity control comprises those practices that detain stormwater runoff to regulate its rate of release to receiving waters or to infiltrate runoff into the ground so it does not become surface flow. Water quantity control can be further subdivided into three categories.

- Flood control

- Stream channel protection
- Infiltration or low stream flow augmentation

Flood protection

Historical efforts to prevent increases in downstream flood levels involved construction of stormwater management ponds to temporarily hold large volumes of stormwater during extreme events and releasing them over a longer time period than would have occurred normally. Current ARC requirements for downstream flood protection are generally that site post-development peak discharges for the 2 and 10 year storm events shall not exceed predevelopment peak discharges for those events. If there are existing flooding problems downstream, management may include control and release of the 100 year post-development peak discharge at the predevelopment peak discharge release rate. Section 5.4.1 provides more information on this topic for pond designers.

Stream channel protection

It is increasingly recognised that urbanisation causes increased stream channel instability as flows are increased in volume and frequency. This is achieved by storage and release of an initial volume of runoff, which for regulatory purposes is defined as the runoff associated with the first 34.5 mm of rainfall over a 24 hour period. This can significantly reduce or eliminate downstream channel erosion as a result of urban alteration of the hydrologic cycle. There is more detail in Chapter 5, Section 5.4.1, Channel protection objectives.

Infiltration or low stream flow augmentation

Urbanisation, through increased impervious surfaces and greater soil compaction, reduces groundwater recharge. A reduction in groundwater recharge lowers groundwater levels and can reduce or eliminate base stream flow. Maintaining, to the degree possible, groundwater recharge, can be an important element in protection of perennial stream flow. There are so many uncertainties in the methods for estimating groundwater levels and soil recharge rates to justify setting a required level of recharge. However, applicants should itemise opportunities have been considered to maximise recharge given the intended land use.

4.2.2 Water quality control

Water quality control applies to those practices that remove contaminants having the potential to be in or that are already in stormwater runoff. There is a wide range of water quality practices. Roofing an area that can generate stormwater contamination if exposed to rainfall is a water quality practice. Stormwater runoff from a parking lot cannot generally be treated at each location where vehicles travel or park so a water quality control practice may be most appropriate at a point to which stormwater flow can be directed. Consideration of water quality control can generally be broken into two categories: source control and treatment practices or measures.

Source control

Specific pro-active actions can prevent rain entraining potential sources of contamination and carrying them into the stormwater drainage system. A good resource document is the ARC's "Environmental Operations Plan - Do-It-Yourself Environmental Checklists For A Clean, Safe and Profitable Business".

Source control practices are often divided into structural and nonstructural groups. Nonstructural practices mainly embrace preventive actions that do not require building anything, such as management and source control practices. Structural practices are those which involve construction of some form of protection to prevent rainfall coming into contactwith contaminants.

While TP 10 is primarily devoted to the design, construction, and maintenance of stormwater quantity and treatment practices, we reinforce the importance of source control when considering site development and usageand urge applicants to incorporate it as one of the components of an effective stormwater management system during site development.

Treatment practices

While quality control can be nonstructural (policies to retain natural soil and vegetation cover), it generally involves building a facility such as a detention pond. The general criterian for constructed water quality treatment devices is a 75% reduction in suspended solids leaving the site. That general requirement may be expanded to other contaminants depending on the land use (see table 4-6). Treatment practices into two main categories: vegetative and structural.

The water quality benefits of vegetative practices derive from two main principles: filtering of contaminants by the vegetation, and infiltration of stormwater into the ground. Most vegetative practices consist of filter strips and swales. Others such as rain gardens rely upon filtering and infiltration, but for the purposes of this document those practices are considered as structural.

A suite of structural water quality treatment practices involve a variety of treatment processes. Water quality treatment can be provided by settlement of contaminants, filtering of contaminants by the passage of stormwater through a filter media or into the ground, or gravity flotation for oil and litter.

There are other treatment mechanisms such as attachment to plant material, biological uptake, bacterial decay, and precipitation, but those processes are secondary and their effectiveness at contaminant reduction is not easily quantified.

Flocculation for sedimentation is one practice increasingly popular. Colloidal particles, may, under the right chemical and flow conditions, flocculate and settle out. This process is becoming more common in sedimentation ponds through the use of aluminium sulfate or poly-aluminium chloride (PAC). Sediment removal rates of over 90% has been achieved in sediment ponds treated by flocculation.

4.2.3 Aquatic ecosystem protection or enhancement

Aquatic ecosystem protection or enhancement is an emerging issue of concern in the Region, and is dependent on addressing both water quantity and water quality. Maintaining the physical structure of streams as much as possible is just as important as maintaining good water quality.

Physical structure

If stream ecosystem protection is important then water quantity must be considered in terms of the following:

> limiting the increase in peak rates of runoff,
> reducing to the extent possible the increased volume of stormwater discharged,
> attempting to limit the erosive duration of stormwater flows, and
> thermal impacts.

Water quality

Contaminants affect aquatic life in a number of ways. The most obvious cause and effect is smothering of bottom dwelling organisms by sediment or sediments filling in riffle pool areas to deprive organisms of habitat. Sediment also reduces light penetration, clogs gills, and causes any number of other adverse side effects.

Contaminants other than sediment also have impacts on aquatic organisms. Acute and chronic toxicity can stress local populations or cause mortality. Toxicity can impact at a particular level of the food chain which can disrupt the overall diversity and abundance of an aquatic ecosystem. Impacting on macroinvertebrates can adversely affect the fisheries population in a given stream or reach of stream.

4.3 Stormwater practices

Stormwater quantity and quality control practices can be grouped in various ways. One classification is:

* Storage practices
  - ponds
  - vaults and tanks
  - American Petroleum Institute (API) separators
* Vegetative practices
  - swales
  - filter strips
  - wetlands (natural and constructed)
  - landscape management
* Infiltration practices
  - bores and tunnels
  - basins
  - trenches
  - porous pavements
* Filtration practices
  - sand filters
  - leaf compost filters
  - other

Storage practices can benefit quantity control, quality control, or both. In a number of instances, one mode of operation (storage, vegetative treatment, or infiltration) predominates but the practice incorporates other modes.

The trend is to combine the capabilities of two or more options by establishing “treatment trains” of complementary practices to achieve in series overall stormwater management benefits.

4.4 Site constraints

The success of any management practice depends on selecting the appropriate options for the site’s control objectives and conditions at an early stage. The objectives must be clearly delineated at the outset and site conditions investigated in enough detail to match the practice to the site so as to meet the objectives. Decisions need to be made whether quantity control, quality control, or for ecosystem protection or enhancement, both are provided, as well as what contaminants need to be treated and how.

Deciding whether a practice is relevant means looking at the catchment area, soils, hydrogeologic conditions, circumstances of the receiving water and nearby properties, cost, land ownership, and so on. Each practice’s constraints for implementation are discussed in its specific chapter. This discussion overviews the process of weighing up various practices when initiating the site design process.

4.4.1 Catchment area

Stormwater practices are only effective when they are used in the right place. A major consideration is the catchment area that drains to the practice. Some practices, due to treatment or hydrologic factors are more appropriate to smaller or larger catchment areas. Practices that rely on vegetative or filter media filtering of runoff are more appropriate for smaller catchment areas, as large flows may overwhelm their ability to filter the runoff. Ponds, on the other hand, are more appropriate for larger catchment areas.

Table 4-1
Stormwater management practice versus catchment area for water quality treatment

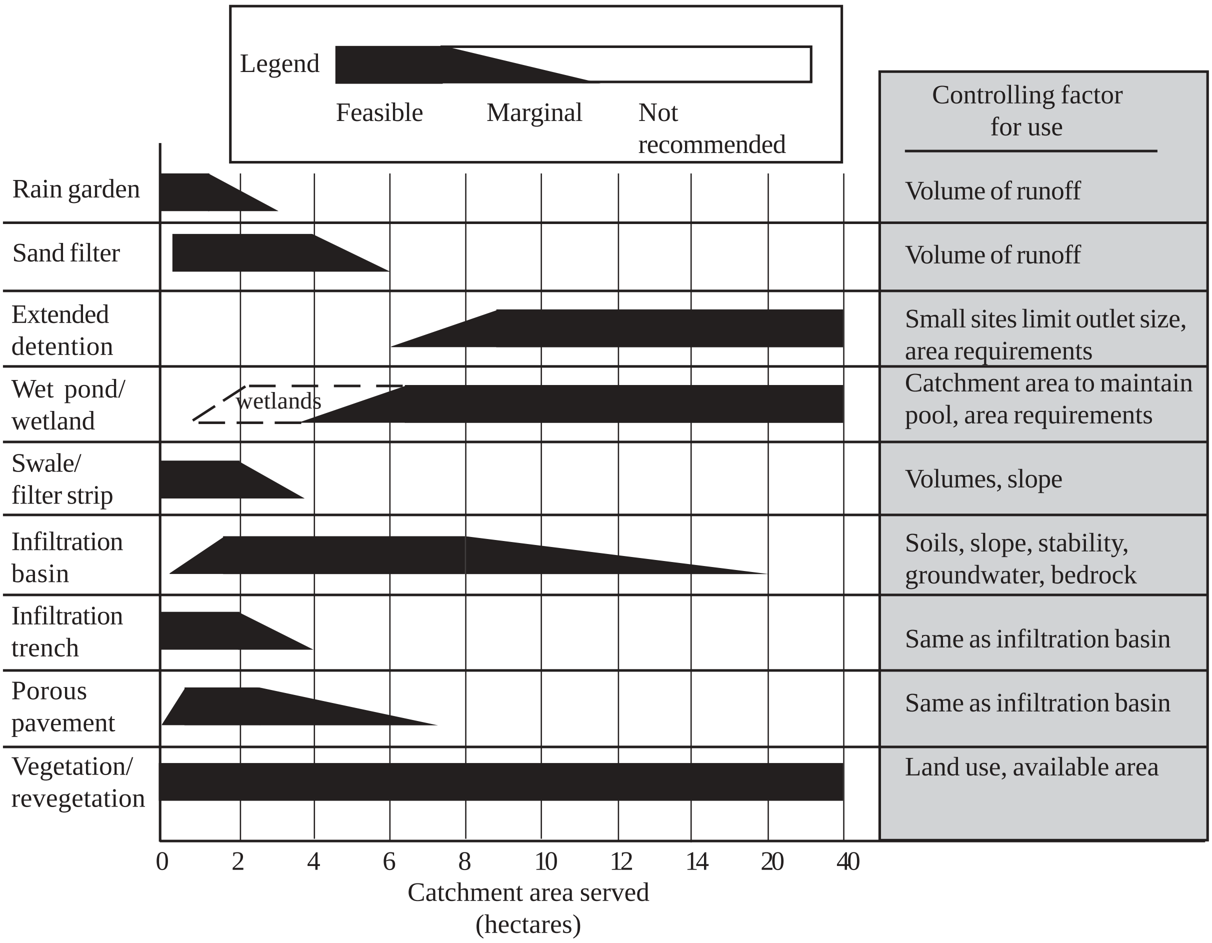


Table 4-1 shows the catchment areas for which various practices are most appropriate.

4.4.2 Soil type

The function of stormwater practices is very dependent on the underlying soils. More permeable soils can enhance the operation of some practices, but adversely affect that of others. For example, wet ponds or wetlands, rely on a pool of water or saturated subsoils to provide the basis for water quality treatment. Permeable soils would prevent the retention of a normal pool of water unless a liner was installed.

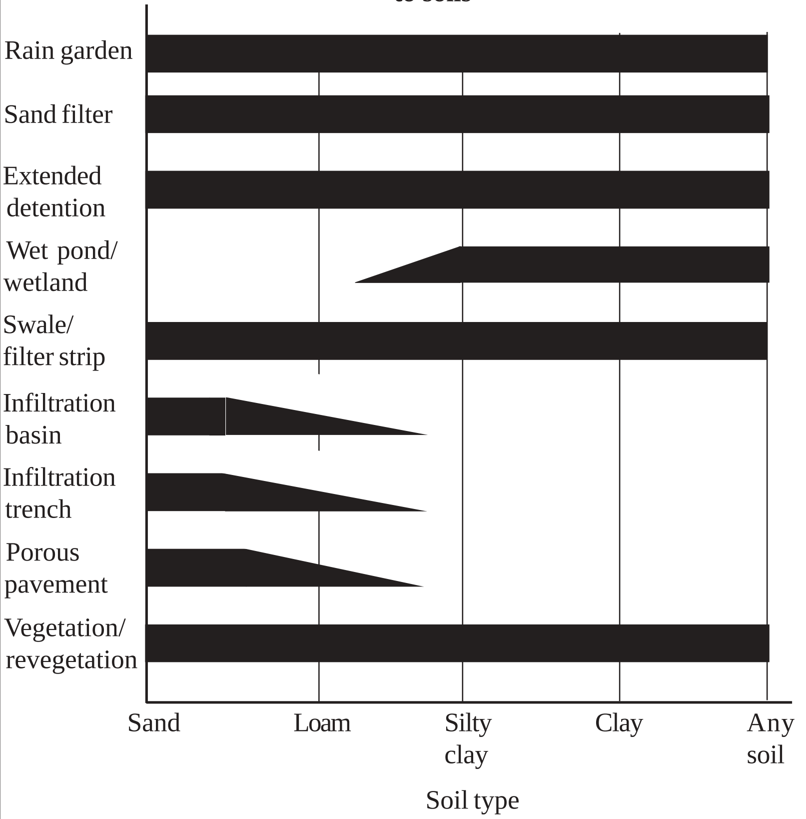
On the other hand, infiltration practices rely on the passage of water through the soil profile and more permeable soils transmit greater volumes of water. Some practices, such as filtration or biofiltration, do not rely upon site soils for proper function, although their performance may be enhanced by the water passing over and through coarser soils. Filtration practices rely on the permeability of the filter material to provide for water quality treatment, while biofiltration relies upon the passage of water through vegetation to provide contaminant capture. Table 4-2 overviews the suitability of stormwater practices to various soil conditions.

4.4.3 Slopes

Slope is an important consideration when choosing a practice. Steeper slopes may eliminate some practices from consideration, may require other practices to be modified from a more desired approach, or have little impact on the use of others.

Ponds provide temporary or permanent storage of water, with certain minimum surface area or storage volume requirements to achieve a minimum level of treatment. It becomes increasingly difficult to meet these

Table 4-2
The suitability of stormwater management practices related to soils

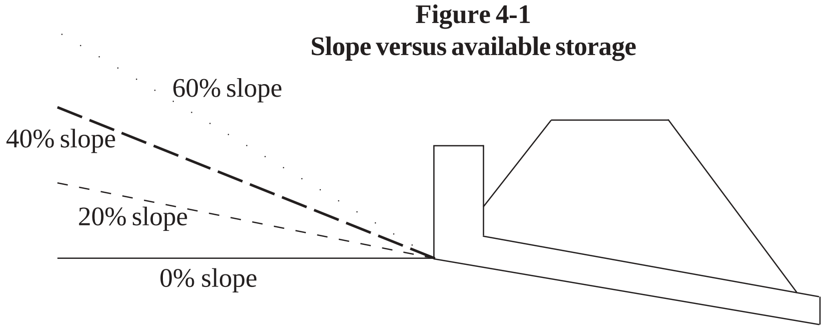


requirements as slope angle steepens. An example of the loss of storage ability versus slope is shown in Figure 4-1.

Other practices such as vegetated swales may be adapted for steeper slopes if the swales are placed along the contours rather than up or down the slope. Performance of biofiltration practices depends on the residence time of stormwater flows through the swale. Steep slopes result in high velocities of flow and reduced residence time. Filter strips, on the other hand, cannot generally be placed along the contour so their use is restricted to gentler slopes. Actual slope limitations for biofiltration practices are given in the detailed discussion of those practices.

Infiltration practices are also limited to gentle slopes for two reasons. Infiltration practices, similar to ponds, must provide storage of runoff until the water can soak into the ground. Steeper slopes reduce the potential storage volume and reduce the water quality benefits. In addition, infiltration of water into a slope may cause saturation further down, which could cause slope instability or re-ermergence of stormwater.

Figure 4-1
Slope versus available storage



Slope (%)	Area of storage available (bottom to crest) in m^2
0	7.5
20	5.0
40	2.8
60	1.9

Depending on the design and approach, filtration practices, including rain gardens, may or may not be sensitive to slope. Prefabricated filter chambers that service small areas may be placed on steeper slopes with little problem.

Revegetation as a stormwater management practice can be used on any slope, and In fact offer better benefits on steep slopes. The sediment yield from a slope triples as the slope doubles, so revegetation of steeper slopes provides a proportionatly greater benefit then for lesser slopes.

4.4.4 General constraints on treatment practices

As well as slope, soil type and catchment area, a number of other constraints may affect the applicability of a specific treatment device in a specific context. Table 4-3 provides guidance on various BMPs and the constraints to their use.

Table 4-3
Constraints on use of stormwater treatment practices

BMP	Steep slopes	High water table	Close to bedrock	Slope stability concerns	Space consumption limitation	Maximum depth limitation	High sediment input	Thermal impacts
API separator	~	~	>	~	~	-	-	~
Extended detention pond	>	~	>	>	-	~	>	~
Wet pond/ wetland	-	~	>	-	-	-	>	-
Vegetated swale/filter strip	>/-	>	>	>	>	~	-	~
Infiltration practices	-	-	-	-	>	-	-	~
Filtration practices	~	>	~	~	~	~	~	~

~ Generally not a restriction
\> Can be overcome with careful site design
\- May preclude the use of a BMP

4.5 Contaminant generation and removal process

In the past, the ARC has focused on suspended solids as the key contaminant of concern. This focus will remain for stormwater treatment. Suspended solids smother bottom dwelling organisms, reduce light penetration in water, destroy aquatic habitat and adversely affect aquatic organisms. There are, however, other environmental contaminants generated from human activities. Table 4-4 presents typical loadings for a number of contaminants and land uses. Although it does show a range of measurement values greater variation may be probably from year-to-year at the same place. The general order of contaminant production, from highest to lowest is:

industrial and commercial > motorway > higher density residential >
lower density residential > farm land > forest

Although not listed in the sequence above, the construction phase can produce far higher loadings of solids than any finished land use. However, from established land uses metals and synthetic organics are of particular concern because of their potential for toxicity to human consumers of water and to aquatic life. They make up most of what are generally considered as priority contaminants. Table 4-5 lists priority contaminants most frequently detected in urban runoff samples as reported in the United States Environmental Protection Agency (USEPA) National Urban Runoff Program (NURP) monitoring project in 23 cities in the early 1980s.

Three metals (lead, zinc, and copper) were found in almost all samples, and four additional metals were detected in approximately half. Phthalate, the most common synthetic organic was found in only 22 percent of the samples. Present in 10 to 19 percent were three chlorinated hydrocarbons (two pesticides and a wood preservative) and four polynuclear aromatic hydrocarbons (PAHs). As can be seen, urban stormwater runoff is a multifaceted and complex problem to manage.

Synthetic organics are an exceptionally large and diverse category of chemicals. They include hundreds of

Table 4-4
Contaminant loading ranges for various land uses
Figures are in kg/ha/yr except for FC (no./ha/yr)

Land use	TSS	TP	TN	Pb (median)	Zn	Cu	FC	COD
Road	281-723	.59-1.5	1.3-3.5	.49-1.1	.18-.45	.03-.09	1.8E+08	112-289
Commercial	242-1369	.69-.91	1.6-8.8	1.6-4.7	1.7-4.9	1.1-3.2	5.6E+09	306-1728
Residential (low)	60-340	.46-.64	3.3-4.7	.03-.09	.07-.20	.09-.27	9.3E+09	NA
Residential (high)	97-547	.54-.76	4.0-5.6	.05-.15	.11-.33	.15-.45	1.5E+10	NA
Terraced	133-755	.59-.81	4.7-6.6	.35-1.05	.17-.51	.17-.34	2.1E+10	100-566
Bush	26-146	.10-.13	1.1-2.8	.01-.03	.01-.03	.02-.03	4.0E+09	NA
Grass	80-588	.01-.25	1.2-7.1	.03-.10	.02-.17	.02-.04	1.6E+10	NA
Pasture	103-583	.01-.25	1.2-7.1	.004-.015	.02-.17	.02-.04	1.6E+10	NA

specialised products for industrial and commercial uses, as well as compounds produced incidentally through chemical reactions. Examples of the latter are the polynuclear aromatic hydrocarbons. These by-products of fossil fuel combustion appear in vehicle exhausts, lubricants and smokestack emissions. New chemicals can also be formed through environmental reactions after the release of a material.

Table 4-4 summarises the frequency of detection of contaminants from various land uses. Because different land uses generate different contaminants, when a new site is being developed or stormwater management is being implemented, the contaminants kikely to arise from the future land use or uses must be considered in

Table 4-5
Frequently detected priority contaminants of samples in NURP sites

Inorganics	Organics
Detected in 75% or more of samples	
94% Lead 94% Zinc 91% Copper	None
Detected in 50-74% of samples	
58% Chromium 52% Arsenic	None
Detected in 20-49% of samples	
48% Cadmium 43% Nickel 23% Cyanides	22% Bis(2-ethylhexyl)phthalate 20% α-Hexachloro-cyclohexane
Detected in 10-19% of samples	
13% Antimony 12% Beryllium 11% Selenium	19% α-Enfosulfan 19% Pentachlorophenol[a] 17% Clordane[a] 15% Lindane[a] Pyrene[b] 14% Phenol 12% Phenanthrene[b] 11% Dichloromethane 10% 4-Nitrophenol 10% Chrysene[b] 10% Fluoranthene[b]

[a] Chlorinated hydrocarbon
[b] Polynuclear aromatic hydrocarbon

any stormwater management strategy. This is particularly important when the contaminants are not attached to sediments. As commercial and industrial land use produces a disproportionate level of contamination of a

Table 4-6
Industrial activity and commonly found contaminants

Activity	Contaminant
Wood preserving activities	Arsenic, Copper, TSS, Oil and Grease
Industrial inorganic chemicals	Aluminium, Iron, Nitrate + Nitrite
Plastics, synthetic resins	Zinc
Soaps, detergents, cosmetics, perfumes	Nitrate + Nitrite, Zinc
Agricultural chemicals	Nitrate + Nitrite, Lead, Iron, Zinc, Phosphorus
Asphalt paving and roofing materials	TSS, Zinc, TPH
Concrete products	TSS, Iron, pH
Steel works	Aluminium, Zinc
Iron and steel foundaries	Aluminium, TSS, Copper, Iron, Zinc
Landfills	Iron, TSS, Aluminium, Cadmium, COD, Copper, Cyanide, Lead, Magnesium, Nitrate + Nitrite
Automobile dismantler yards	TSS, Aluminium, Iron, Lead, Oil and Grease, Zinc, Cadmium
Scrap recycling	Copper, Aluminium, Iron, Lead, Zinc, TSS, COD, Cadmium, Arsenic, Magnesium, Selenium
Fabricated metal products except coating	Iron, Aluminium, Zinc, Nitrate + Nitrite
fabricated metal coating and engraving	Zinc, Nitrate + Nitrite

variety of constituency, it is beneficial to list various commercial and industrial activities and the contaminants that are generally found in those activities. Table 4-6 lists a number of industrial activities that the USEPA, through monitoring, has found frequently exceed water quality standards for the contaminants listed in the table. Other contaminants may exist on those sites but the ones listed frequently exceed standards.

To properly specify, design and operate treatment practices, one needs to understand the precesses that can operate to prevent contaminants from entering receiving waters. Table 4-7 lists all the main processes that can capture, hold and transform various classes of contaminants in urban stormwater runoff and factors that enhance the operation of each process to improve water quality.

A key factor in the effectiveness of all processes is time. The likelihood of settling a solid particle is directly related to the time provided to complete sedimentation at the particle's characteristic settling velocity. Time is also a crucial determinant of the degree to which chemical and biological processes operate. Characteristic rates of chemical reactions and biologically mediated processes must be recognised and designed for in order to obtain their treatment benefits. For all of these reasons, water residence time is the single most basic and important variable to consider when designing treatment practices that will be cost-effective.

The designer and operator have a high degree of control over many of the processes that promote favourable water quality outcomes (possibly excluding soil). More specific objectives require more intervention, such as developing some desired soil condition.

4.6 Appropriate practice(s) for stormwater quantity/water quality/aquatic ecosystem goals

In many cases, a given BMP can provide both effective water quantity and quality control for a given site. However in some situations, this may not be possible and multiple practices may have to be used to achieve stated objectives or consent requirements. For example, ponds may provide water quantity and quality control, but the constraints of a particular site may prevent their use. Sand filtration, on the other hand, provides for water quality treatment but has very limited ability to provide any water quantity control. Table 4-8 details the general capability of various stormwater management practices to provide for water quantity control.

In addition to water quantity performance, stormwater practices also vary in the level of water quality

Table 4-7
Summary of contaminant removal mechanisms

Mechanism	Contaminants affected	Promoted by
Physical sedimentation	Solids, BOD, Pathogens, Particulate COD, P, N, Metals, Synthetic Organics	Low turbulence
Filtration	Same as sedimentation	Fine, dense herbaceous plants, constructed filters
Soil incorporation	All contaminants	Medium-fine texture
Chemical precipitation	Dissolved P, metals	High alkalinity
Adsorption	Dissolved P, metals, synthetic organics	High soil Al, Fe high soil organics, circumneutral pH
Ion exchange	Dissolved metals	High soil cationic exchange capacity
Oxidation	COD, petroleum hydrocarbons, synthetic organics, pathogens	Aerobic conditions
Photolysis	Same as oxidation	High light
Volatilisation	Volatile petroleum hydrocarbons and synthetic organics	High temperature and air movement
Biological microbial decompostion	BOD, COD, petroleum hydrocarbons, synthetic organics, pathogens	High plant surface area and soil organics
Plant uptake and metabolism	P, N, metals	High plant activity and surface area
Natural die-off	Pathogens	Plant excretions
Nitrification	NH_3-N	Dissolved oxygen > 2 mg/l low toxicants, temperature > 5-7^{0}C, circumneutral pH
Denitrification	NO_3+NO_2-N	Anaerobic, low toxicants temperature > 15^{0}C
Features that help achieve any objective	**Features that help achieve metals control**	**Features that help achieve organics control**
increasing hydraulic residence time low turbulence fine, dense herbaceous plants medium-fine textured soil	high soil organic content high soil cation exchange capacity circumneutral pH	aerobic conditions high light high soil organic content low toxicants circumneutral pH

performance they can achieve. Water quality performance must also be considered in terms of the contaminants of concern. A water quality practice that is effective at reducing suspended solids may not provide

Table 4-8 Water quantity effectiveness of stormwater management practices						
Practice	**Peak discharge control**			**Volume control**	**Groundwater recharge/low flow maintenance**	**Streambank erosion control**
	2- yr. storm	**10-yr. storm**	**100-year storm**			
API separators	-	-	-	-	-	-
Extended detention dry pond	+	+	+	-	-	+
Wet pond	+	+	+	-	-	+
Constructed wetland	+	+	+	>	>	+
Infiltration practices	+	>	-	+	+	+
Revegetation	+	-	-	+	+	>
Sand filter	+	-	-	-	-	-
Biofiltration (swale, filter strip, rain garden)	>	-	-	>	>	-
Water reuse	>	-	-	+	>	+

+ Usually provided
> Sometimes provided with careful design
- Seldom or never provided

much reduction in oil and grease. Table 4-9 details the potential contaminant reduction capability of various stormwater management practices.

In addition to how well different stormwater management practices can achieve specific objectives such as water quantity or water quality control, some have secondary impacts.

An example of a negative impact would be a stormwater management pond that has a normal pool of water. While being good at removing contaminants, the pond may be a source of thermal contamination of down-stream receiving waters. The pond water, if there is no base flow into or out of the pond, may become heated by bright sunlight on a warm summer day. If there are aquatic organisms downstream which are sensitive to stream temperature changes the ongoing discharge from the pond may have adverse impacts downstream even though the pond is providing water quality treatment. Table 4-10 provides an overview of the potential secondary impacts of stormwater treatment devices.

Positive secondary effects often include amenity and passive recreational benefits such as walking around the perimeter, picnicking, and so on.

4.7 Which device or devices to choose

This chapter has provided information that helps to lead a stormwater management plan designer to select appropriate practices. Figure 4.2 provides a decision path for design whereby a project can be evaluated and a decision can be arrived at based on the key variables. Practice evaluation and selection should be based on collection of information in conjunction with a logical progression of thought and analysis. A brief example demonstrates an appropriate approach.

Table 4-9
Potential contaminant removal effectiveness of stormwater management practices

Practice	Suspended Solids	Oxygen Demand	Total Lead	Total Zinc	Total Phosphorus	Total Nitrogen	Bacteria
API separators	-	o	o	o	o	o	o
Extended detention dry pond	+	>	+	>	>	-	o
Wet pond	+	>	+	>	>	-	o
Constructed wetland	+	+	+	+	+	+	o
Infiltration practices	+	+	+	+	+	>	+
Revegetation	+	+	+	+	>	>	-
Sand filter	+	-	+	+	>	-	>
Biofiltration (swale, filter strip, rain garden)	+	-	+	>	-	-	o

+ High potential for removal **>** Moderate potential for removal
- Low potential for removal **o** Insufficient knowledge

4.7.1 Example problem

Site and catchment conditions

Type of development:: Commercial shopping centre
Size: 3 hectares
Soils: Waitemata silts and clays
Slope: 8%
Site stability: good
Receiving system: typical degraded urban catchment, freshwater stream draining to estuary

Design considerations

Contaminants of concern: total suspended solids, metals, possibly nutrients
Stormwater issues: water quantity (10 yr., 100 yr.) and water quality
Catchment area/appropriate practices: vegetation, sand filter, infiltration practices
Secondary issues: public health and safety
Maintenance: property owner responsibility

Practice consideration

Applicable practices for contaminant removal: dry and wet pond (TSS, lead, zinc),
wetland (TSS, lead, zinc, phosphorus),
infiltration (TSS, lead, zinc, phosphorus),
revegetation (TSS, lead, zinc),
sand filter (TSS, lead, zinc),
biofiltration (TSS, lead)

Table 4-10
Potential secondary impacts of stormwater treatment practices

Practice	Aquatic habitat creation	No temperature increase	Landscape enhancement	Recreational benefits	Public safety	Community acceptance
API separator	-	+	-	-	+	+
Extended detention dry pond	-	+	>	>	>	>
Wet pond	+	-	+	+	>	+
Constructed wetland	+	>	>	>	>	>
Infiltration practices	-	+	-	-	+	+
Revegetation	+	+	+	>	+	>
Sand filter	-	+	-	-	+	+
Biofiltration (swale, filter strip, rain garden)	-	+	>	-	+	>
Water reuse	-	+	-	-	+	>

+ Usually provided
> Provided with design modification
- Seldom provided

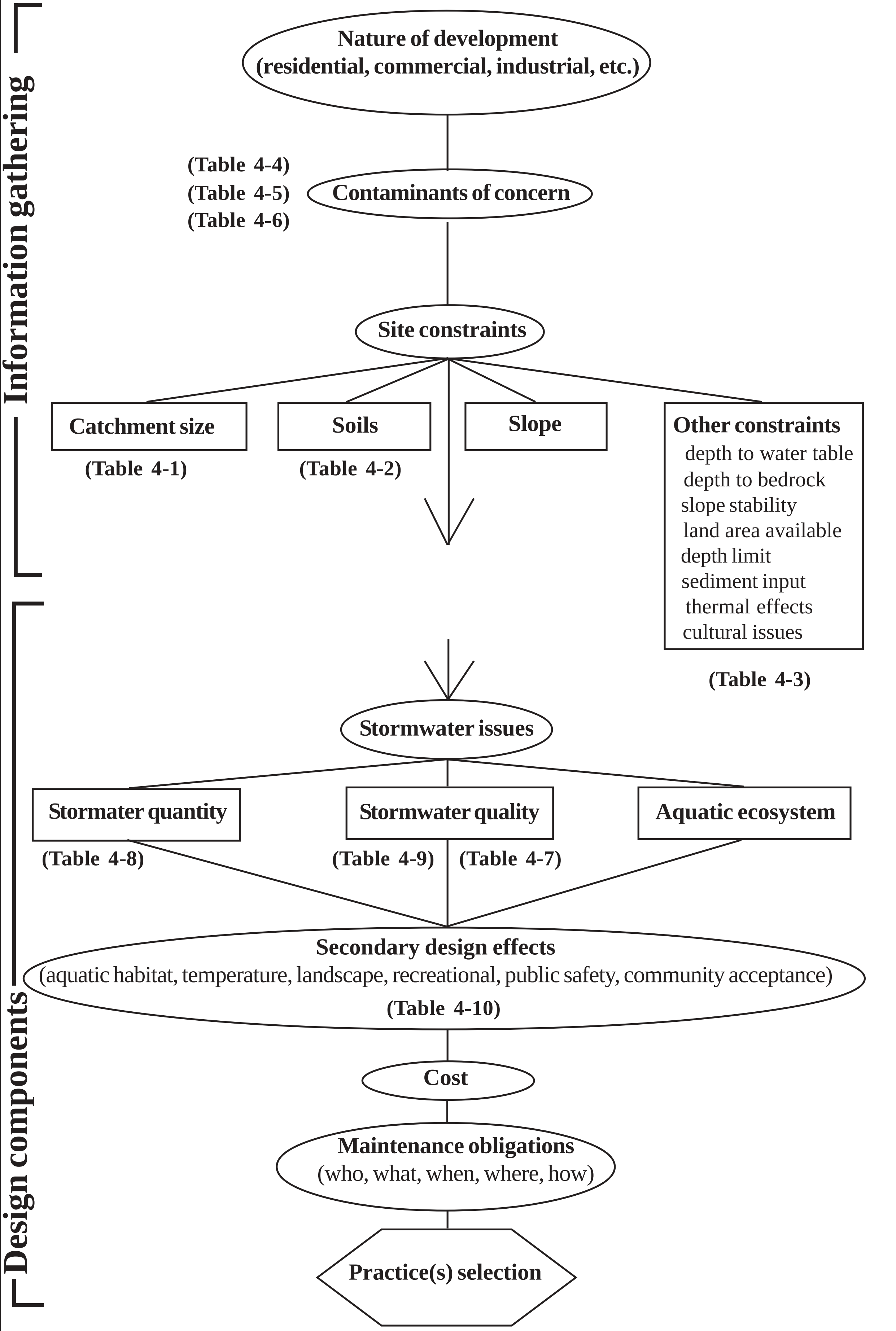
Applicable practices for water quantity	ponds, wetlands
Treatment practice for 3 ha. catchment area	rain garden, sand filter, infiltration, biofiltration
Treatment practice related to clay soils	rain garden, sand filter, ponds, swale, revegetation
Aquatic ecosystem	not a concern on this project (goes into reticulation)
Landscape	attractive
Public health and safety	important

Choosing practices

The example case study indicates that both water quantity and water quality are issues of concern. The appropriate practice(s) then relates back to the site and catchment conditions, design considerations, and practice considerations.

As the example shows, it is difficult to address both water quantity and water quality issues with one single practice. It would be best to conceptually select an approach that addresses both issues and then integrate the practices as needed for final design.

Figure 4-2
Process of stormwater management practice evaluation and selection

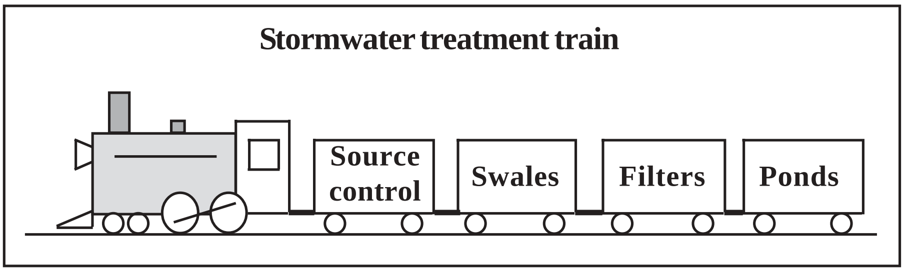


Water quantity practices involve the storage of stormwater and release over a longer period of time to manage downstream flooding. Stream channel stability is not an issue so that the storage and release of the first 34.5 mm of rainfall over a 24 hour period is not an issue. What can be considered is a dry stormwater detention pond whose purpose is to reduce outflow rates to pre-development levels. This does not address water quality, which will need to be considered with a separate practice.

Water quality control needs to consider total suspended solids and metals. Nutrients are not considered to be critical for this catchment. Ponds are not considered as practical for this site as the total site area precludes consideration of a wet pond. With this site, parking is an important issue and biofiltration may be the most practical option. Swales in between parking spaces having kerb cuts to allow water entry into the swale is the selected option. If used, swales would have to follow site contours and meet the residence requirement time.

For this site, stormwater quantity control requires a dry detention pond in one corner of the property while water quality control is provided by vegetated swales. Another option could be to design and construct a constructed wetland that addresses both quantity and quality issues.

4.8 The treatment train: which suite of practices suit your site



As the example shows, it may be difficult for one practice to provide for multiple benefits. The ARC will place more emphasis on the "Stormwater Treatment Train" concept where several types of stormwater practices are used together and integrated into a comprehensive stormwater management system. Although this is obvious when multiple issues are considered (such as stormwater quantity, quality, and aquatic ecosystem protection), it is also sometimes needed when considering a single issue. For example, stormwater quality may include a variety of contaminants to manage, but processes that facilitate one type of contaminant in one practice may not facilitate removal of a contaminant in another phase (liquid versus particulate). The treatment train approach to stormwater management will become increasingly important to reduce overall stormwater impacts of the urban environment.

4.9 Device operation and maintenance

As well as land use and site location, another element that should be considered during the design phase is operation and maintenance. Presented below are two recommended techniques to assist in consideration of operating conditions, costs of selected practices and other responsibilities throughout the design process. They can either be used as review techniques following completion of a practice design or, ideally, be incorporated into the overall design process and used continually during it:

> Spend a mental year at the practice
> Who, what, when, where, and how

4.9.1 Spend a mental year at the practice

To use this technique, the stormwater designer simply imagines conditions at the completed practice throughout an entire year. This should not only include rainy and sunny weather, but also light rain showers. Other site conditions may include hot, dry weather or drought, when vegetation is stressed or dead. Finally, for safety purposes, the designer should also imagine what the system will be like at night.

As these conditions are visualised, the designer should also imagine how they may affect not only the operation of the system itself, but also the people that will maintain it or otherwise interact with it. Will the outlet structure's trash rack be prone to clogging from vegetation floating in the stormwater runoff? Is there a safety issue with small children?

What about night conditions? Will the constructed wetland next to the office parking lot that is attractive during summer lunch hours become a safety hazard to workers leaving the office at night?

At first, it may be exasperating to realise that the number of possible site conditions and circumstances can be as numerous and varied as the number of possible practice types. But then again, that is the point of this exercise. It is intended to help the designer consider and design for all possible conditions at the practice, not just the 1 in 2 or 10 year storm event. In doing so, the practice designer will not only meet the letter of the RMA requirements but also the spirit of the entire stormwater programme.

4.9.2 Who, what, when, where, and how

The second recommended review technique a practice designer may employ is to simply focus on one or more operation and maintenance characteristics or functions of the practice and then ask (and answer) the following questions:

> *Who will perform it?* Does the stormwater practice's design require operation and maintenance specialists or will someone with general maintenance equipment and training be able to do the job?
>
> *What needs to be maintained?* Preparing a list of all practice components included in the design may prompt a revised design with a shorter operation and maintenance list.
>
> *When will maintenance need to be performed?* Once a day? A week? A year? Remember, the recurring costs of practice maintenance can be substantial. In addition, can maintenance only be performed during dry weather? If so, what happens during the lengthy time periods of wet, rainy weather. What happens when repairs need to be made or debris removed during a major storm event? In terms of effort and possible consequences, it is easier for the designer to find answers to these questions now, than for maintenance or emergency personnel to scramble for them later.
>
> *Where will maintenance have to be performed?* Will the maintainer be able to get there? Once there, will they have a stable, safe place to stand and work? In addition, where will such material as sediment, debris, and trash removed from the practice be disposed of? Before answering that question, do you know how much there might be and what it might contain? Are there toxic or hazardous materials in the sediment or debris? If so, is the place you originally intended to use for disposal still suitable? Once again, it is easier to address these questions now than when the dump truck is loaded.
>
> *How will maintenance be performed?* The simple instruction to remove the sediment or harvest the vegetation can become rather complicated if there hasn't been any provision made to allow equipment to get to the bottom of the practice or even into the site. Mowing the grass can be dangerous on steep, long slopes. How will you explain to your client why the stormwater management practice they have invested in has become a liability to themselves and their community?

Similar to the mental year review technique, the questions raised in this technique are intended to make the designer more aware of all the possible impacts the facility may have and, further, to encourage the designer to address those impacts now, during the design phase, rather than leave them for others, particularly maintenance personnel, to cope with later. Even if the designer cannot completely answer all of the questions, he or she will be able to advise the others of any unavoidable needs or problems that will be inherent in the practice and allow them time to adequately prepare.

4.10 Bibliography

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