Chapter 7
Filtration design, construction and maintenance

7.1 Introduction

Filtration includes a diverse group of practices for treating stormwater runoff. The common factor is that each uses some kind of filtering media such as sand, soil, gravel, peat, or compost to filter out contaminants. They are especially suited for small catchment areas, are primarily water quality practices and they generally have little water quantity control benefit.

Although diverse, stormwater filters have several common design components.

- inflow regulation
- pretreatment
- filter media
- outflow mechanism

This chapter discusses sand filtration and rain gardens.

Sand filters can be either surface or underground, and their designs are similar. Sand filters work by sedimentation and filtration, generally with an inflow point to a sedimentation chamber and an underdrain in a subsequent filtration chamber that discharges filtered stormwater.

The ARC is investigating the use of alternative filter media over the next year for enhanced contaminant reduction, especially of soluble contaminants.

Rain gardens are generally surface depressions with key elements including a grass filter, a sand/loam soil mixture, shallow ponding, plantings of trees and shrubs, and an underdrain.

7.2 Water quality performance

Filtration practices have:

- an excellent ability to remove suspended solids
- a variable ability to reduce phosphorus
- low nitrogen removal in sand filtration systems but a moderate ability in rain gardens
- higher ability to remove bacteria, metals and hydrocarbons than other practices such as ponds

Filters reduce contaminants by a variety of chemical, physical, and biological processes. The dominant process will vary from site to site and between contaminants. In some cases the contaminants are transformed (decomposition, decay) and in other cases they simply accumulate in the filer media. The removal processes include:

- sedimentation
- adsorption
- volatilisation
- filtration
- biological processes

Plate 7-1: Unitec sand filter under construction showing various components

Sedimentation

Sedimentation is one of the principal mechanisms for the removal of many contaminants from the water column. Sedimentation is important for the removal of suspended solids, particulate nitrogen, hydrocarbons and heavy metals.

Adsorption

Adsorption of contaminants onto the surface of suspended solids is the dominant mechanism for dissolved contaminants. Adsorption occurs through three main processes:

- electrostatic attraction,
- physical attraction and
- chemical reaction.

Adsorption is important for removing ammonium ions, phosphorus, viruses and heavy metals.

Precipitation, dissolution, and complexation

Many metals dissolve or precipitate in response to changes in water chemistry. Metals form insoluble sulphides under reducing conditions and insoluble oxides and hydroxides under oxidising conditions.

Volatilisation

Contaminants may enter the atmosphere by evaporation and aerosol formation under windy conditions. Common contaminants removed by volatilisation include oil, chlorinated hydrocarbons and mercury.

Filtration

This occurs as particulates are mechanically filtered through a filter media, vegetation and biota. Dense vegetation and low velocities promote greater removal efficiencies. Organic matter, phosphorus, bacteria, and sediments are effectively removed by infiltration through the soil.

Biological processes

Vegetation offers high contaminant absorption and biological uptake potential as well as providing an environment for significant microbial activity.

Rain gardens utilise additional processes that can further improve water quality function. Mulch has been found to be very effective in removing heavy metals through organic complexing with the hydroxyl and carboxyl sites on the organic molecules. Soil bacteria can metabolise (use as a carbon energy source) oil, grease, and petrol into CO_2 and water in the presence of adequate nutrients and oxygen. Plants are known to uptake, transpire, accumulate and detoxify heavy metals and many other toxic compounds.

In summary, the overall contaminant removal of stormwater filter systems is on a par with that for other practices with higher removal for some contaminants, and lower removal for others. Table 7-1 provides expected removal efficiencies for sand filters. Also included in the table is a comparison of removal expectations and results from monitoring efforts at the Unitec sand filter.

Table 7-1
Contaminant removal expectations (%)

Contaminant	Removal expectations	Unitec site
Sediment	>75	92
Total lead	>75	98
Total zinc	>75	93
Total copper	>75	90
Hydrocarbons	>75	not done

While the results of the Unitec monitoring are extremely good, the monitoring period was of short duration (two months) and the largest storm monitored was 7.7 mm of total rainfall. The results therefore should be considered indicative as opposed to absolute. Overseas data does support the range of results that have been obtained in the ARC study and show sand filters to be effective at contaminant removal.

In addition to the water quality performance, peak discharge rates were reduced significantly between inflow and outflow. For all storms, the mean reduction in peak flow was 64%. The greater the inflow peak, the greater the reduction in peak discharge. For the top 25 percentile of peak inlet flows (i.e. > 11.5 l/s), the flow reduction averaged 90%. These results were for small storm events. It is expected that discharges beyond the filters design specification (water quality storm) would have diminishing benefits.

7.3 Design approach

7.3.1 Objectives

1. To reduce coarse sediments, metals, nutrients, PAH, bacteria and gross contaminants from stormwater runoff from low and high levels of imperviousness for residential, commercial, and industrial site.

2. These practices are primarily water quality treatment practices and consideration must be given to larger flows.

Rain gardens are used primarily in residential areas but can, with careful design and a good maintenance programme, be used on commercial sites. Components of a rain garden include a grass pretreatment area, temporary ponding, planting soil, sand mixing with the soil, an organic layer, and plant material. Infiltration can be a component depending on soil conditions.

Plate 7-2: Example of a rain garden used in a parking lot

Figure 7-1
Typical detail of a flow diversion structure

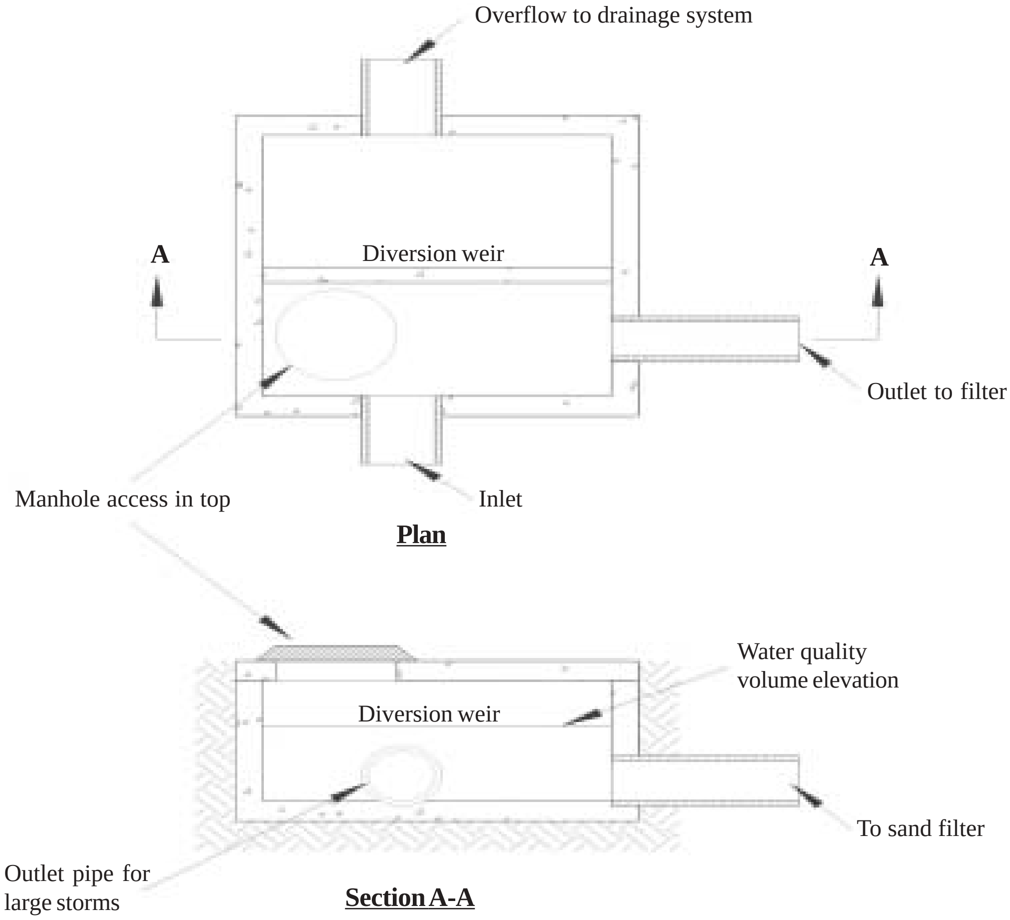


Figure 7-1 provides a typical detail of a flow diverter which can be used primarily for concentrated flow into a sand filter. Rain gardens should have an overflow spillway set above the water quality storm or an overland flow path for larger events.

7.3.2 Applicability

Sand filters are primarily used for high percentages of impervious surfaces where the majority of sediments are in the coarse fraction. When used, they should have a forebay or sedimentation chamber for capture of the coarser sediments and a filtration chamber, having an underdrain, for removal of finer suspended solids, hydrocarbons, and metals. A major component of a sand filter is temporary ponding over the sand. The major limitation is catchment area. Filters are most suited for catchments less than four hectares.

Sand filters can be used in most residential, commercial and industrial developments and are most applicable in areas where impervious surface percentage is high. Specific applications include:

- parking lots for commercial and industrial sites
- service stations
- high density residential housing
- roadways
- bridges

Filters are best located off-line and are suited for retrofits with space constraints and new developments. When considering using a sand filter, designers need to assess:

- the loading rate
- filter loading capacity
- the minimum maintenance frequency

Most street and road particulate matter is in coarser fractions, roughly in sand and gravel equivalent sizes. However, most stormwater contaminants are associated with fine particles. As sand filters have two chambers, the sedimentation chamber is more effective at removing the sand and gravel component. The finer silts and clays are more effectively captured by the filtration component.

As mentioned in the Objectives section, rain gardens are ideally suited for residential developments but can be used on other land uses if pre-treatment is provided to reduce potential clogging. They are ideally suited for small catchments of less than one hectare. They are generally on-line practices with an overflow provided for larger storms.

7.4 Design procedure

The design approach for sand filters and rain gardens is somewhat different and will be discussed individually. Both rely on treating the runoff from the water quality storm and the use of filter media for treatment. However the rain garden approach is a bit more complicated as the flow must travel through an organic/sand media, not just sand.

7.4.1 Sand filter design procedure

For the most part, sand filters will be used to treat stormwater runoff from impervious surfaces so the calculation of water quality storm volume is relatively simple. Figure 7-2 shows a perimeter sand filter so that the design approach can be visualised.

Design steps

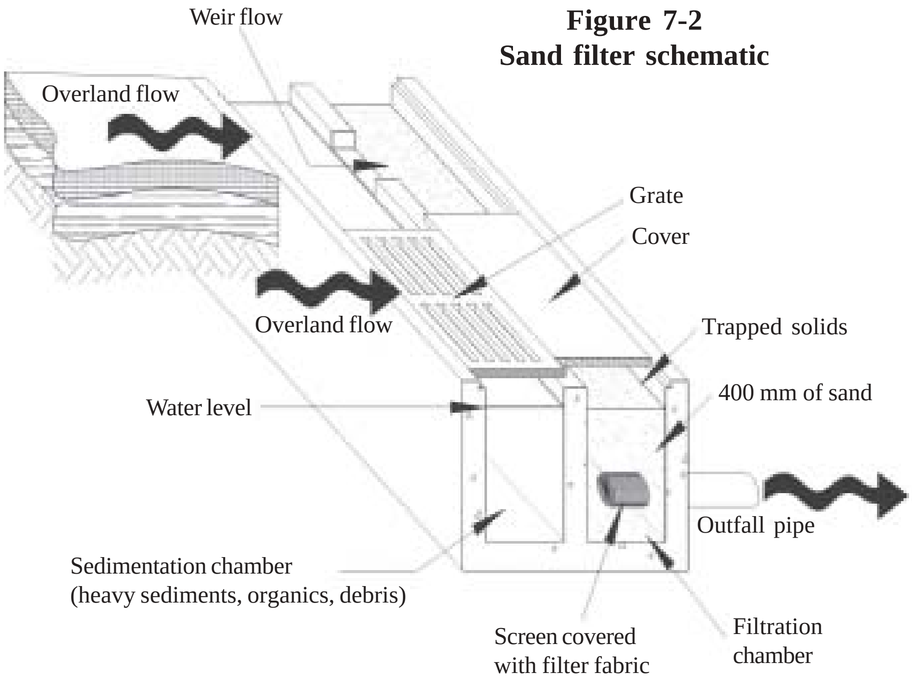


Figure 7-2
Sand filter schematic

1. Calculate the water quality volume to be treated using 1/3 of the 2 year-24 hour rainfall for a given location using TP 108. The water quality calculations should be done by considering the pervious and impervious areas separately.

   Capture and isolate the water to be treated by diversion baffles and weirs. A typical approach to isolate the water quality volume is to construct a diversion weir in the stormwater channel or pipe. When additional runoff greater than the water quality volume enters the diversion weir area, it will spill over the weir, and mixing with water stored in the filter will be minimal.

2. A minimum of 37% of the water quality volume must be available as live storage to ensure that the total water quality volume passes through the filter without bypass.

3. The sand filtration chamber should be sized by the following equation:

$$A_f = \frac{I_a H d_f}{k(h+d_f)t_f}$$

where

A_f = surface area of sand bed in (m^2)
I_a = impervious drainage area contributing runoff (m^2)
H = runoff depth to be treated (m)
d_f = sand bed depth (m)
k = coefficient of permeability for sand filter in metres per day
h = average depth of water (WQ storm) above surface of sand in metres (1/2 max. depth)
t_f = time required for runoff to pass through the filter media in days

The following values should be used:

I_aH = the water quality volume in cubic metres
t_f = 2 days (maximum)
k = 1 metre per day
d_f = 0.4 metres (minimum)

Key filtration chamber design specifications:

(a) The minimum filter bed depth is 0.4 metres
(b) Sand specifications are:

Sieve size (mm)	Percentage passing
9.5	100
6.3	95-100
3.17	80-100
1.5	50 - 85
0.8	25 - 60
0.5	10 - 30
0.25	2 - 10

No locally available sand grades fall within the desired specifications. However, a number are close to the lower limit and can be used. It is important to meet as closely as possible the specified limits as coarser aggregate will allow for more contaminant migration and finer aggregrate will clog more quickly.

(c) An underdrainage system shall be provided. The system usually consists of perforated lateral pipes that feed a collector pipe. The perforated lateral pipes shall be covered by a geotextile fabric that retains sand but does not provide excessive flow resistance. Laterals and mains should be sized to pass the design filter flow at the pipe gradient.

(d) If the system is ‘on-line’ an overflow needs to be provided in order to pass flows greater than the water quality design storm.

3. Design the sedimentation chamber

Key sedimentation chamber design specifications:

(a) Inflow into the chamber must not cause resuspension of previously deposited sediments
(b) The sedimentation chamber outlet delivers flow to the filtration chamber as sheet flow

(c) The sedimentation chamber must be at least 25% of the filtration area detailed in step 2
(d) Flow velocities in the sedimentation area are required to be below 0.25 m/s
(e) The sedimentation chamber must have a permanent pool with a minimum depth of 0.4 metres to reduce resuspension of trapped sediments
(f) The sedimentation chamber should be configured to avoid short-circuiting of the flow. This requires a long narrow pool or tank, the use of baffles to lengthen the flow path or baffles to provide flow resistance at the inlet.

7.4.2 Rain garden design

Rain garden design, as shown in Figure 7-3, differs from sand filter design only slightly. Where sand filtration relies on water quality treatment via passage of stormwater through sand, rain gardens incorporate plants and soils for removal of contaminants. Rain gardens may have aesthetic benefits not provided by sand filter systems, are more appropriate for residential implementation, and provide greater water quality benefits for a wider range of contaminants as a result of additional biological processes provided by plants.

The main components of a rain garden include:

- Grass filter strip
- Ponding area
- Planting soils
- Ground cover or mulch layer
- Plant material
- Underdrain system

Where sand filters tend to have (but don't necessarily require) impermeable linings, rain gardens generally interface with natural ground. This has both advantages and disadvantages.

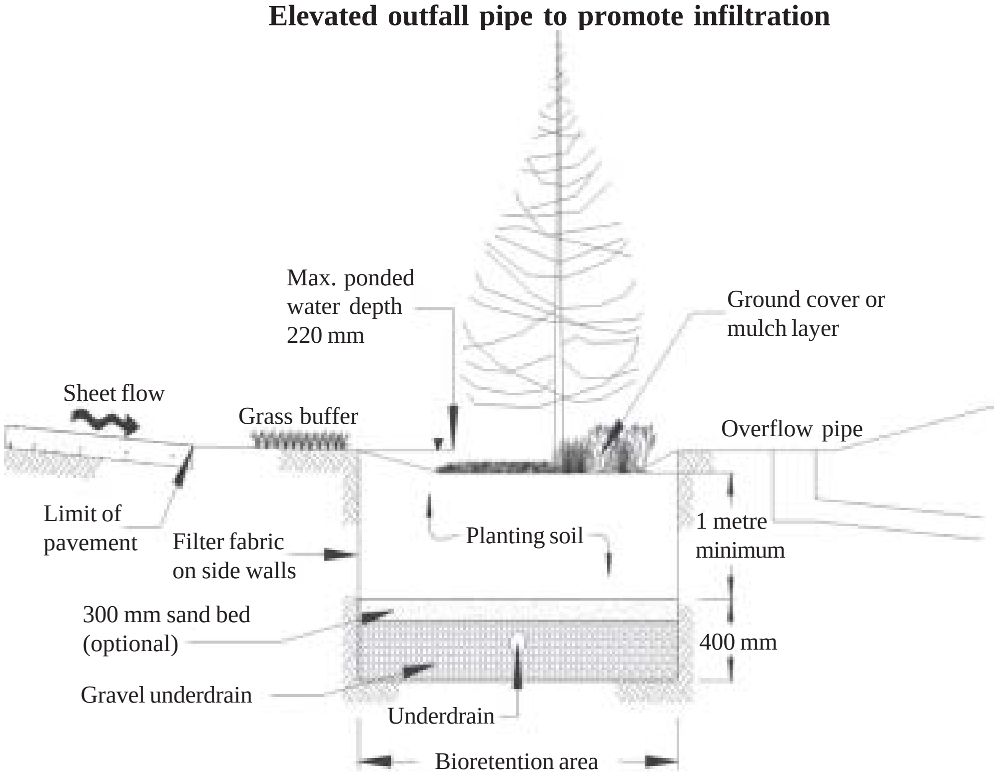
Advantages of a design similar to Figure 7-3 include an elevated underdrain that will promote groundwater recharge where soils and geology allow.

The disadvantages relate to areas where the natural slopes and soils are unstable. In those areas Figure 7-4 can be used, where the rain garden has an impermeable lining with the underdrain pipe located at the bottom to prevent water standing in the bottom.

An underdrain must always be used in both designs.

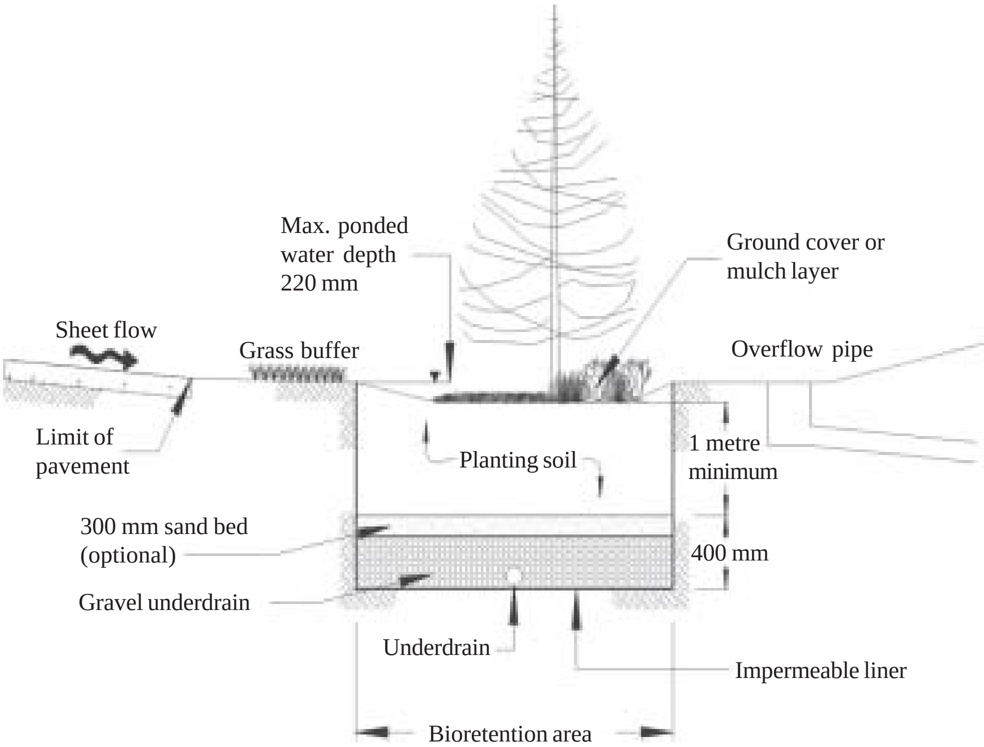
Both designs also allow for an optional sand layer at the bottom with a gravel

Figure 7-3
Elevated outfall pipe to promote infiltration



underdrain system. It is not recommended that a filter cloth be placed between the planting soil, sand bed and gravel underdrain because the fabric represents an area of potential clogging. A small amount of soil migration may be expected but the system will stabilise. Filter fabric (open weave in stable soils; impervious in unstabile soils) should be used, at least on the side walls, to prevent migration of adjacent soil particles into the rain garden.

Figure 7-4
Outfall pipe located at the bottom of the raingarden



The gravel underdrain will collect and distribute treated excess runoff. A properly designed underdrain system helps keep the soil from becoming saturated. The underdrain system consists of a gravel layer with a 100 - 150 mm perforated piping system. There should be a minimum of 50 mm of gravel cover over the perforated pipe.

Rain Garden Design Approach

1. determine water quality storage volume – use 1/3 of the 2 year-24 hour rainfall for site location per TP 108. The calculations shall be done considering the pervious and impervious catchment areas separately and their totals then summed.

   Calculate volume using TP 108. Minimum time of concentration is 0.17 hours.

2. Minimum live storage volume shall be 40% of the WQV.

3. Calculate the required surface area of the filter.

$$A_f = \frac{(WQV)(d_f)}{k(h+d_f)(t_f)}$$

A_f	= surface area (m^2)
WQV	= treatment volume (m^3)
d_f	= planting soil depth (m)
k	= coefficient of permeability (m/day)
h	= average height of water (m) = ½ max. depth
t_f	= time to pass WQV through soil bed (use one day to be conservative)

The following values shall be used:

d_f	= planting soil depth (m) one metre
k	= coefficient of permeability (m/day) = 0.3 m/day
h	= average height of water (m) = 0.11 metres
t_f	= time to pass WQV through soil bed (use one day for residential and up to 1.5 days for non-residential to be conservative)

General comments on rain gardens

1. The 220 mm depth of water on the rain garden is an approximate amount, the live storage ability is important to maintain. If less depth is used, the area of storage must be increased so the same volume of live storage is provided. Where the full depth cannot be provided (based on agreement with the ARC) A_f as calculated shall then be multiplied by the ration of the normal depth (1 metre) divided by the actual depth.

$$A_f/\text{actual depth} = \text{revised surface area requirement}$$

2. Keep drainage areas small and avoid the temptation to size them for too large a catchment area. As a general rule, keep their contributing catchments less than 1000 m^2. It is better to have more rain gardens than larger ones.
3. Place them in areas where they will not interfere with the normal use of the property.
4. Design them as off-line systems.
5. Make them look attractive so property owners will continue to maintain them.
6. The one day time to drain for residential properties is important so that property owners don't perceive that there is a drainage problem due to standing water.

Composition of planting soil

The characteristics of planting soils are very important. The soil must be permeable enough to allow runoff to filter through the media, while being able to promote and sustain a vegetative cover. Soils must balance soil chemistry and physical properties in order to support biotic communities above and below ground.

The best planting soil should conform to the following specifications:

- a sandy loam, loamy sand, loam, or a loam/sand mix (35-60% sand)
- clay content should be less than 25%
- permeability should be at least 0.3 metres per day
- free of stones, stumps, roots, or other woody material over 25 mm in diameter
- free of brush or seeds from noxious plants
- placed in lifts of 300 - 400 mm and loosely compacted (tamped lightly with a backhoe bucket)

Having a mulch layer on the surface of the ground can play an important role. The mulch layer assists in maintaining soil moisture and avoids surface sealing, which reduces permeability. Mulch helps prevent erosion and provides a micro-environment suitable for soil biota at the mulch/soil interface. The mulch should be:

- standard landscape type shredded wood mulch or chips
- well aged and free of other materials such as weed seeds, soil, roots, etc
- applied to a maximum depth of 75 mm.

7.5 Plant material

Consider the following when making planting recommendations:

1. Native plant species should be specified over exotic or foreign species
2. Appropriate vegetation should be selected based on their hydric tolerance

Table 7-2
Trees and shrubs

Trees and shrubs	
Brachyglottis repanda **rangiora**	Coastal shrub or small tree growing to 4m+. Large attractive pale green leaves with white fuzz on underside.
Coprosma acerosa **sand coprosma**	Grows naturally in sand dunes. Yellow, interlaced stems and fine golden foliage. Forms a tangled shrubby ground cover. Tolerates drought and full exposure. Prefers full sun.
Coprosma robusta / C. lucida **karamu, shining karamu**	Shrubs or small trees growing to 3m+, with glossy green leaves. Masses of orange-red fruit in autumn are attractive to birds. Hardy plants.
Cordyline australis **ti kouka, cabbage tree**	Palm-like in appearance with large heads of linear leaves and panicles of scented flowers. Sun to semi-shade. Prefers damp to moist soil. Grows eventually to 12m+ height.
Cordyline banksii **ti ngahere, forest cabbage tree**	Branching from the base and forming a clump. Long strap-shaped leaves with red-orange coloured veins. Prefers good drainage and semi-shade.
Corokia buddleioides **korokio**	Bushy shrub to 3m, with pale green leaves with silvery underside. Many small bright yellow starry flowers are produced in spring. Prefers an open situation but will tolerate very light shade.
Entelea arborescens **whau**	Fast growing shrub or small tree (to 5m height) with large bright green heart-shaped leaves. Spiny seed capsules follow clusters of white flowers in spring. Handsome foliage plant
Geniostoma rupestre **hangehange**	Common forest shrub with pale green glossy foliage, growing to 2-3m. Tiny flowers give off strong scent in spring. Looks best in sunny position where it retains a bushy habit, and prefers well drained soil.
Hebe stricta **koromiko**	Shrub or small tree growing to 2-5m in height. Natural forms have white to bluish flowers. Many cultivars and hybrids available with other colours, but unsuitable for use near existing natural areas. Full sun.
Leptospermum scoparium **manuka**	Shrub or small tree growing to 4m+ in height. Natural forms have white to pinkish flowers. Many cultivars and hybrids available with other colours, but unsuitable for use near existing natural areas. Hardy and tolerant of difficult conditions.
Metrosideros robusta **rata**	Eventually forms a large tree. Flowers bright red in summer. Will tolerate dryness and exposure. Full sun.
Pittosporum cornifolium **tawhirikaro**	A slender branched shrub grown for its attractive fruiting capsules which are brilliant orange when split open. Sun or semi-shade.
Pittosporum kirkii	A small tree with dark green leaves and large yellow flowers in the summer. Prefers shade
Pseudopanax crassifolius **horoeka**	Very narrow rigid and leathery leaves in its juvenile form. Stunning in amongst bold leaved plants. Sun or semi-shade.

Table 7-3
Grasses, ground covers, and other plants

Grasses, ground covers, and other plants	
Arthropodium cirratum **Rengarenga, renga lily**	A lily with fleshy pale green – greyish leaves and white flowers. Ground cover in semi shady situation
Asplenium bulbiferum **mouku, hen and chicken fern**	A robust fern with small plantlets produced on the fronds. Tolerates dryness and prefers shade
Asplenium oblongifolium **huruhuruwhenua, shining spleenwort**	Fern with large shiny fronds. Tolerates dryness. Prefers shade
Astelia banksii **kowharawhara, coastal astelia**	Clump forming plant up to a metre high with flax-like leaves. Requires semi-shade. Tolerates full exposure. Frost tender
Astelia solandri **kowharawhara, perching astelia**	An epiphytic plant in natural situations. Long drooping bright green leaves. Tolerates dryness. Prefers shade
Carex flagellifera **manaia, Glen Murray tussock**	Sedge up to 70cm high with reddish-brown spreading foliage. Prefers damp soil and full sun. Tolerates exposure
Carex testacea **sedge**	Coastal sedge up to 40cm high with shiny orange foliage. Prefers full sun and exposure. Tolerates dry soil conditions
Cortaderia fulvida **toetoe**	Branching from the base and forming a clump to 4m high. Long strap-shaped leaves with red-orange coloured veins. Prefers good drainage and semi-shade
Dianella nigra **turutu**	Lily with reddish leaves, and striking violet-blue fruit. Ground cover; prefers open well-drained situation
Disphyma australe **glasswort**	Fleshy leaved ground cover with mauve flowers in the spring. Tolerates drought and full exposure. Frost tender
Doodia media **pukupuku, rasp fern**	Hardy fern growing to 25cm. Young fronds coloured bright red when in full sun. Sensitive to frost
Libertia grandiflora & ***L. ixioides*** **mikoikoi, native iris**	Clump forming native irises with narrow, upright leaves. Small white flowers in spring. Sun or shade
Phormium cookianum **wharariki, mountain flax**	Clump-forming flax with yellow –green drooping leaves, to 2m. Full exposure and sun
Phormium tenax **harakeke, flax**	Clump-forming flax with large stiff leaves, to 3 m. Full exposure and sun

3. Species layout should generally be random and natural
4. A canopy should be stabilised with an understory of shrubs and herbaceous plants
5. Woody vegetation should not be specified in the vicinity of inflow locations
6. Trees should be planted primarily along the perimeter of the rain garden area
7. Stressors (wind, sun, exposure) should be considered when developing the planting plan
8. Noxious weeds should not be specified
9. Aesthetics and visual characteristics should be a prime consideration
10. Traffic and safety issues must be considered
11. Existing and proposed utilities must be identified and considered
12. Consider using native plants that already exist on the site that otherwise would be removed during site construction.

Recommended plant species for rain gardens includes trees, shrubs, grasses, ground covers, and other plants as shown in the following tables 7-2 and 7-3

7.6 Construction

7.6.1 Sand filters

Sand filters may involve reinforcing steel, concrete and significant site preparation and excavation before construction. The approved plans should be reviewed and discussed for any concerns at the preconstruction meeting. The following construction times and items are important to recognise during the site inspection.

1. Stake out the filtration facility location.
2. Generally, do not use filters for sediment control during construction.
3. Pre-fabricated structural components should be available on-site to verify adequacy of materials. Reinforcing bars should meet design specifications as should all other structural components such as any pipes, aggregate material and filter fabric.
4. Clear foundation areas of any organic material which could cause uneven settlement as the material decomposes. Unsuitable foundation material should be removed and replaced with suitable material.
5. Compact the foundation area to sustain the load placed on it by the filtration system. Level the foundation as detailed on the plans to ensure proper drainage of the facility.
6. Ensure the ARC or TA inspector is on site when the facility has been formed up with reinforcing bars in place but before pouring the concrete so pouring can be observed.
7. During concrete pouring, the inspector must verify that the concrete meets design specifications for the design load.
8. If the filtration practice is composed of prefabricated units, the inspector must approve the means of joining the sections and the steps taken to prevent leakage from between the prefabricated units.
9. Before backfilling, fill the filters with water once the concrete has set (or joints on prefabricated units have been sealed) and allowed to sit for 24 hours and observe whether the unit has any leaks.
10. When installation has been completed to meet size and volume requirements, has no leakage and the contributing catchment areas have been stabilised, place the underdrains on the proper slope and wrap them in filter fabric to prevent migration of the filtration material out of the facility.
11. Place the filter material in the facility. The material should meet criteria specified on the design plans. The sand should be clean, washed aggregate. Other materials, such as peat or compost, may become more accepted if their performance demonstrates their value.
12. Conduct a final inspection to verify that the filter material is placed correctly and the first sedimentation chamber is clean of any accumulated sediments or other construction debris. Site inspection forms are at the end of the Chapter.

7.6.2 Rain gardens

1. Ideally, defer building the rain garden until after the contributing drainage area has been stabilised.
2. Do not use the area excavated as a sediment ponding area during site construction, as finer sediments may seal the bottom before it starts operation.
3. Stake out the general location of the rain garden so that location and dimensions can be considered in terms of site suitability.
4. Excavate the rain garden and connet the underdrains to the stormwater drainage system. If there is no stormwater system, the underdrain should be connected to a flow distribution system to avoid concentrated flows downstream. Impervious lining or filter fabric should be placed at this time.
5. Place gravel backfill, sand backfill and planting soil in excavation. Verify composition of materials and compaction.
6. Plant vegetation, lay mulch and complete site stabilisation.

7.6.3 As-built plans

Consent conditions may require an As-built plan to verify that construction was done in accordance with the approved consent.

The As-built plan must verify the:

1. Dimensions and materials of the filtration system or rain garden match the design dimensions
2. Filter material is per specification
3. Inlets and outlets are constructed correctly
4. Underdrains are installed to grade
5. Prefabricated joints are sealed (filtration practice)
6. 24 hour water test verified no leakage of filtration chamber (filtration practice)

7.7 Operation and maintenance

7.7.1 Sand filters

As is the case with all stormwater practices, the frequency of maintenance depends on the contaminant loadings entering the practice.

Two major components of sand filters include:

- a sedimentation chamber
- a filtration chamber

Sedimentation chamber

The sedimentation chamber settles and stores coarser sediments and debris mainly by gravity. Maintenance inspectors should ensure that the depth of stored materials is below the level where they will migrate to the filtration chamber. This depth is relatively easy to measure.

Maintenance of the sedimentation chamber is generally not needed more than every two to ten years. Sedimentation chambers are normally wet, so the accumulated material is easily removed with vacuum type equipment. Volumes to be removed are generally fairly, reflecting the smaller catchment areas these practices serve. This makes vacuuming a practical method.

Access must be provided to the sedimentation chamber for entry and performance of maintenance.

Filtration chamber

Maintenance of filter chambers depends on the magnitude of the incoming contaminant loadings, but filters generally require cleanout every 6 - 12 months.

The finer sediments may be raked from the surface of the sand and removed, or a flat bottom shovel may skim off the surface of the sand to re-establish sand permeability.

Filtration chambers are more sensitive than sedimentation chambers to clogging by fine sediments and other fine grained materials, such as oils and greases. While the sedimentation chamber functions primarily through gravity settling of the incoming materials, the filtration chamber is where filtering of contaminants occurs. This chamber will be more effective at removal of the finer sediments, which are retained primarily in the top 50 mm of the filter media.

Filtration chambers need more frequent maintenance than sedimentation chambers. If the sand filter is in an area with a significant contaminant loading, filter maintenance may be needed at least twice per year to ensure that the design flows travel through the practice. Diminished permeability of the sand will result in more frequent overflows into the conventional drainage system with less stormwater treatment. It will be fairly easy to see the depth of penetration of the contaminants and how much filter media needs removal. Usually, it is not necessary to replace all of the filter media, only the top layer.

When portions of the filter media must be replaced, only materials which meet the stormwater programme's filter specifications should be used. There is research being done with alternative filter media such as compost, zeolite, fly ash, activated carbon, alum, and so on. If the ARC allows or specifies an alternative filter media as a replacement, this should be documented in the inspection and owner's files as a departure from the approved plans.

Vandalism

As with all stormwater management facilities, there is always the potential for vandalism. This can include damage to the practice itself, theft of practice components or illegal dumping of waste products such as waste oil. Planning is essential in order to enable prompt remedial action.

A primary method to reduce vandalism is a community education program explaining stormwater contaminant generation, the importance of stormwater practices such as filter systems and the need to limit contaminant entry into BMPs. One component of this education program could be stenciling of the inlets to the filter. This may prevent some misuse resulting from ignorance of the facility's purpose.

Other maintenance concerns such as scour, leakage, spalling of concrete or cracks in concrete and grates need to be addressed when they are discovered. If the normally wet sedimentation chambers become dry, there is leakage, and the leakage must be stopped for the facility to function correctly. If the leaking area cannot be identified, a dye test may be necessary to track the flow of water in the leaking chamber. In addition, concrete will deteriorate over time, especially if subject to live loads. The concrete must be routinely inspected, and repaired when necessary.

7.7.2 Rain gardens

Rain gardens treat runoff by filtering it through vegetation and then passing it vertically through an organic soil which filters the runoff. Besides vegetative filtration, treatment may, if designed for, rely upon infiltration of runoff into underlying soils or to an underdrain.

Therefore, maintenance is primarily concerned with:

> Maintenance of flow to and through the biofilter
> Maintaining planted vegetation and preventing undesired overgrowth vegetation from taking over the area
> Removal of accumulated sediments
> Debris removal

Vegetation

Vegetation enhances rain garden performance for stormwater treatment and then requires close attention. Maintenance includes fertilising plants, removing noxious plants or weeds, re-establishing plants that die and maintaining mulch cover.

Regular inspections by the responsible entity (TA, ARC, maintenance organisation) must be done to ensure that the desired vegetation remains and is not overtaken by invasive undesirable plants. In some situations the replacement of the planted vegetation by a volunteer species may be beneficial, but only if the invasive species provides equal or increased water quality benefits and is accepted by the owners of the site.

Sediment

Sediments accumulate in rain gardens and their removal may be the most expensive aspect of rain garden maintenance. Removal should occur when surface ponding lasts significantly longer than the one day drain time, which indicates surface clogging. When sediments are to be removed, it is essential to restore the vegetation and soil conditions to the originally constructed condition. Sediment removal will necessitate disturbance of the vegetation, so steps will have to be taken to re-establish the vegetation upon completion of sediment removal. Erosion control in the contributing drainage area also will be necessary to prevent scour and excessive sedimentation in the rain garden until there is once again a dense stand of vegetation.

Sediment may also impede effective performance of a rain garden by clogging the soil surface and preventing design storms from being treated. If stormwater backs up into the upstream drainage area, overflow may occur and bypass the treatment area.

Debris

Similar to other types of practices, debris removal is an ongoing maintenance function at all rain garden systems. Debris, if not removed, can block inlets or outlets, and can be unsightly if located in a visible location. Inspection and removal of debris should be done on a monthly basis, with debris also removed whenever it is observed on site.

Just as it is important to know when a rain garden needs to be maintained, it is important to know when maintenance does not have to be done. The original plan for the site provides the best information at that time on the design and construction of the rain garden. Over time the facility may change in appearance and function. These changes may not necessarily be bad. Having a knowledgeable inspector conduct regular inspections may be one way to allow a rain garden to evolve into an improved facility with reduced maintenance costs.

7.8 Case studies

7.8.1 Case study 1 - sand filter

A sand filter is to be constructed for a 2000 m^2 carpark. Being a carpark, the impervious surface is 100% of the total area.

2-year 24-hour rainfall = 75 mm

1. Water quality storm extrapolation 75 mm for 2-year, 24 hour storm = 25 mm (75/3)
2. From TP 108, the required water quality volume - WQV = 41.4 m^3
3. Live storage provide = (0.37)(41.4) = 15.3 m^3
4. Surface area of filter

$$A_f = \frac{I_a H d_f}{k(h+d_f)t_f} = \frac{(41.4)(0.4)}{1(0.5+0.4)(2)} = 9.2\ m^2$$

5. Sedimentation area = 9.2/4 = 2.3 m^2

7.8.2 Case study 2 - rain garden

A rain garden is to be constructed on a residential property that is located in Kumeu. The total catchment draining to the rain garden is 1000 square metres of which 200 square metres is impervious surface.

1. Water quality storm extrapolation 81 mm of rainfall for 2 year, 24 hour storm = 27 mm
2. From TP 108, calculated separately, the required water quality volume - WQV = 8.01 m^3
3. Live storage to be provided = (0.4)(8.01)

3.

$$A_f = \frac{(WQV)(d_f)}{k(h+d_f)(t_f)}$$

$A_f = (8.01\ m^3)(1m)/(0.3\ m/day)(0.11m+1m)(1day)$
$A_f = 24.0\ m^2$

7.9 Bibliography

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Filtration system
Inspection forms
Construction inspection forms

Auckland Regional Council TE RAUHITANGA TAIAO	**STORMWATER COMPLIANCE INSPECTION ADVICE** (Under Section 332 of the Resource Management Act 1991)	Investigating Officer:
		Date:
		Time:
		Weather: Rainfall over previous 2-3 days?
		Person contacted during visit:
		Page 1 of 2

Site Name:		File No:	
Consent Holder:		Consent No:	
Engineer:		Catchment:	

FILTRATION FACILITY OPERATION & CONSTRUCTION INSPECTION CHECKLIST	: 9	Needs immediate attention Not Applicable	V	Okay	;	Clarification Required

Filtration Facility Components:

Items Inspected	Checked		Satisfactory	Unsatisfactory		Checked		Satisfactory	Unsatisfactory
Pre-construction	Y	N			**Completed Facility Components**	Y	N		
1. Runoff diverted					13. 24 hour water filled test (if applicable)				
2. Facility area cleared									
3. Facility location staked out					14. Contributing area stabilised				
Excavation					15. Filter material per specification				
4. Size and Location									
5. Side slopes stable					16. Underdrains installed to grade				
6. Foundation cleared of debris									
7. Foundation area compacted					**Final Inspection**				
Structural Components					17. Dimensions				
8. Dimensions and materials					18. Structural Components				
9. Forms adequately sized					19. Proper outlets				
10. Concrete meets standards					20. Effective site stabilisation				
11. Prefabricated joints sealed									
12. Underdrains (size, materials)									

OFFICERS REMARKS:

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ACTION TO BE TAKEN:

No action necessary. Continue routine inspections? Y / N

Correct noted site deficiencies by ____

1st Notice: ____

2nd Notice: ____

Submit plan modifications as noted in written comments by ________________________________

Notice to Comply issued ____

Final inspection, project completed ____

Officers signature: ______________________________

Consent Holder/Engineer/Agent's signature: ______________________________

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Auckland Regional Council TE RAUHITANGA TAIAO	**STORMWATER COMPLIANCE INSPECTION ADVICE** (Under Section 332 of the Resource Management Act 1991)	Investigating Officer: Date: Time: Weather: Rainfall over previous 2-3 days? Person contacted during visit: Page 1 of 2

Site Name:		File No:	
Consent Holder:		Consent No:	
Engineer:		Catchment:	

RAIN GARDEN CONSTRUCTION INSPECTION FORM	: 9	Needs immediate attention Not Applicable	V	Okay	;	Clarification Required

Rain Garden Construction Components:

Items Inspected	Checked		Satisfactory	Unsatisfactory	STRUCTURAL COMPONENTS	Checked		Satisfactory	Unsatisfactory
PRE-CONSTRUCTION					11. Inflow & outlets installed correctly	Y	N		
1. Runoff diverted	Y	N			12. Overflow system installed correctly	Y	N		
2. Facility area cleared	Y	N			13. Pretreatment devices installed	Y	N		
3. Facility location staked out	Y	N			**VEGETATION**				
4. Contributing drainage are stabilised	Y	N			11. Complies with planting specification	Y	N		
EXCAVATION					12. Topsoil adequate in composition & placement	Y	N		
5. Size & location	Y	N							
6. Excavated to appropriate grade	Y	N			13. Mulch laid	Y	N		
7. Appropriate liners placed as required	Y	N			**FINAL INSPECTION**				
UNDERDRAINS & FILTER MEDIA					14. Dimensions	Y	N		
8. Perforated underdrain installed correctly	Y	N			15. Proper outlet	Y	N		
					16. Effective stand of vegetation & stabilisation	Y	N		
9. Storm drain system installed & connected	Y	N			17. Construction generated sediments removed	Y	N		
10. Gravel, sand, & planting soil back backfilled	Y	N							

OFFICERS REMARKS:

ACTION TO BE TAKEN:

No action necessary. Continue routine inspections? Y / N

Correct noted site deficiencies by ______________________________

1st Notice: ______________________________

2nd Notice: ______________________________

Submit plan modifications as noted in written comments by ______________________________

Notice to Comply issued ______________________________

Final inspection, project completed ______________________________

Officers signature: ______________________________

Consent Holder/Engineer/Agent's signature: ______________________________

Filtration system Inspection forms
Operation and maintenance

Auckland Regional Council TE RAUHITANGA TAIAO	**STORMWATER COMPLIANCE INSPECTION ADVICE** (**Under Section 332 of the Resource Management Act 1991)**	Investigating Officer: Date: Time: Weather: Rainfall over previous 2-3 days? Person contacted during visit: Page 1 of 2

Site Name:		File No:	
Consent Holder:		Consent No:	
Engineer:		Catchment:	

FILTRATION FACILITY OPERATION & MAINTENANCE INSPECTION CHECKLIST	: 9	Needs immediate attention Not Applicable	V	Okay	;	Clarification Required

"As builts"	Required Y / N	Available Y / N	Adequate Y / N	Approx. check to verify vol(s). Y / N
"Operation & Maintenance Plan"	Required Y / N	Available Y / N	Adequate Y / N	
"Planting Plan"	Required Y / N	Available Y / N	Adequate Y / N	

Filtration Facility Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
DEBRIS CLEANOUT	Y	N	Y	N	**6M**	**SEDIMENT DEPOSITION**	Y	N	Y	N	**A**
1. Contributing areas clean of debris						11. Filtration chamber clean of sediment					
2. Filtration facility clean of debris						12. Water chambers not more than ½ full of Sediments					
3. Inlets and outlets clear of debris						**STRUCTURAL COMPONENTS**					**A**
VEGETATION					**3M**	13. No evidence of structural deterioration					
4. Contributing drainage area stabilised						14. Any grates are in good condition					
5. No evidence of erosion						15. No evidence of spalling or cracking of structural parts					
6. Area mowed and clippings removed						**OUTLETS / OVERFLOW SPILLWAY**					**A**
OIL AND GREASE					**3-6M**	16. Good condition, no need for repair					
7. No evidence of filter surface clogging						17. No evidence of erosion (if draining into a natural channel)					
8. Activities in drainage area minimise oil & grease entry						**OVERALL FUNCTION OF FACILITY**					**A**
WATER RETENTION WHERE REQUIRED					**6M**	18. No evidence of flow bypassing facility					
9. Water holding chambers at normal pool depth?						19. No noticeable odours outside facility					
10. No evidence of leakage											

Inspection Frequency Key **A = Annual, M = Monthly, 3M = Three monthly, 6M = Six Monthly, 3-6M = Three to Six Monthly**

Warning: If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

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OFFICERS REMARKS:

OVERALL CONDITION OF FACILITY:

In accordance with approved design plans? Y / N In accordance with As Built plans? Y / N

Maintenance required as detailed above? Y / N Compliance with other consent conditions? Y / N

Comments: ____

Dates by which maintenance must be completed: / /

Dates by which outstanding information as per consent conditions is required by: / /

Officers signature: ________________________________

Consent Holder/Engineer/Agent's signature: ______________________________

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Auckland Regional Council TE RAUHITANGA TAIAO	**STORMWATER COMPLIANCE INSPECTION ADVICE** (Under Section 332 of the Resource Management Act 1991)	Investigating Officer: Date: Time: Weather: Rainfall over previous 2-3 days? Person contacted during visit: Page 1 of 2

Site Name:		File No:	
Consent Holder:		Consent No:	
Engineer:		Catchment:	

RAIN GARDEN MAINTENANCE INSPECTION CHECKLIST	:	Needs immediate attention	V	Okay	;	Clarification Required
	9	Not Applicable				

"As builts"	Required Y / N	Available Y / N	Adequate Y / N	Approx. check to verify vol(s). Y / N
"Operation & Maintenance Plan"	Required Y / N	Available Y / N	Adequate Y / N	
"Planting Plan"	Required Y / N	Available Y / N	Adequate Y / N	

Rain Garden Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
DEBRIS CLEANOUT	Y	N	Y	N	**M**	**OUTLETS/OVERFLOW SPILLWAY**	Y	N	Y	N	**A, AMS**
1. Rain gardens and contributing areas clean of debris						13. Good condition, no need for repair					
2. No dumping of yard wastes into rain garden						14. No evidence of erosion					
3. Litter (branches, etc) have been removed						15. No evidence of any blockages					
VEGETATION					**M**	**INTEGRITY OF BIOFILTER**					**A**
4. Planting height not less than design water depth						16. Rain garden has not been blocked or filled inappropriately					
5. Fertilised per specifications						17. Mulch layer still in place					
6. No evidence of erosion						18. Noxious plants or weeds removed					
7. Is plant composition still according to approved plans											
8. No placement of inappropriate plants											
DEWATERING AND SEDIMENTATION											
9. Rain garden dewaters between storms											
10. No evidence of standing water											
11. No evidence of surface clogging											
12. Sediments should not be > than 20% of swale design depth											

Inspection Frequency Key A = Annual, M = Monthly, AMS = After Major Storm

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OFFICERS REMARKS:

OVERALL CONDITION OF FACILITY:

In accordance with approved design plans? Y / N In accordance with As Built plans? Y / N

Maintenance required as detailed above? Y / N Compliance with other consent conditions? Y / N

Comments: ____

Dates by which maintenance must be completed: / /

Dates by which outstanding information as per consent conditions is required by: / /

Officers signature: _______________________________

Consent Holder/Engineer/Agent's signature: _____________________________

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