Chapter 8
Infiltration design, construction and maintenance

8.1 Introduction

Infiltration practices direct urban stormwater away from surface runoff paths and into the underlying soil. In contrast to surface detention methods, which are treatment or delay mechanisms that ultimately discharge all runoff to streams, infiltration diverts runoff into groundwater. Of all the traditional stormwater management practices, infiltration is one of the few practices (together with revegetation and rain tanks) that reduce the overall volume of stormwater being discharged.

Infiltration practices comprise a suite of different practices, including:

- trenches
- dry wells
- modular block porous pavement
- to a certain extent, rain gardens, swales and filter strips that are considered separately.

Infiltration practices are used for three primary purposes:

- reducing the total volume of stormwater runoff,
- reducing the contaminant loadings downstream, and
- low streamflow augmentation.

The use of infiltration practices for water quality treatment must be considered with caution. Infiltration practices are much more sensitive to clogging than are ponds or filters. As much as possible, sediment should be prevented from entering these practices.

Infiltration trenches receive runoff in a shallow excavated trench that has been backfilled with stone to form a below-grade reservoir. Water then enters the underlying subsoil according to its infiltration rate.

Dry wells function in a similar fashion with the excavated subgrade being filled with stone and relying upon the void spaces to provide for stormwater storage until the runoff infiltrates into the soil.

Modular block porous pavement permits precipitation to drain through paving blocks with a pervious opening. Paving blocks are appropriate only for areas with very light or no traffic or for parking pads. They are laid on a gravel subgrade and filled with sand or sandy loam turf but can also be used with grass in the voids which may require irrigation and lawn care during the summer months.

Plate 8-1: Infiltration trench treating roadway runoff

8.2 Water quality performance

Infiltration systems do not have underdrains, so the design and soil characteristics determine how much runoff is captured and how efficient the treatment.

Among the various runoff treatment options, only soil infiltration systems have been reliable in removing soluble phosphorus. This result likely applies to other relatively soluble contaminants as well. Dissolved contaminant reduction is incomplete but is still higher than with any other treatment method. Table 8-1 estimates runoff contaminant removals.

Table 8-1
Long-term contaminant removal rates

Contaminant	Sized based on: Runoff from 25 mm rainfall	Sized based on: 2-year storm runoff volume
Total suspended solids	90	99
Total Phosphorus	60-70	65-75
Total Nitrogen	55-60	60-70
Metals	85-90	95-99
BOD	80	90
Bacteria	90	98

With capture of the runoff from taking 1/3 of the 2 year-24 hour rainfall as per TP 108, approximately 80 percent of the total runoff volume would be captured, depending on the soil and the amount of impervious area. If it were possible to apply infiltration on a widespread basis in a catchment, summer stream baseflows would remain within approximately 90 percent of predevelopment conditions.

8.3 Applicability

Soil permeability is the most critical consideration for the suitability of infiltration practices. Practices are generally built in the native soil; but when this is inappropriate, a soil system can be constructed with media such as sand, peat, or a combination. Table 8-2 provide information on the suitability of various soils for infiltration. Infiltration practices normally convey most runoff directly into the soil to eventually enter the groundwater. Constructed soil systems usually require underdrains.

Table 8-2
Infiltration rate from soil textural class

Texture class	Minimum infiltration rate (f) in mm/hr
Sand	210
Loamy sand	61
Sandy loam	26
Loam	13
Silt loam	7
Sandy clay loam	4.5
Minimum allowable rate - 3mm/hr	
Clay loam	2.5
Silty clay loam	1.5
Sandy clay	1.3
Silty clay	1.0
Clay	0.5

The next most crucial considerations for the suitability of infiltration practices, are:

- avoiding clogging
- avoiding potential to contaminante groundwater.

Infiltration practices should be constructed in medium textured soils. They are generally unsuitable for clay because of restricted percolation and for gravel and coarse sands because of the risk of groundwater contamination (unless effective pretreatment is provided).

Plate 8-2: Infiltration trench with a swale for pretreatment

Any impermeable soil layer close to the surface may need to be penetrated. If the layer is too thick, underdrains may be required. As a minimum measure to prevent clogging, infiltration trenches should require a pretreatment device to settle larger solids and reject runoff from eroding construction sites. Infiltration dry wells accept only roof runoff so pretreatment is not expected, Pretreatment is not possible for modular paving either.

The following guidance is applicable to design and implementation of all infiltration practices.

<u>8.3.1 Site characteristics</u>

Site characteristics relate to whether the infiltration practice is intended for quantity control alone or for both quality and quantity control. While quantity control is best achieved with a rapid percolation rate, this rate could be too fast to provide sufficient contact with the soil for contaminant capture, if the groundwater table is relatively close to the surface.

Consequently, the ARC:

- specifies a maximum and a minimum percolation rate to protect groundwater and attain contaminant capture objectives. Infiltration rates greater than 1 m/hr may indicate a direct link to a very permeable aquifer while slower than 3 mm/hour is too slow
- requires runoff pretreatment to meet water quality objectives before the pretreated runoff is infiltrated for quantity control or base streamflow augmentation

The following criteria aims to reduce the substantial risks of failure and groundwater contamination, and to achieve the desired urban stormwater management benefits:

- The invert of the infiltration practice should be at least one metre from the seasonal high water table, bedrock, or relatively impermeable soil layer
- The percolation rate should be at least 3 mm/hr.
- The soil should not have more than 30 percent clay or more than 40 percent clay and silt combined
- If the infiltration practice is to function for primary water quality treatment, infiltration rates must not be greater than that given for sand. Injection into basalts must be preceeded by water quality treatment prior to injection
- Infiltration practices must not be constructed in fill material
- Infiltration practices must not be constructed on slopes exceeding 15 percent

- > Catchments draining to infiltration practices must not exceed four hectares, but preferably not more than two hectares
- > Infiltration basins, while listed as a practice in Chapter 4, are not encouraged for use unless approved on a case-by-case basis because their long term historical performance has not been good, mainly as a result of surface clogging

8.3.2 Pretreatment

The use of vegetative filters as a pretreatment BMP to improve long term performance of infiltration practices cannot be stressed enough.

Of primary importance to the long term function of infiltration practices is the need to keep all contributing catchment areas stablised. Sediment loadings into the practice must be kept to a minimum. All inspections of these practices must include inspection for site stabilisation. All areas draining to the infiltration practice must be stabilised or premature clogging of the facility will result. The infiltration practice checklists recommend annual inspections for sediment accumulation. The frequency of actual maintenance activities depend on loadings from contributing catchment areas.

8.4 Objectives

Because infiltration practices are the only traditional stormwater management practice that reduces the total volume of runoff, objectives relate to:

- > peak flow reduction
- > contaminant removal
- > low stream flow augmentation

Due to the sensitivity of infiltration practices to clogging, they are best utilised to augment low stream baseflow, with pretreatment to reduce contaminant loads so that the cleaner water infiltrates to maintain groundwater levels and maintain low stream flow.

If long term responsible maintenance can be assured, infiltration is appropriate as a water quality treatment practice

8.5 Design approach

There are a number of items that should be considered when infiltration practices are used.

8.5.1 Site characteristics

A site characterisation must be done to determine the following:

- > Topography within 150 metres of the proposed infiltration practice
- > Site use
- > Location of any water supply wells within 150 metres of the proposed infiltration practice
- > Local site geology to gain understanding of soil and rock units likely to be encountered, the groundwater regime and geologic history of the site.
- > For infiltration trenches, at least one test pit or test hole per 15 metres of trench length and 2.5 times deeper than the invert depth of the trench.
- > For dry wells, at least one test pit for each dry well. The test pit should be 2.5 times deeper than the invert depth of the dry well.
- > For modular porous pavement, there must be one test pit per 500 m^2 of infiltrating surface and the test pit should be 2.5 times deeper than the invert depth of the filter bed.
- > The depth, number of test holes or test pits and sampling should be increased, if, in the judgement of

the geotechnical engineer, the conditions are highly variable and increasing the depth or the number of explorations is necessary to accurately estimate the performance of the infiltration practice. In addition, the number of explorations may be decreased if, in the opinion of the geotechnical engineer, the conditions are relatively uniform and the borings/test pits omitted will not influence the design.

> Detailed logs for each test pit or test hole must be prepared along with a map showing the location of the test pits or holes. Logs must include at a minimum, depth of pit or hole, soil description, depth to water, depth to bedrock or impermeable layer, and presence of stratification.

> Install ground water monitoring wells (unless the highest ground water level is far below the infiltration practice) to monitor the seasonal ground water levels at the site.

8.5.2 Procedure for conducting an infiltration test

The required approach consists of a relatively large-scale infiltration test to better approximate infiltration rates for design of infiltration practices. This approach reduces some of the scale errors associated with relatively small-scale double ring infiltrometre or "stove pipe" infiltration tests.

1. Excavate the test pit at least 1.5 metres below the bottom of the proposed infiltration practice. Lay back the slopes sufficiently to avoid caving and erosion during the test.
2. The surface area of the bottom of the test pit shall be at least 1 square metre.
3. Install a vertical minimum 1.5 metre long measuring rod marked in 10 mm increments in the centre of the pit bottom.
4. Use a rigid 150 mm pipe with a splash plate on the bottom to convey water to the bottom of the pit and reduce side-wall erosion or excessive disturbance of the ponded bottom.
5. Add water to the pit at a rate that will maintain a water level of between 1 - 1.25 metres above the bottom of the pit. A rotametre can be used to measure the flow rate into the pit.
6. Every 15-30 minutes, record the cumulative volume and instantaneous flow rate in litres per minute necessary to maintain the water level at the same point on the measuring rod.
7. Add water to the pit for a minimum of 17 hours or until one hour after the flow rate into the pit has stabilised (constant flow rate) while maintaining the same ponded level.
8. After 17 hours or one hour after the flow rate has stabilised, turn off the water and record the rate of infiltration in mm/hour from the measuring rod data, until the pit is empty.
9. Based on partial clogging, reduce the derived infiltration rate by a factor of 0.5 and reduce this reduced rate in the design calculations.

8.5.3 Site data analysis

> Determine representative site infiltration rate from soil test results and the stratification identified during the site investigation.

> Determine the textural class from the U.S. Department of Agriculture (USDA) textural triangle in Figure 8-1. Sand is defined to have a diameter between 2000 um and 50 um while clay has a diameter of less than 2 um. Once the texural class has been determined, the infiltration rates can be found.

> Determine infiltration rates by taking direct in-situ measurements of soil infiltration rates.

> Long term infiltration rates greater than one metre per hour (as per steps 8 and 9 above) are considered too

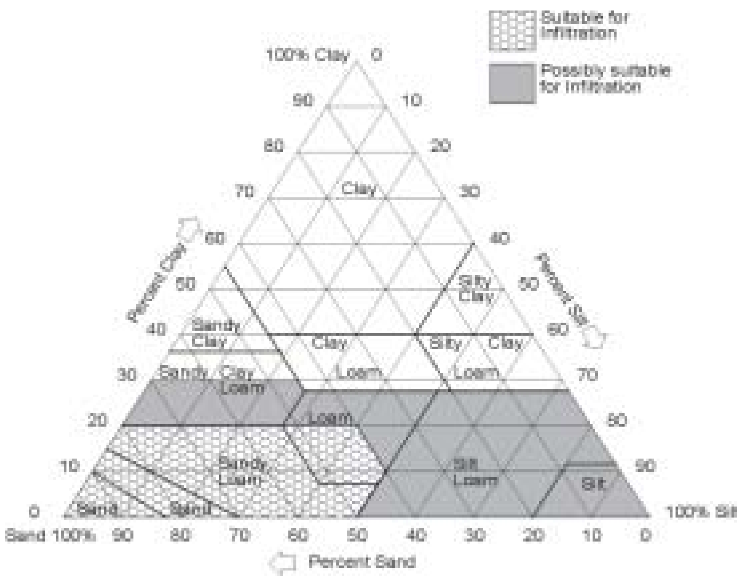


Figure 8-1
USDA. soil textural triangle

rapid to allow significant water quality treatment to occur and pretreatment will have to be provided.

8.6 Design procedure

This approach relies on the use of Darcy's Law, which expresses flow through a porous medium. The resulting equations for the surface area (A_s) and infiltration practice volume (V_t) are:

1. Determine water quality storm - take 1/3 of the 2 year-24 hour rainfall at the site location using the separated approach for pervious and impervious surfaces detailed in Chapter 3, Section 3.5.
2. Use TP 108 to calculate the water quality volume
3. Size the practice area to allow complete infiltration within 48 hours, including rainfall falling directly onto the practice. To do this, use the following equation:

$$A_s = \frac{WQV}{((f_d)(i)(t) - p)}$$

where:

A_s = Surface area of practice (m^2)
WQV = Water Quality Volume (m^3)
f_d = Percolation rate (m/hour); measured rate multiplied by 0.5 for factor of safety
i = Hydraulic gradient (m/m) assumed to be 1
t = Time to drain from full condition (hours) - maximum time 48 hours
p = Rainfall depth for water quality storm (m)

4. Size the practice depth to provide storage for 37% of the volume required to infiltrate.

$$V_t = 0.37(WQV + pA)/V_r$$

where:

V = Practice volume required with aggregate added
V_r = Void space ratio of stone, normally .35 (scoria is rated at .50)

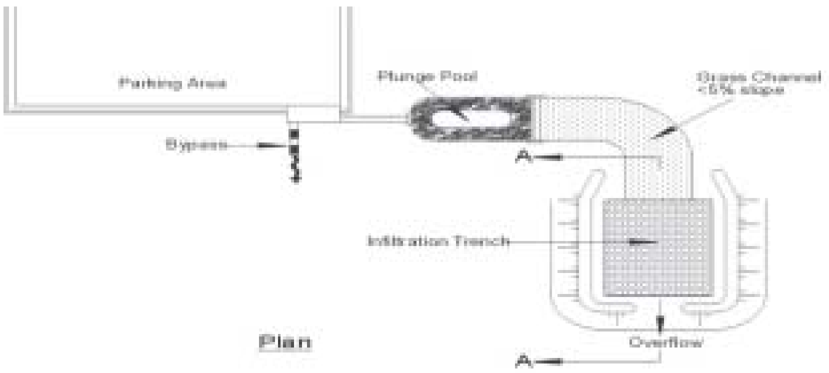


Figure 8-2
Infiltration trench standard detail and shown with a pretreatment swale

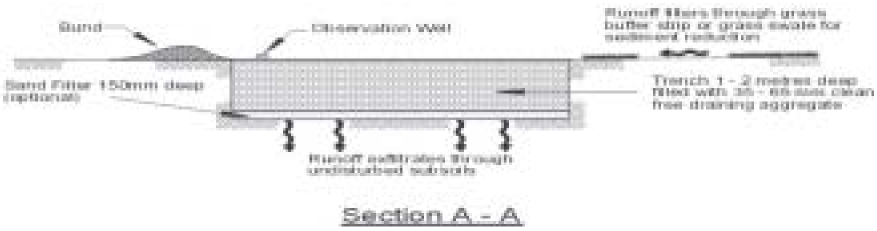


Figure 8-3
Typical application for an infiltration trench

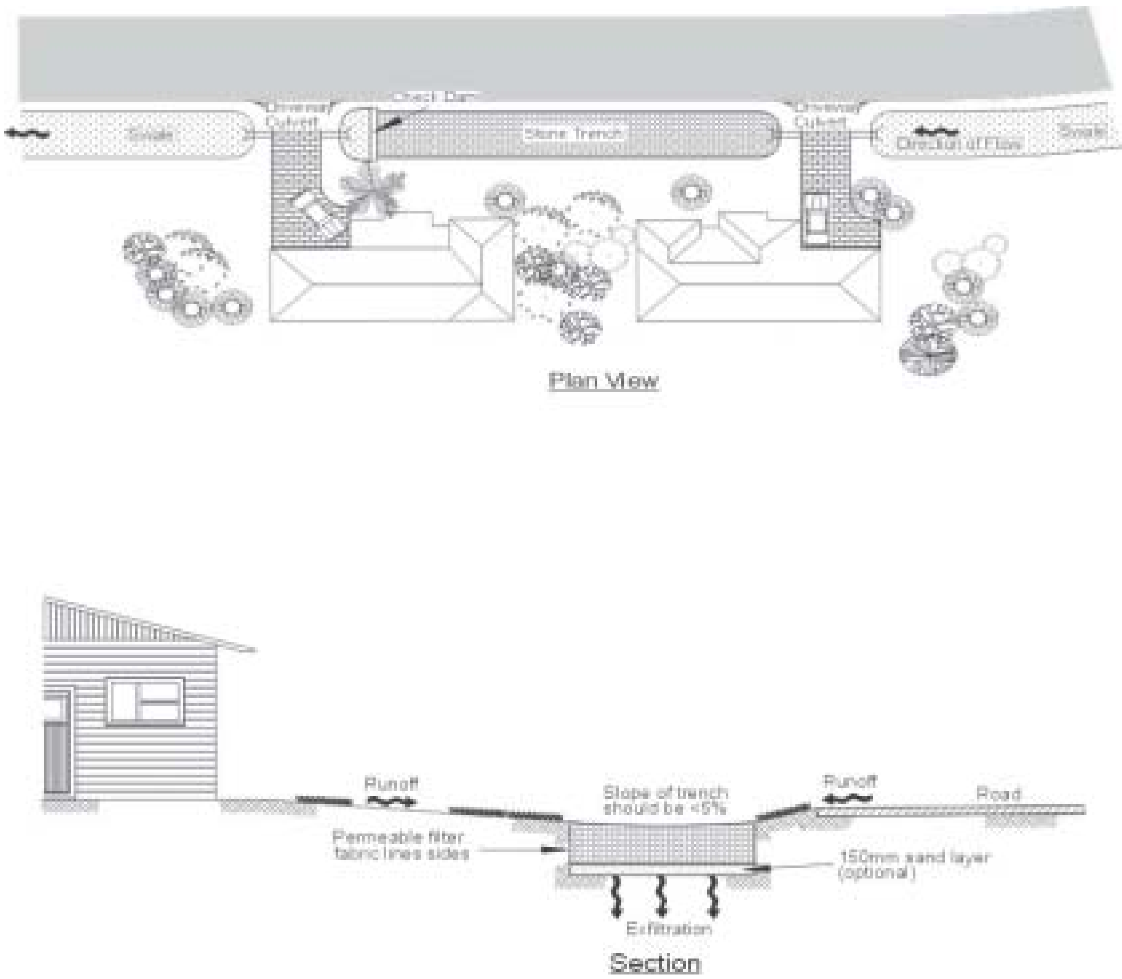
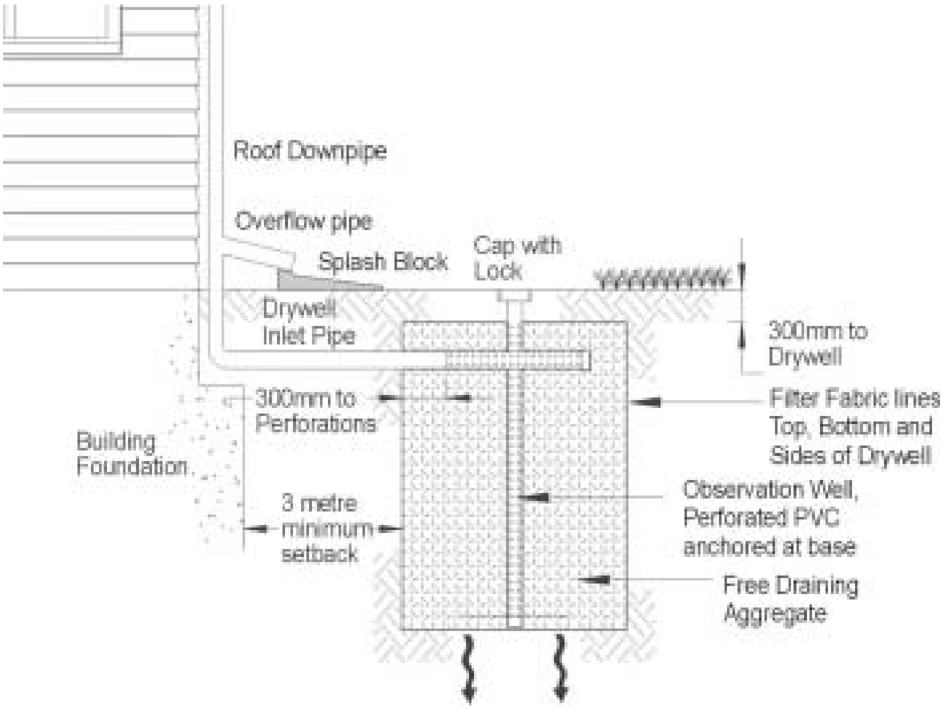


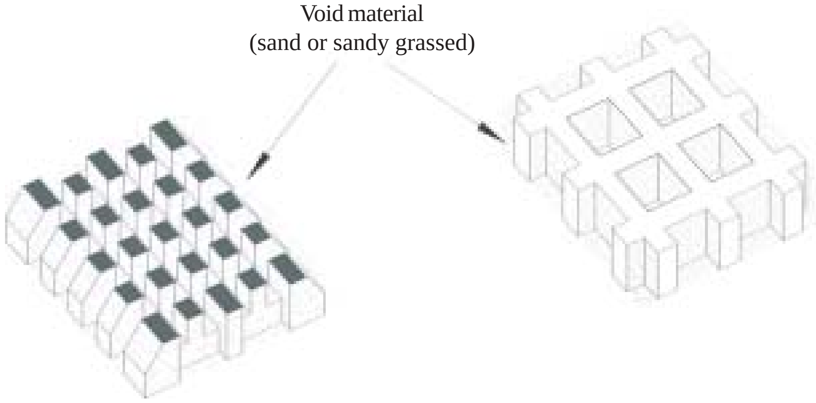
Figure 8-4
Typical detail for an infiltration drywell



Standard details for trenches, dry wells, and modular pavements are provided in Figures 8-2, 8-3, 8-4, 8-5, and 8-6.

As can be seen, infiltration is assumed to occur only out of the bottom of the practice and not the sides. With concerns about partial clogging of infiltration practices and the limited extent of exfiltration that can be expected out of the side walls, it is appropriate to use bottom area only in calculations.

Figure 8-5
Examples of modular paving



8.7 Construction

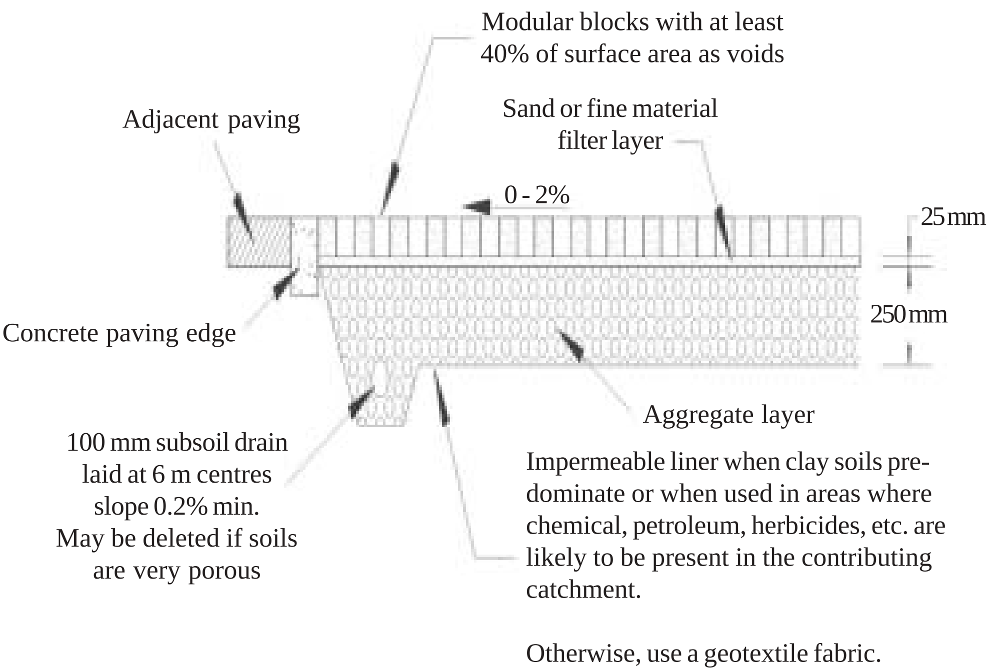
The proper construction of infiltration practices is very important if long term performance is to be expected. These practices are very susceptible to clogging by site generated sediments. It is vital to prevent sediment-laden runoff from construction to enter the practice. There is also a time period after site stabilisation during which excess sediment loads still are transported downstream from revegetated areas before they build up organic material and higher plant density. This is why pretreatment of runoff before it enters the infiltration practice is needed.

The following general guidelines apply to the construction phase of all infiltration practices.

1. Infiltration practices should not be constructed until after permanent stabilisation and permanent erosion control of areas draining to the facilities has been accomplished.

2. Infiltration practices should not be used for temporary sediment ponding during construction. If an infiltration practice must be used for sediment control, the bottom of the practice should be placed at

Figure 8-6
Standard detail for modular paving



least 300 mm above the design bottom elevation. If the practice develops a normal pool of water due to bottom clogging by finer sediments, it should be dewatered and allowed to dry before excavation to final design bottom elevations. If the material is removed while wet, there will be the potential for the water to become turbid and for finer sediments to remain in the water column. This will reduce soil permeability at the final bottom elevation.

3. Other than infiltration dry wells and modular block porous pavement, all infiltration practices shall be designed so that the stormwater runoff first passes through a pretreatment system to remove suspended solids before the runoff enters the infiltration practice.

4. The location of infiltration practices should be clearly marked at the site to prevent vehicle traffic across this area. The traffic will compact the soils and reduce soil infiltration rates.

8.7.1 Characteristics of individual infiltration practices that warrant specific attention

Although grouped together due to their common goals, infiltration practices also are very different in their construction and site utilisation. Consequently, they will be discussed separately to provide specific guidance to an inspector.

Infiltration trenches

Infiltration trenches tend to to be deep, with a large length to width ratio. Filled with stone, scoria, gravel or sand aggregate, they are generally used in areas where space available for stormwater management is limited. Runoff is stored in the voids of the aggregate material, which are normally is between 30 and 40% of the total volume. Scoria has a higher void space ratio of approximately 50%. The stored runoff then exits the trench through the side and bottom walls into the soil profile. Construction inspection should include the following items:

A. Verify the infiltration trench dimensions and location on site before trench construction. Verify distance to foundations, septic systems, wells, and so forth.
B. Excavate the trench using a backhoe or a ladder type trencher. Front-end loaders or bulldozers should not be used, as their blades can seal the infiltration soil surface. Place excavated materials far enough away from the sides of the excavated area, in order to minimise the risk of sidewall cave-ins and prevent migration of the soils back into the trench after the stone, gravel, or sand aggregate has been placed.
C. Inspect the trench bottom and side walls and remove objectionable material such as tree roots that protrude and could possibly puncture or tear the filter fabric.
D. Line the sides and bottom with filter fabric. The side wall fabric will prevent migration of soil particles from the side walls into the trench. The bottom fabric will prevent sealing of the aggregate soil interface.
E. Lay the fabric with sufficient length to overlap the top of the trench. Covering the trench after

Plate 8-3: Infiltration trench under construction showing observation well, footplate, and fabric

placement of the aggregate will protect the completed practice by preventing excess site sediment from entering it.

F. Install an observation well in the aggregate so that future inspections can determine whether the practice is functioning as designed. The observation well should consist of a perforated PVC pipe, 100 - 200 mm in diameter and have a footplate and a cap. The footplate will prevent the entire observation well from lifting up when the cap is removed during future inspections.

G. Inspect the aggregate material before placement to ensure that it is clean and free of debris. The size of the material should be as specified on the approved plans.

H. Upon completion of trench construction, the adjacent areas should be vegetatively stabilised. Direct the trench overflow to a non-erosive outlet channel.

I. Install a pretreatment device such as a biofiltration swale or other approved method before the runoff enters the trench in order to remove suspended solids.

J. Cap the observation well and measure and record the initial depth measured and noted on the inspection checklist.

Infiltration drywells

Similar to infiltration trenches, drywells are excavated areas that are filled with an aggregate material. The main difference is that drywells accept runoff only from roofs. They therefore receive lower loadings of suspended solids loadings than that expected from ground surface runoff.

Plate 8-4: Infiltration dry well

The major concern with infiltration drywells is that, by serving roof areas, they must be located in the vicinity of building foundations. Careful consideration must be given to the correct placement of drywells so that building foundation problems do not result. A big advantage of a drywell over other runoff controls is that the drywell is underground and does not represent a loss of site area to the land developer. Construction inspection should include the following items:

A. Verify the infiltration drywell dimensions and location onsite before drywell construction. Verify distance to foundations, septic systems, wells, and so forth.

B. Excavate the drywell using a backhoe or ladder type trencher. Front-end loaders or bulldozers should not be used as the equipment blades may cause excessive compaction of the drywell bottom.

C. Place excavated materials a sufficient distance from the sides of the excavated area to minimise the risk of sidewall cave-ins and to prevent migration of the soils back into the trench after the stone, gravel, or sand aggregate has been placed.

D. Inspect the drywell bottom and side walls and remove objectionable material such as tree roots that protrude and could possibly puncture or tear the filter fabric.Schedule the work so that the drywell can be covered in one day to prevent wind-blown or water carried suspended solids from entering the drywell.

E. Line the sides and bottom with filter fabric. The side fabric placement will prevent migration of soil particles from the side walls into the trench. The bottom filter fabric will prevent sealing of the aggregate soil interface.

F. Once the aggregated has been placed, place filter fabric over the drywell and final site grading should be done.

G. Install an observation well in the aggregate to allow future inspections to determine whether the practice is still functioning. The observation well should consist of a perforated PVC pipe, 100 - 200 mm in diameter and have a footplate and a cap. The footplate will prevent the entire observation well from lifting up when the cap is removed during future inspections.

H. Inspect the aggregate material before placement to ensure that it is clean and free of debris. The size of the material should be as specified on the approved plans.

I. Install a debris and grit trap consisting of fine-mesh screen covering the downspout (roof leader) to prevent objectionable materials from entering the aggregate subbase through the inflow pipe. Install roof gutter screens to protect gutters and grit traps from clogging due to wash-off of leaves, pine needles, etc. from the roof area.

J. Cap the observation well and measure and record the initial depth measured and noted on the inspection checklist.

Plate 8-5: Modular paving at the Auckland zoo

Modular block porous paving

These practices create road and parking lot surfaces that allow for stormwater runoff to travel through the surface into the ground. Under the porous surface, an aggregate material serves as a reservoir base for temporary storage of the runoff until the water infiltrates into the ground. Their best applications are in areas where there is a low volume of traffic or where overflow parking is needed on a periodic basis, and where subsoils have not been so compacted as to reduce the infiltration rate to below 3 mm/hr..

Lattice block is a modular unit which is generally placed in square sections. It is concrete with large void areas which are filled with a porous material, such as sand or pea gravel. Lattice block still should have filter course, reservoir course and filter fabric lining, prior to entry into the soil. Construction inspection should include the following items:

A. To help preserve the natural infiltration rate of the subgrade soils prior to excavation, prevent soil compaction of the infiltration paving area by heavy construction equipment. The area should be marked off and traffic kept off it to the greatest extent possible.

B. Verify the infiltration paving dimensions and location on site before construction. Verify distances to foundations, septic systems, wells, and so forth.

C. Carefully excavate the area of the paving to prevent excessive compaction of the soils during the subgrade preparation. All grading should be carried out using wide tracked equipment.

D. Once the subgrade has been reached, place filter fabric on the bottom. The type of fabric should be specified on the approved plans.

Plate 8-6: Example of a porous block parking area

E. Once the fabric has been placed, place the reservoir course to the design depth. This course should be clean, washed stone having a void ratio between 30 and 40%. Lay the reservoir course in 300 mm lifts and lightly compact it. Spread aggregate uniformly.

F. Place the aggregate filter on the reservoir course using clean washed stone ranging in size from 10 - 20 mm This stone provides a uniform base for the lattice course.

G. Never let sediments enter the infiltration paving construction area.

H. Lay the surface course. Fill the void areas of the lattice block with the appropriate specified material.

8.7.2 As-built plans

Where consent conditions require, there may be a requirement for an As-Built Plan to verify that construction was done in accordance with the approved consent.

The As-built plan should verify that:

1. Dimensions of the practice meet design dimensions
2. Filter fabric meets specifications
3. Aggregate material is sized as specified
4. Observation well is installed as required
5. Required pretreatment practice is in place
6. Contributing catchment is stabilised
7. Aggregate filter course is placed as required for modular paving
8. Porous surface course is installed properly for modular paving
9. Where appropriate, lattace area is backfilled correctly

8.8 Operation and maintenance

Maintenance issues are generally related to one of two major concerns:

- clogging
- standing water

Clogging of these practices can occur when sediments enter the facility and seal the soil surface, preventing infiltration of runoff. Clogging can also occur if excess oils and greases enter the practice, or from microorganism growth which results when water stands too long in the facility. Whatever the reason, clogging will cause failure of infiltration practices creating long term problems.

Infiltration practices must dry out between storm events to provide maximum stormwater management benefits. Clogging means less runoff is infiltrated and more goes into the overflow system on a more frequent basis. Clogging may also mean that water is permanently present in the facility, which can then become a mosquito breeding area.

Standing water can also result from seasonal high water tables or ground water mounding in the vicinity of the facility. If either of these problems occur, the practice's performance will depend on exfiltration out of the sides instead of the bottom.

Maintenance inspections must identify if there is standing water during a period of time when it hasn't rained. If so, then the cause must be determined whether clogging of the facility, seasonal water table conditions or ground water mounding. This analysis is crucial for determining the next steps. If clogging is the reason, maintenance activities will need to be performed to restore desired infiltration rates.

If the problem is caused by a high water table or mounding or persistent clogging, an entire new strategy will be needed to correct the problem. This could include conversion of the infiltration practice to a practice which includes a permanent pool of water such as a wet detention or constructed wetland system, or providing the practice with a structural outlet to prevent seasonal or permanent water pooling. If either of these options are necessary, the appropriate inspection and/or approval agency should be contacted to ensure approval of the modifications. In such cases, future inspections will be based on the modifications rather than maintaining expectations associated with the originally approved and constructed facility.

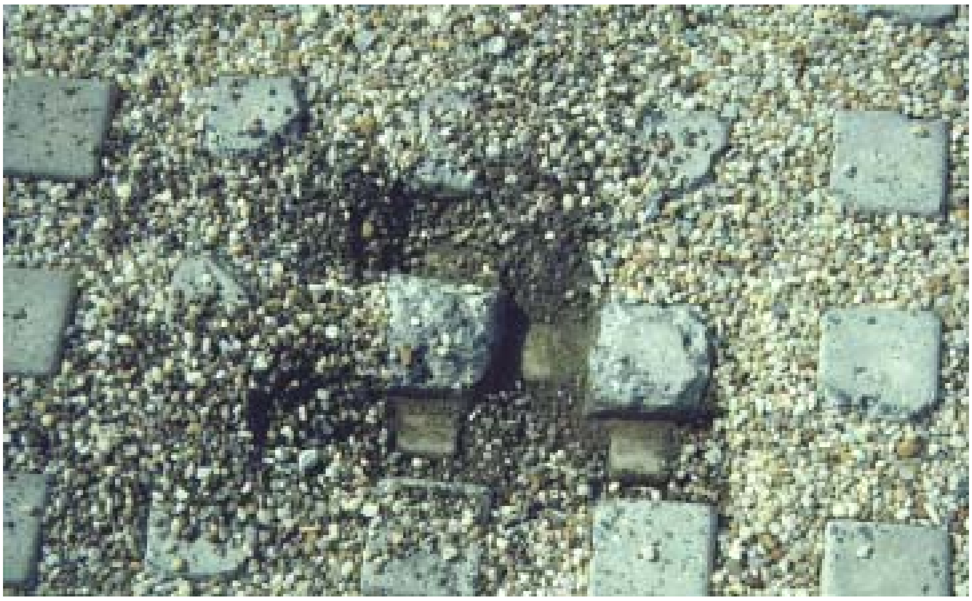


Plate 8-7: Modular paving with pea gravel filler

If the practice is totally clogged, correction is much more difficult. The practice should be drained and allowed to dry out before removing sediments. If sediment removal is attempted while water is standing in the practice, the finer sediments will become suspended and not be removed. These suspended sediments are responsible for the initial clogging of the practice, and their resuspension will last only until quiescent conditions allow for resettlement. The practice will never achieve the desired re-establishment of infiltration rates.

Safeguards should be installed during construction to reduce maintenance concerns. However, even with design and construction being sensitive to future maintenance, maintenance problems will occur as they do for all stormwater management practices. For example, to facilitate maintenance, rock filled infiltration trenches should be designed to have filter fabric placed approximately 300 mm below the surface of the practice. This fabric is a design point of failure which allows the underlying stone to remain clean. If standing water persists on the surface of the practice, the top 300 mm of stone should be removed and the filter fabric removed and replaced. This design prevents the need to replace the entire stone reservoir base.

Lattice block systems are unique. Pretreatment for reduced maintenance cannot be designed into them as for other infiltration practices by using biofiltration, fabrics or forebays. Design options to reduce maintenance for infiltration paving are predominantly limited to

- using them in areas of low traffic, where paving is still necessary
- specifying a certain frequency of inspection, infiltration rate verification and block removal and sediment cleanout..

Education is especially important in reducing maintenance requirements of infiltration paving practices. It is very important that owners are aware of the pervious nature of the paving surface. A common approval condition may be to require that signs be placed around the parking area to notify all users that the surface is pervious, and that sediment tracking needs to be minimised. Covenents also alert owners of the need for in-kind replacement of the pervious pavement, if needed.

Lattice block paving can include filter fabric under the blocks to facilitate future maintenance. When maintenance is necessary, the lattice block can be lifted up in individual sections, the filter fabric under the block replaced, and the blocks restored to their original places. However, some form of maintenance will probably be necessary on an annual basis.

8.9 Case study

The development is a 1/2 hectare commercial site that is 50% impervious and 50% grassed with a loam soil. The water quality storm is 27 mm of rainfall. The measured infiltration rate is 14 mm/hr. Use 1/2 of that rate for factor of safety = 7 mm/hr. Soil is a silt loam.

1. Water quality storm is 1/3 of the 2 year - 24 hour rainfall - in this case 27 mm of rainfall
2. Water quality volume is determined by use of TP 108: calculations for the post-development catchment give:
   Runoff depth from pervious areas = 4.4 mm
   Runoff volume from pervious areas = 11 m^3
   Runoff depth from impervious areas = 22.7 mm
   Runoff volume from impervious areas = 57 m^3
   Total runoff volume = 68 m^3 = WQV
3. Size the practice area

$$A_s = \frac{WQV}{((f_d)(i)(t) - p)} \qquad = 68\ m^3/\ ((.007\ m/hr)(1)(48\ hr) - .027\ m) = 220\ m^2$$

4. Size the storage volume

$$V_t = 0.37(WQV + pA)/V_r = 0.37((68\ m^3 + (.027\ m)(220\ m^2))/0.35 = 78\ m^3$$

The required minimum depth of trench is therefore 78 m^3/220 m^2 = 0.355 m

8.10 Bibliography

Ferguson, Bruce, Stormwater Infiltration, CRC Press, Inc., Boca Raton, Florida, U.S.A., 1994

Horner, R., Skupien, J., LIvingston, E., Shaver, E., Fundamentals of Urban Runoff Management: Technical and Institutional Issues, Terrene Institute, August, 1994.

Watershed Management Institute, Operation, Maintenance, & Management of Stormwater Management Systems, August, 1997.

Infiltration practice
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:	

SEDIMENT / STORMWATER MANAGEMENT DRY WELL CONSTRUCTION CHECKLIST	: 9	Needs immediate attention Not Applicable	V	Okay	;	Clarification Required

Pond Components:

Items Inspected	Checked		Satisfactory	Unsatisfactory		Checked		Satisfactory	Unsatisfactory
PRE-CONSTRUCTION					10. Clean / washed material	Y	N		
1. Runoff diverted	Y	N			11. Placed properly	Y	N		
2. Area stabilised	Y	N			**OBSERVATION WELL/ROOF LEADER**				
EXCAVATION									
3. Size & Location	Y	N			12. Pipe size	Y	N		
4. Side slope stable	Y	N			13. Removable cap/footplate	Y	N		
5. Soil Permeability	Y	N			14. Initial depth = _____m	Y	N		
6. Groundwater / Bedrock	Y	N			**FINAL INSPECTION**				
FILTER FABRIC PLACEMENT					15. Pretreatment facility in place	Y	N		
7. Fabric specification	Y	N			16. Debris / gutter screens	Y	N		
8. Placed on bottom, sides, & top	Y	N			17. Stabilisation	Y	N		
AGGREGATE MATERIAL					18. Outlet	Y	N		
9. Size as specifed	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: ______________________

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:	

INFILTRATION TRENCH CONSTRUCTION INSPECTION FORM	: 9	Needs immediate attention Not Applicable	V	Okay	;	Clarification Required

Infiltration Trench Components:

Items Inspected	Checked		Satisfactory	Unsatisfactory		Checked		Satisfactory	Unsatisfactory
PRE-CONSTRUCTION					10. Clean / washed material	Y	N		
1. Runoff diverted	Y	N			11. Placed properly	Y	N		
2. Area stabilised	Y	N			**OBSERVATION WELL**				
EXCAVATION					12. Pipe size	Y	N		
3. Size & location	Y	N			13. Removable cap / footplate	Y	N		
4. Side slope stable	Y	N			14. Initial depth = _______m	Y	N		
5. Soil Permeability	Y	N			**FINAL INSPECTION**				
6. Groundwater / Bedrock	Y	N			15. Pretreatment facility in place	Y	N		
FILTER FABRIC PLACEMENT					16. Stabilisation	Y	N		
7. Fabric specification	Y	N			17. Outlet	Y	N		
8. Placed on bottom, sides, & top	Y	N							
AGGREGATE MATERIAL									
9. Size as specified	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: ______________________

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 :	

INFILTRATION MODULAR PAVING CONSTRUCTION INSPECTION FORM	: 9	Needs immediate attention Not Applicable	V	Okay	;	Clarification Required

Infiltration Modular Paving Components:

Items Inspected	Checked		Satisfactory	Unsatisfactory		Checked		Satisfactory	Unsatisfactory
PRE-CONSTRUCTION					10. Clean / washed material	Y	N		
1. Runoff diverted	Y	N			11. Placed properly	Y	N		
2. Area stabilized	Y	N			**AGGREGATE FILTER COURSE**				
EXCAVATION					12. Size as specified	Y	N		
3. Size & location	Y	N			13. Clean / washed material	Y	N		
4. Side slope stable	Y	N			14. Place properly	Y	N		
5. Soil Permeability	Y	N			**POROUS SURFACE COURSE**				
6. Groundwater / Bedrock	Y	N			15. Proper installation	Y	N		
FILTER FABRIC PLACEMENT					**FINAL INSPECTION**				
7. Fabric specification	Y	N			16. Lattace area backfilled correctly	Y	N		
8. Placed on bottom, sides, & top	Y	N			17. Final stabilization	Y	N		
AGGREGATE BASE COURSE									
9. Size as specified	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: _________________________________

Infiltration practice
Inspection forms
Operation and maintenance 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:	

INFILTRATION DRY WELL 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	

Infiltration Dry Well Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
DEBRIS CLEANOUT	Y	N	Y	N	**M**	**INLETS**	Y	N	Y	N	**A**
1. Roof drains & downspouts clean						6. Good condition of down spouts					
VEGETATION ON TOP OF DRY WELL						7. No evidence of deterioration					
2. Mowing done when needed					**M**	8. Roof gutters drain correctly into dry well					
3. Fertilised per specifications						**OUTLETS / OVERFLOW SPILLWAY**					**A**
4. No evidence of erosion					**M**						
DEWATERING						9. Good condition, no need for repair					
5. Dry well dewaters between storms											
						10. No evidence of erosion					

Inspection Frequency Key A = Annual, M = Monthly

OFFICERS REMARKS:

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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:	

INFILTRATION TRENCH 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	

Infiltration Trench Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
DEBRIS CLEANOUT	Y	N	Y	N	**M**	**INLETS**	Y	N	Y	N	**A**
1. Trench surface clear of debris						13. Good condition					
2. Inlet areas clear of debris						14. No evidence of erosion					
3. Inflow pipes clear of debris						**OUTLETS/OVERFLOW SPILLWAY**					**A**
4. Overflow spillway clear of debris						15. Good condition, no need for repair					
SEDIMENT TRAPS, FOREBAYS, OR PRETREATMENT SWALES					**A**	16. No evidence of erosion					
5. Obviously trapping sediment						**AGGREGATE REPAIRS**					**A**
6. Greater than 50% of storage volume remaining						17. Surface of aggregate clean					
VEGETATION					**M**	18. Top layer of stone does not need replacement					
7. Mowing done when needed						19. Trench does not need rehabilitation					
8. Fertilized per specifications						**VEGETATED SURFACE**					**M**
9. No evidence of erosion						20. No evidence of erosion					
DEWATERING					**M**	21. Perforated inlet functioning adequately					
10. Trench dewaters between storms						22. Water does not stand on vegetative surface					
SEDIMENT CLEANOUT OF TRENCH					**A**	23. Good vegetative cover exists					
11. No evidence of sedimentation in trench											
12. Sediment accumulation does not yet require cleanout											

Inspection Frequency Key A = Annual, M = Monthly

OFFICERS REMARKS:

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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:	

MODULAR PAVING 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	

Modular Paving Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency		Checked		Maintenance Needed		Inspection Frequency
DEBRIS ON INFILTRATION PAVING PARKING AREA	Y	N	Y	N	**M**	**DEWATERING**	Y	N	Y	N	**M**
1. Paving area clean of debris						5. infiltration paving dewaters between storms					
VEGETATION (ANY BUFFER AREA OR PREVIOUS AREAS IN DRAINAGE AREA					**M**	**SEDIMENTS**					**M**
						6. Area clean of sediments					
						STRUCTURAL CONDITION					**A**
2. Mowing done when needed						7. No evidence o f surface deterioration					
3. Fertilised per specification											
						8. No evidence of rutting or spalling					

Inspection Frequency Key A = Annual, M = Monthly

OFFICERS REMARKS:

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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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