Policy 11: Land Development Guidelines

Section 13 Water Sensitive Urban Design (WSUD) Guidelines

13.11 Porous and Permeable Paving

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13.11.1 Introduction

Porous pavement is a load bearing pavement structure that is permeable to water. There is a wide variety of porous pavement types, each with advantages and disadvantages for various applications. The common features of porous pavements include a permeable surface layer overlying an aggregate storage layer. The surface layer of porous pavement may be either monolithic (such as porous asphalt or porous concrete) or modular (clay or concrete blocks). The reservoir storage layer consists of crushed stone or gravel which is used to store water before it is infiltrated to the underlying soil or discharged towards a piped drainage system.

Porous paving can be used as an alternative to conventional paving and hardstand surfaces within urban developments to reduce stormwater runoff velocity and volume by:

- limiting the amount of impervious surface area on a site;
- encouraging infiltration of surface runoff;
- detaining and slowly releasing water from a site.

Water quality improvement is achieved through:

- filtering through the pavement media and underlying material;
- potential biological activity with in the base and sub-media;
- reduction of pollutants through reduced runoff volumes.

A number of porous paving types are available including:

Porous Asphalt or Concrete (Monolithic Structures)	Open graded asphalt or concrete with reduced or no fines and a special binder that allows water to pass through the pavement by flowing through voids between the aggregate.
Modular Pavers	Pavers may be made of porous material or where pavers themselves are not permeable, are installed with gaps between the pavers to allow stormwater to penetrate into the subsurface.
Grid or Lattice Systems	These are made of concrete or plastic grids filled with soil or aggregate that water can percolate through. These systems may also be vegetated (usually with grass).

Porous pavers make up the surface of the porous paving system, however there are a number of layers to the overall system (refer to **Figure 13.11-A**). Pavers are generally laid on a bedding layer of coarse sand. Beneath the porous pavement surface and bedding layer is an aggregate storage or reservoir layer (the detention volume) underlain with geotextile fabric. The aggregate also serves as the road or parking area's support base and must be sufficiently thick to support traffic loads. A final filter layer is provided at the base of the paving system below the aggregate layer. This is usually fine sand (or finer material), that contains the underdrainage system of is the final layer prior to infiltration to surrounding soils or discharge to a piped drainage system. Geotextile fabric is used to provide separation between the bedding layer, the aggregate layer and the filter layer beneath. Stormwater runoff from the paved surface and adjacent impervious areas passes through the porous pavement to the aggregate reservoir where it is filtered and stored.

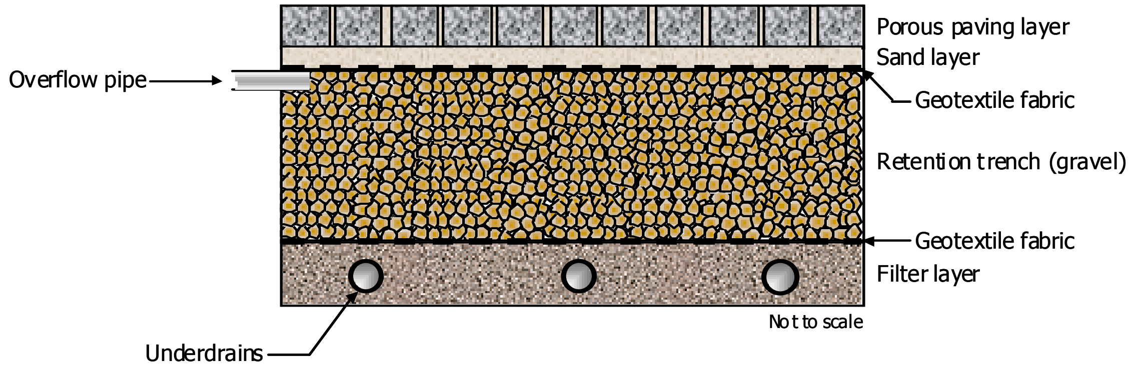

Figure 13.11-A: Typical Porous Paving Section

Permeable pavement systems can function in two ways:

- as an infiltration system, holding water to allow percolation in underlying soils;
- as a detention system, holding surface water temporarily to reduce peak flows by later release of stormwater to the drainage system.

Infiltration porous paving systems are not encouraged for use in Gold Coast City, particularly where they are located adjacent to conventionally paved/ concreted areas such as roads. Water infiltration adjacent to road pavements can cause damage such as asphalt stripping and loss of strength in sub-grades. Porous paving should not be included in treatment trains where they would become Council owned or maintained assets. Porous paving systems in Gold Coast City should be privately owned and maintained.

For infiltration porous paving systems, direction should be taken from **Section 13.8 – Infiltration Measures**, taking into consideration the design guidance provided regarding site soil conditions, setback distances, etc. and the design procedure in that section.

13.11.2 Design Considerations

13.11.2.1 Design Objectives

Porous paving systems can be designed to achieve a range of objectives including:

1. Minimising the volume of stormwater runoff from a development.
2. Preserving predevelopment hydrology.
3. Capturing and detaining or infiltrating flows up to a particular design flow.
4. Enhancing groundwater recharge or preserving predevelopment groundwater recharge.
5. Removing some sediments and attached pollutants by passing runoff through an underlying media layer.

The design objective will vary from one location to another and will depend on site characteristics, development form and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and approved by GCCC prior to commencing the engineering design.

This procedure should be used when porous paving is to provide flow attenuation and water quality treatment. Porous paving may also be used as a general measure to reduce the impervious fraction of a site where it is not considered itself as a treatment measure. This procedure should not be used in these cases.

13.11.2.2 Selecting the Type of Porous Paving

Selection of the type of paving for a particular application must occur as part of the conceptual design process (ie. Site Based Stormwater Management Plan) by assessing the site conditions and desired amenity or built environment/ local character requirements against the functional types of paving systems. **Table 13.11-A** shows a range of suitable applications for different porous paving types in Gold Coast City.

Table 13.11-A: Potential Applications of Porous Paving in Gold Coast City

Condition/ Use	Porous Asphalt/ Concrete	Porous Pavers/ Grid Systems	Interlocking Concrete Paving Systems
Commercial parking lots	✓	✓	✓
Perimeter/ overflow parking	✓	✓	✓
Residential/ light commercial driveways	✓	✓	
Patios other paved areas	✓	✓	
Sporting courts	✓		
Industrial storage yards/ loading zones	✓	✓	
Parking pads (eg. caravan parks)		✓	✓

Porous paving is not recommended for the following applications in Gold Coast particularly where the asset is to be handed over to Council, nor should porous paving be located immediately adjacent to the following areas:

- road pavement;
- on-street parking;
- road shoulders;
- median strips;
- footpaths and bikeways;
- other uses in parkland, civic spaces or municipal areas to be maintained by GCCC.

13.11.2.3 Sizing

The size of a porous paving system requires consideration of the volume and frequency of runoff discharged to the paved area, the available 'detention volume' and the infiltration rate (product of 'infiltration area' and hydraulic conductivity of the paving system).

The required 'detention volume' is defined by relating the volume of inflow and outflow for a particular design storm, and then deriving the 'infiltration area' to ensure the system empties prior to the commencement of the next storm event.

13.11.2.4 Siting

Permeable paving systems should be located in areas to avoid:

- high water tables;
- saline soils;
- acid sulphate soils;
- wind blown areas;
- runoff from areas expected to have a high sediment load;
- high traffic volumes.

The design should demonstrate avoidance of these areas.

13.11.2.5 Pretreatment of Stormwater

Pretreatment of stormwater entering a porous paving system is primarily required to minimise the potential for clogging of the paving media and to protect groundwater quality where infiltration is proposed. Stormwater should be treated to remove coarse and medium sized sediments and litter to prevent blockage of the porous paving system. Suitable pretreatment to porous paving systems includes vegetated buffers, swales, or a small sediment forebay depending on the nature of runoff to the paving system.

13.11.2.6 Vegetated Systems

In modular or grid paving systems, grass may be grown in the voids however the following factors will result in this being unsuccessful due to:

- lack of sufficient soil depth and nutrients for grass to grow;
- heat retained in the pavers;
- wear from vehicle movement.

Grass should only be considered where these factors will not affect plant growth. The design should demonstrate mitigation of these factors if vegetated systems are proposed.

13.11.2.7 Site Terrain

The surface of the 'porous paving area' must be flat or as close to this as possible to ensure uniform distribution of flow and to prevent hydraulic overloading on a small portion of the surface. Generally porous paving systems should be on a slope of less than 3% and should not be considered for slopes >5%.

13.11.2.8 Flow Management

Where possible, 'above design' flows will bypass the porous paving systems. This can be achieved in a number of ways. An overflow pipe or pit, which is connected to the downstream drainage system, can be used.

'Above design' flows or overflows from the porous paving must be diverted towards the stormwater system and design of overflows should demonstrate that overflow will no be directed towards or cause damage to buildings, structures and services.

13.11.2.9 Structural Integrity

A proposed design will have to consider the likely damage to the pavement by the expected vehicle load and demonstrate structural integrity of the pavement to a standard at least similar to the requirements of the following guidelines:

- **Austroads**;
- **Main Roads Queensland**;
- **Section 3.3** of the **Land Development Guidelines**.

13.11.2.10 Safety

Designers must also consider the likelihood of pedestrian traffic across the pavement surface and ensure the porous paving does not create a public safety risk. Key considerations in the design of porous paving systems in pedestrian traffic areas will include minimising trip hazards and minimising slips and falls associated with a slippery pavement surface.

13.11.3 Design Process

The following sections detail the design steps required for porous paving. Key design steps are:

13.11.3.1 Step 1: Confirm Concept Design and Treatment Performance

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure the correct porous paving system design method is selected. The treatment performance of the system should be confirmed (including revisiting and checking of any modelling used to assess treatment performance). The type of porous paving system will be selected by assessing the site conditions against the relative merits of the different porous paving types, and in consideration of integration with the built environment and amenity.

a) Check Service Locations

As part of the confirmation of objectives and review of the conceptual design, the designer must check that there are no existing or proposed services in the proposed site for the porous paving.

The designer should liaise with civil designers and GCCC officers to ensure:

- porous paving will not result in water damage to existing services or structures;
- access for maintenance to existing services in maintained;
- no conflicts arise between the location of services and WSUD devices.

13.11.3.2 Step 2: Pretreatment Design

As outlined in **Section 13.11.2.5**, both Level 1 Pretreatment (minimising risk of clogging) and Level 2 Pretreatment (groundwater protection) may be required for porous paving systems. To determine Level 2 requirements, an assessment of the groundwater must be undertaken to define existing water quality, potential uses (current and future) and suitability for recharge.

Pretreatment measures include the provision of leaf and roof litter guards along the roof gutter, vegetated swales, sediment forebays or buffer strips.

13.11.3.3 Step 3: Determine Design Flows

The hydraulic design for porous paving should be based on the following design flows:

- minor Storm Event for sizing the surface area, detention volume and overflow pit of the paving system;
- major Storm Event for overflow or bypass of the system. These flows will flow over or bypass the system and enter the stormwater drainage system (either piped system or overland flow) for the relevant design event.

A range of hydrologic methods can be applied to estimate design flows. If typical catchment areas are relatively small, the Rational Method design procedure is considered suitable.

13.11.3.4 Step 4: Size Porous Paving System

Where the design objective for a particular porous paving system is peak discharge attenuation or the capture and infiltration of a particular design storm event, then the design storm approach may be adopted for sizing the porous paving system.

a) Design Storm Selection (Q_{des})

The first step is to select the design storm to capture for detention or infiltration. This must occur in consultation with GCCC and will generally relate to 3 month ARI and 1 year ARI design storms.

b) Detention Volume

The required ‘detention volume’ of a porous paving system is defined by the difference in inflow and outflow volumes for the duration of a storm.

The inflow volume (V_i) will depend on the source runoff being routed through the porous paving system. Inflow may include:

- rainfall onto the porous paving system only;
- a combination of rainfall onto the porous paving system and runoff from other impervious areas.

The inflow volume for the design storm on the porous paving system (treatment surface) only is (**Argue 2007**):

$$V_i = \frac{A_s \cdot i}{10^3 \times 360} \cdot D$$

Where:

V_i	=	inflow volume
A_s	=	estimate surface area of the paving (m^2)
i	=	average rainfall intensity for design storm (mm/hr)
D	=	duration of storm (hr)

Equation 13.11.1

The inflow for a combination of rainfall onto the porous paving system and runoff from other impervious areas is determined, as the product of the design storm flow and the storm duration.

$$V_i = Q_{des} \cdot D$$

Where:

V_i	=	inflow volume (for storm duration D) (m^3)
Q_{des}	=	design storm flow for sizing
		(Rational Method, Q= CIA/ 360 (m^3/s)
D	=	storm duration (hrs x 3600 s/hr)

Equation 13.11.2

Outflow from the porous paving system is via the base (and on some cases the sides) of the infiltration media and is dependent on the area and depth of the structure. It is calculated using the filtration rate through the filter layer media and the storm duration.

The maximum filtration rate represents the maximum rate of flow through the paving system and is calculated by applying Darcy's equation as follows:

$$Q_{max} = K_{sat} \cdot A \cdot \frac{h_{max} + d}{d}$$

Where:

Q_{max}	=	maximum filtration rate (m^3/s)
K_{sat}	=	filter layer saturated hydraulic conductivity (m/s)
A	=	area of the porous paving (m^2)
h_{max}	=	depth of pondage above the soil filter (m)
d	=	depth of filter media (m)

Equation 13.11.3

Given there is no detention depth or pondage above surface of the porous paving, and conditions are likely to be fully drained, then:

$$\frac{h_{max} + d}{d} = 1$$

Outflow volume is calculated as:

$$V_0 = Q_{max} \cdot D$$

Where:

V_o	= outflow volume (m^3)
Q_{max}	= maximum filtration rate (m^3/s)
D	= duration of storm event

Equation 13.11.4

Thus, the required detention volume (V_d) of an porous paving system can be computed as follows:

$$V_d = \frac{V_i - V_o}{p}$$

Where:

V_d = required detention volume (m^3)

V_i = inflow volume (m^3)

V_o = outflow volume (m^3)

p = porosity of the retention trench(gravel = 0.35)

Equation 13.11.5

Note: Volume calculations may need to be revised if further steps in the design process result in changes to the expected surface area of the porous paving system.

c) Depth

The depth of the porous paving system will be determined from site constraints and the structural requirements of the paving system (refer **Section 13.11.2.9**).

d) Surface Area Check

To this point in the design process an assumed surface area may have been used. A check and final surface area of the porous paving should be determined using two steps:

- calculate surface area based on the volume and required depth;
- check surface area has capacity to infiltrate peak flows for design storm.

The surface area of the porous paving system should be checked using the following equation from **Argue (2007)**:

$$A_s = \frac{Q_{peak}}{(1 - B) \cdot K_{sat}}$$

Where:

Q_{peak} = Peak inflow to porous paving surface (m^3/s)

B = Blockage Factor (this should be estimated based on non-porous structural elements (eg. plastic/ concrete grids)

K_{sat} = saturated hydraulic conductivity of paving surface (eg. concrete/ asphalt)/ or porous material between pavers.

Equation 13.11.6

13.11.3.5 Step 5: Underdrainage Design and Check

To ensure slotted pipes are of adequate size, several checks are required to ensure:

- the perforations are adequate to pass the maximum filtration rate;
- the pipe itself has sufficient capacity;
- that the material in the filter layer will not be washed into the perforated pipes (consider a transition layer).

The capacity of the perforated under-drains need to be greater than the maximum filtration rate to ensure the filter media drains freely and does not become the hydraulic 'control' in the porous paving system (ie. to ensure the filter layer sets the travel time for flows from the aggregate layer rather than the perforated under-drainage system).

To ensure the perforated under-drainage system has sufficient capacity to collect and convey the maximum filtration rate, it is necessary to determine the capacity for flows to enter the under-drainage system via the perforations in the pipes. To do this, orifice flow can be assumed and the sharp edged orifice equation used. Firstly, the number and size of perforations needs to be determined (typically from manufacturer's specifications) and used to estimate the flow rate into the pipes, with the maximum driving head being the depth of the porous paving system. It is conservative, but reasonable to use a blockage factor to account for partial blockage of the perforations by the drainage layer media. A 50 % blockage of the perforations should be used.

The flow capacity of the perforations is thus:

$$Q_{perf} = B \cdot C_d \cdot A\sqrt{2 \cdot g \cdot h}$$

Where:

Q_{perf}	=	flow through perforations (m^3/s)
C_d	=	orifice discharge coefficient (0.6)
A	=	total area of the orifice (m^2)
g	=	gravity (9.81 m/s^2)
h	=	maximum depth of water above the pipe (m)
B	=	blockage factor (0.5)

Equation 13.11.7

If the capacity of the drainage system is unable to collect the maximum filtration rate additional under-drains will be required.

After confirming the capacity of the under-drainage system to collect the maximum filtration rate, it is necessary to confirm the conveyance capacity of the underdrainage system is sufficient to convey the collected runoff. To do this, Manning's equation can be used (which assumes pipe full flow but not under pressure). The Manning's roughness used will be dependant on the type of pipe used (refer to **QUDM Table 5.21.3 (DPI, IMEA & BCC 1992)**).

Under-drains should be extended vertically to the surface of the porous paving system to allow inspection and maintenance when required. The vertical section of the under-drain should be unperforated and capped to avoid short-circuiting of flows directly to the drain.

13.11.3.6 Step 6: Check Emptying Time

Emptying time is defined as the time taken to fully empty a detention volume following the cessation of rainfall. This is an important design consideration as the computation procedure associated with **Equation 13.11.4** assumes that the storage is empty prior to the commencement of the design storm event. **Australian Runoff Quality (Engineers Australia 2006)** suggests an emptying time of the detention storage of porous paving systems to vary from 12 hours to 84 hours. Designers should aim to have a drainage time of 24 to 48 hours.

Emptying time is computed simply as the ratio of the volume of water in temporary storage (dimension of storage x porosity) to the filtration rate through the filter layer(hydraulic conductivity x infiltration area):

$$t_e = \frac{1000 \cdot V_d \cdot P}{A_{inf} \cdot K_{sat}}$$

Where:

t_e	=	emptying time (hours)
V_d	=	detention volume (m^3)
P	=	perimeter length of the infiltration area (m)
A_{inf}	=	infiltration area (m^2)
K_{sat}	=	filter layer saturated hydraulic conductivity (mm/hr)

Equation 13.11.8

13.11.3.7 Step 7: Check Requirement for Impermeable Lining

The saturated hydraulic conductivity of the natural soil profile surrounding the paving system should be tested together with depth to groundwater, chemical composition and proximity to structures and other infrastructure. This is to establish if an impermeable liner is required at the base (only for systems designed to preclude ex-filtration to *in-situ* soils) and/or sides of the pavement sub-layers. If the saturated hydraulic conductivity of the paving system is more than one order of magnitude (10 times) greater than that of the surrounding *in-situ* soil profile, no impermeable lining is required.

13.11.3.8 Step 8: Specify Porous Paving Layers Elements

The following design and specification requirements must be documented as part of the design process for porous pavement systems.

a) Porous Paving Surface

The porous paving layer will depend on the type of paving decided on through the design process. The porous paving surface type must be specified along with any proprietary requirements and specifications. The pavers are set on a coarse sand or fine gravel bedding layer. The purpose of this layer is to provide a smooth, flat surface on which to lay the porous paving.

b) Retention/ Aggregate Layer

Where the ‘detention volume’ is created through the use of a gravel-filled trench then the gravel must be clean (free of fines) stone/ gravel with a uniform size of between 25 - 100 mm diameter.

c) Geofabric

Geofabric must be installed along the side walls and through the base of the detention volume to prevent the migration of *in-situ* soils, and material from the bedding and filter layers into the system. Geofabric with a minimum perforation or mesh of 0.25 mm should be used.

13.11.3.9 Step 9: Size Overflow Pit/ Pipe

Overflow from a porous paving system can be via overflow pipes located just underneath the sand bedding layer, in the top of the detention/ aggregate layer or can be via an overflow pit or similar structure.

a) Overflow Pipes

Pipe flows are to be calculated in accordance with **Section 3.5** and **QUDM (DPI, IMEA & BCC 1992)** which use standard pipe equations that account for energy losses associated with inlet and outlet conditions and friction losses within the pipe. For most applications, the pipe or culvert will operate under outlet control with the inlet and outlet of the pipe/ culvert being fully submerged. With relatively short pipe connections, friction losses are typically small and can be computed using Manning’s equation. The total energy (head) loss (ΔH) of the connection is largely determined by the inlet and outlet conditions and the total losses can be computed using the expression as provided in **QUDM (DPI, IMEA & BCC 1992)**:

$$\Delta H = h_f + h_s$$

Where:

h_f	=	S_f . L = head loss in pipe due to friction (m)
h_s	=	$(K_{in} + K_{out}) . V^2/ 2g$ = head loss at entry and exit (m)
S_f	=	friction slope which is computed from Manning’s Equation (m/ m)
L	=	is the length pipe (m)
$K_{in} + K_{out}$	=	the head loss coefficients for the inlet and outlet conditions (typically, and conservatively, assumed to be 0.5 and 1.0, respectively)
V	=	velocity on flow in pipe (m/s)
g	=	gravity (9.79 m/s^2)

Equation 13.11.9

b) Overflow Pit

In porous paving systems, the overflow pit is designed so that the pit crest is at the level of the pavement surface. It may be raised slightly above the surface of the paving to ensure flows do not divert to the overflow pit before infiltrating the pavement surface.

To size an overflow pit, two checks should be made to test for either drowned or free flowing conditions. A broad crested weir equation can be used to determine the length of weir required (assuming free flowing conditions) and an orifice equation used to estimate the area between openings required in the grate cover (assuming drowned outlet conditions). The larger of the two pit configurations should be adopted (as per **Section 5.10 QUDM (DPI, IMEA & BCC 1992)**). In addition, a blockage factor is to be used that assumes the grate is 50 % blocked.

For free overfall conditions (weir equation):

$$Q_{weir} = B \cdot C_w \cdot L \cdot h^{3/2}$$

Where:

Q_{weir}	= flow into pit (weir) under free overfall conditions (m^3/s)
B	= blockage factor (0.5)
C_w	= weir coefficient (1.66)
L	= length of weir (perimeter of pit) (m)
h	= flow depth above the weir (pit) (m)

Equation 13.11.10

Once the length of weir is calculated, a standard sized pit can be selected with a perimeter at least the same length of the required weir length.

For drowned outlet conditions (orifice equation):

$$Q_{orifice} = B \cdot C_d \cdot A\sqrt{2 \cdot g \cdot h}$$

Where:

$Q_{orifice}$	=	flow rate into pit under drowned conditions (m^3/s)
C_d	=	discharge coefficient (drowned conditions = 0.6)
A	=	area of orifice (perforations in inlet grate) (m^2)
B	=	blockage factor (0.5)
g	=	gravity (9.81 m/s^2)
h	=	maximum depth of water above the pipe (m)

Equation 13.11.11

When designing grated field inlet pits, reference is to be made to the procedure described in **QUDM Section 5.10.4 (DPI, IMEA & BCC 1992)** and **Section 3.5**.

13.11.3.10 Design Calculation Summary

Following is a design calculation summary sheet for the key design elements of a porous paving system to aid the design process.

Porous Paving Systems	Calculation Summary	
Calculation Task	**Outcome**	**Check**
Catchment Characteristics		
Catchment Area Contributing to Paving System	Ha (or m^2)	
Catchment Land Use (ie. Residential, Commercial, etc)		
Storm Event Entering Porous Paving System (Minor or Major)	year ARI	
Estimated Surface Area of Paving System	m^2	
1 Confirm Design Objectives and Pavement Type		
Confirm Design Objective as Defined by Conceptual Design		
Confirm Treatment Performance		
Confirm Paving Type		
Detention System Only?		
2 Pretreatment design		
Appropriate Treatment Provided to Avoid Clogging?		
3 Determine Design Flows		
Minor Storm	year ARI	
Major Storm	year ARI	
Time of Concentration		
Refer to **Section 3.5** and **QUDM**	minutes	

Porous Paving Systems		Calculation Summary	
	Calculation Task	Outcome	Check
Identify Rainfall Intensities			
	Minor Storm	mm/hr	
	Major Storm	mm/hr	
Design Runoff Coefficient			
	Minor Storm		
	Major Storm		
Peak Design Flows			
	Minor Storm	m^3/s	
	Major Storm	m^3/s	
4 Size Porous Paving System			
	Design Storm Flow	m^3/s	
	Inflow Volume	m^3	
	Outflow Volume	m^3	
	'Detention Volume'	m^3	
	Depth	m	
	Surface Area Check OK?	m^2	
5 Under-Drain Design and Check			
	Flow Capacity of Filter Media	m^3/s	
Perforations Inflow Check			
	Pipe Diameter	mm	
	Number of Pipes		
	Capacity of Perforations	m^3/s	
	Check PERFORATION CAPACITY > FILTER MEDIA CAPACITY		
6 Emptying Time Check			
	Calculated Emptying Time	hrs	
	Emptying Time Okay (12-48 hrs)?		
7 Impermeable Lining Check			
	Impermeable lining required?		
8 Porous Paving Layers Specified			
	Porous Paving Surface Type and Depth	m	
	Bedding Layer Material and Depth	m	
	Underdrainage Layer Material and Depth	m	
9 Inflow/ Overflow structures			
Overflow Pipe			
	Pipe Capacity	m^3/s	
	Pipe Size	mm diam.	
Overflow Pit			
	Pit Capacity	m^3/s	
	Pit Size	mm x mm	

13.11.4 Construction and Establishment

It is important to note in the context of a development site and associated construction/ building works, delivering porous paving can be a challenging task. A careful construction and establishment approach to ensure the system is delivered in accordance with its design intent. The following sections outline a recommended staged construction and establishment methodology for porous paving.

13.11.4.1 Construction and Establishment Challenges

There exist a number of challenges that must be appropriately considered to ensure successful construction and establishment of porous paving including:

- sediment loads during construction phase which can clog paving surface;
- construction traffic and other works which can damage paving surface and layers.

13.11.4.2 Staged Construction and Establishment Method

To overcome the challenges associated within delivering porous paving a Staged Construction and Establishment Method should be adopted:

Stage 1: **Functional Installation**	Construction of the functional elements of the porous paving and the installation of temporary protective measures (ie. stormwater bypass system and suitable erosion and sediment control measures). This should be done towards completion of the development.
Stage 2: **Sediment and Erosion Control**	While other final elements of the development are completed the temporary protective measures preserve the functional infrastructure of the porous paving against damage.
Stage 3: **Operational Establishment**	At the completion of the Building Phase, the temporary measures protecting the functional elements of the porous paving can be removed and the system allowed to operation in accordance with the design intent.

Where large scale porous paving systems are proposed, a detailed construction and establishment plan, including temporary protective measures, should be prepared.

a) Functional Installation

Porous paving should not be laid until all catchment surface areas have been stabilised to prevent sedimentation and early clogging of the system. Installation would generally involve:

- bulking out and trimming;
- installation of the overflow structures;
- placement of non-woven geofabric to sides and base;
- placement of gravel;
- flow to be diverted around porous paving to ensure sediment laden stormwater flows ‘bypass’ the system;
- place silt fences around the boundary of the porous paving to exclude silt;
- place highly visible physical barriers to restrict access.

b) Sediment and Erosion Control

The temporary protective measures are left in place through the remainder of the building phase to ensure sediment laden waters do not enter and clog the porous paving surface.

c) Operational Establishment

At the completion of the Building Phase the temporary measures (ie. stormwater bypass) can be removed and the porous paving allowed to operate. It is critical to ensure that the pretreatment system for a porous paving is fully operational before flows are introduced. If at the commencement of operations there is some clogging of the pavement surface, then the surface should be tilled, vacuum swept or high-pressure-hosed to clean or unblock the surface.

13.11.5 Maintenance Requirements

Maintenance for porous paving aims at ensuring the system does not clog with sediments and that an appropriate infiltration rate is maintained.

Key elements of porous paving maintenance are to ensure:

- protection from pulse sediment loads particularly during and immediately after subdivision and house construction to prevent clogging;
- inspection for cracks and holes and replacement as necessary;
- they are cleaned of debris and surface sediment;
- weeded or mowed where appropriate.

The most important consideration during maintenance is to ensure the surface of the porous paving systems are operating as designed to avoid blockage.

To ensure the system is operating as designed, the infiltration zone should be inspected every 1 – 6 months (or after each major rainfall event) depending on the size and complexity of the system. Typical maintenance of porous paving systems will involve:

- routine inspection to identify any surface clogging/ blockage of the underlying aggregate or filter layers;
- routine inspection of inlet points to identify any areas of scour, litter build up, sediment accumulation or blockages;
- routine inspection of pavement for holes and cracks;
- routine inspection to ensure contributing catchment area is stabilised and not a significant source of sediment;
- routine inspection of pretreatment to ensure it is working effectively;
- periodic inspection to ensure system dewaters following storm events;
- removal of accumulated sediment and clearing of blockages to inlets;
- regular vacuum sweeping and/or high pressure hosing to free pores in the top layer from clogging;
- periodic replacement of aggregate layer (about every 20 years) and replacement of geotextile fabric;
- maintaining the surface vegetation (if present).

All maintenance activities must be specified in an approved Maintenance Plan (and associated maintenance inspection forms) to be documented and submitted to Council as part of the Development Approval process. Maintenance personnel and asset managers will use this Plan to ensure the porous paving continues to function as designed. An example operation and maintenance inspection form is included in the checking tools provided in **Section 13.11.7**. These forms must be developed on a site-specific basis as the nature and configuration of porous paving varies significantly.

13.11.6 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. **Section 13.11.4** provides general advice on the construction and establishment of porous paving and key issues to be considered to ensure their successful establishment and operation. The following checking tools are provided:

- Design Assessment Checklist;
- Construction Inspection Checklist (during and post);
- Operation and Maintenance Inspection Form;
- Asset Transfer Checklist (following ‘on-maintenance’ period).

Figure 13.11-B below shows the stages of the development approval, construction and establishment and asset transfer process and which checklists should be used at each stage.

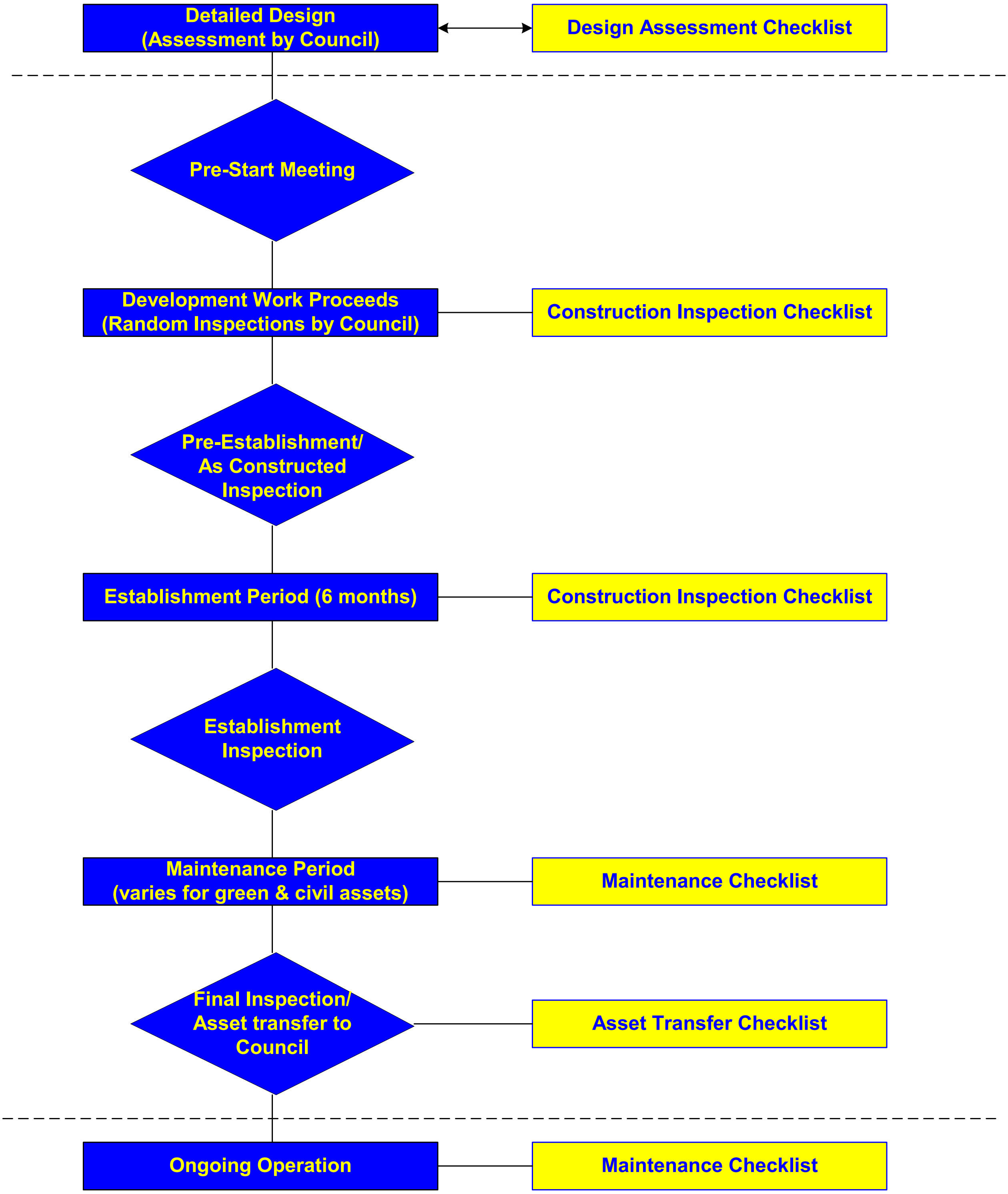

Figure 13.11-B: Development Approval and Handover Stages – Appropriate Checklists

13.11.6.1 Design Assessment Checklist

The design assessment checklist presents the key design features that are to be reviewed when assessing the design of a porous paving system. These considerations include configuration, safety, maintenance and operational issues that need to be addressed during the design phase. If an item receives an ‘N’ when reviewing the design, referral is to be made back to the design procedure to determine the impact of the omission or error.

In addition to the checklist, a proposed design should have all necessary permits for its installation. Council development assessment officers will require that all relevant permits are in place prior to accepting a design.

13.11.6.2 Construction Inspection Checklist

This checklist presents the key items to be reviewed when inspecting the porous paving during and at the completion of construction. The checklist is to be used by Construction Site Supervisors and GCCC Compliance Inspectors to ensure all the elements of the porous paving have been constructed in accordance with the design. If an item receives an ‘N’ in Satisfactory criteria then appropriate actions must be specified and delivered to rectify the construction issue before final inspection sign-off is given.

13.11.6.3 Maintenance Checklist

In addition to checking and maintaining the function of pretreatment elements, the maintenance checklist can be used during routine maintenance inspections of the porous paving and kept as a record on the asset condition. Inspections should occur every 1 - 3 months. More detailed site specific maintenance schedules should be developed for major porous paving systems and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

13.11.6.4 Asset Transfer Checklist

Land ownership and asset ownership are key considerations prior to construction of a stormwater treatment device. At the present point in time, Council will not accept porous paving systems, however this may be determined on a case-by-case basis. A proposed design should clearly identify the asset owner and who is responsible for its maintenance. The proposed owner should be responsible for performing the asset transfer checklist.

Porous Paving Design Assessment Checklist (Detention Systems Only)				
Asset I.D.				
Porous Paving Location:				
Hydraulics:	Minor Storm (m^3/s):	Major Storm (m^3/s):		
Area:	Catchment Area (ha):	Infiltration Area (m^2):	Detention Volume (m^3):	
Pavement Type			**Y**	**N**
Pavement type appropriate to site based on traffic load, amenity and built environment character? Refer **Section 13.11.2.2**				
Porous paving is detention system only (no infiltration)? Refer **Section 13.11.1**. **Section 13.8** to be used for infiltration porous paving systems.				
Porous paving on slope less than 5%? Refer **Section 13.11.2.7**				
Pretreatment			**Y**	**N**
Appropriate pretreatment provided? Refer **Sections 13.1.2.5** and **13.11.3.2**. Roof gutter guards, swales, buffer strips or sediment forebay.				
Contributing catchment adequately stabilised and not a source of sediment? Refer **Section 13.11.2.4**				
Porous Paving System			**Y**	**N**
Design objective established? Refer **Section 13.11.2.1**				
Has the appropriate design storm been selected? Treatment of Q_{3month} to Q_1 flows.				
Porous paving system sized appropriately and checks for detention volume and surface area undertaken? Refer **Section 13.11.3.4**				
Underdrainage provided flowing away from other conventional paved surfaces to stormwater network? Refer **Section 13.11.3.5**				
Emptying time checked? Refer **Section 13.11.3.6**. Should be 24-48 hours.				
Impermeable lining included?				
Porous paving layers specified appropriately?				
Flow Management			**Y**	**N**
Overall flow conveyance system sufficient for design flood event?				
Bypass/ overflow sufficient for conveyance of design flood event?				
Comments				

Porous Paving Construction Inspection Checklist

Asset I.D.:		**Inspected by:**	
Site:		**Date:**	
		Time:	
Constructed By:		**Weather:**	
		Contact During Visit:	

Items Inspected	Checked Y	Checked N	Satisfactory Y	Satisfactory N	Items Inspected	Checked Y	Checked N	Satisfactory Y	Satisfactory N
During Construction									
A. Functional Installation					**Structural Components**				
Preliminary Works					8. Location and levels of porous paving system and overflow points as designed				
1. Erosion and sediment control plan adopted					9. Pipe joints and connections as designed				
2. Traffic control measures					10. Concrete and reinforcement as designed				
3. Location same as plans					11. Inlets appropriately installed				
4. Site protection from existing flows (flows diverted around site)					12. Correct fill media/ modular system used				
Earthworks					13. Provision of geofabric around aggregate layer				
5. Excavation as designed					**B. Sediment and Erosion Control**				
6. Side slopes are stable					14. Stabilisation immediately following earthworks				
Pretreatment					15. Silt fences and traffic control in place				
7. Contributing catchment stabilised/ not a sediment source					16. Temporary protection layers in place (if appropriate)				
					C. Operational Establishment				
					17. Temporary protection layers removed				
					18. Surface of paving installed/ cleaned				
Final Inspection									
1. Confirm levels of inlets and outlets					6. Check for uneven settling of surface				
2. Traffic control in place					7. No surface clogging				
3. Confirm structural element sizes					8. Maintenance access provided				
4. Layers of paving system as specified					9. Construction generated sediment and debris removed				
5. Confirm pretreatment is working									

Comments on Inspection

Actions Required

1.
2.
3.
4.
5.

Inspection officer signature:

Porous Paving Maintenance Checklist			
Inspection Frequency:	1 to 6 monthly	**Date of Visit:**	
Asset I.D.:			
Location:			
Description:			
Site Visit by:			

Inspection Items	Y	N	Action Required (Details)
Sediment accumulation in pretreatment zone?			
Erosion at any points?			
Evidence of dumping (eg. building waste)?			
Evidence of extended ponding times?			
Evidence of silt and clogging of pavement surface?			
Evidence of silt and clogging within 'detention volume'?			
Clogging of flow management systems (sediment or debris)?			
Damage/ vandalism to structures present?			
Drainage system inspected?			
Resetting of system required?			

Comments

Porous Paving Asset Transfer Checklist		
Asset I.D.:		
Asset Location:		
Construction by:		
'On-Maintenance' Period:		
Treatment	**Y**	**N**
System appears to be working as designed visually?		
No obvious signs of under-performance?		
Maintenance	**Y**	**N**
Maintenance plans and indicative maintenance requirements/ costs provided for each asset?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
Asset inspected for defects?		
Asset Inspected for Defects and/or Maintenance Issues at Time of Asset Transfer	**Y**	**N**
Sediment accumulation at any points?		
Litter present?		
Traffic damage present?		
Asset Information	**Y**	**N**
Design Assessment Checklist provided?		
'As constructed' plans provided?		
Copies of all required permits (both construction and operational) submitted?		
Proprietary information provided (if applicable)?		
Digital files (eg. drawings, survey, models) provided?		
Asset listed on asset register or database?		
Comments		

13.11.7 References

Argue JR (ed) 2007, **Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater**, AWA, University of South Australia.

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