Appendix C: Guidelines for filter media in stormwater biofiltration systems

(Version 4.01) - July 2015

CRC for
Water Sensitive Cities

Australian Government
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Cooperative Research
Centres Programme

The following guidelines for filter media in stormwater biofilters have been prepared on behalf of the Cooperative Research Centre for Water Sensitive Cities (CRC WSC) to assist in the development of biofiltration systems, including the planning, design, construction and operation of those systems.

Note: This is a revision of the previous Facility for Advanced Water Biofiltration (FAWB) filter media guidelines (published in 2006 (Version 1.01), 2008 (Version 2.01) and 2009 (Version 3.01)). It attempts to provide a simpler and more robust guideline for both sand-based and engineered filter media. In the development of these guidelines across four versions, the CRC WSC acknowledges the contribution of Terry Woodcock and Michael Robinson (Sportsturf Consultants), Greg Fitzgerald and Shane Howes (Daisy's Garden Supplies), EDAW Inc., Melbourne Water Corporation, Dr Nicholas Somes (Ecodynamics), Alan Hoban (South East Queensland Healthy Waterways Partnership), Shaun Leinster (DesignFlow) and STORM Consulting to the preparation of the revised guidelines.

1 Introduction and summary of the media specifications

Each component of a biofilter, including the various layers of media, serve important roles in the treatment of stormwater runoff. Key components and layers within a biofilter, and the purpose they serve, are illustrated in Figure 1. Selecting appropriate material for the biofilter is crucial to the performance of the biofilter, and use of the wrong materials can lead to system failure, leaching of pollutants to the environment and expensive rectification costs. These guidelines have been developed to help avoid this and instead ensure reliable and effective stormwater treatment.

A summary of the key specifications for each layer of material is given in Table 1. Some requirements are essential specifications (highlighted in blue), while other characteristics are only recommended to provide guidance for the selection of appropriate materials (highlighted in grey). The rationale(s) for each requirement are also given in the table. Readers are referred to the subsequent sections in these guidelines for further discussion and clarification of the media requirements.

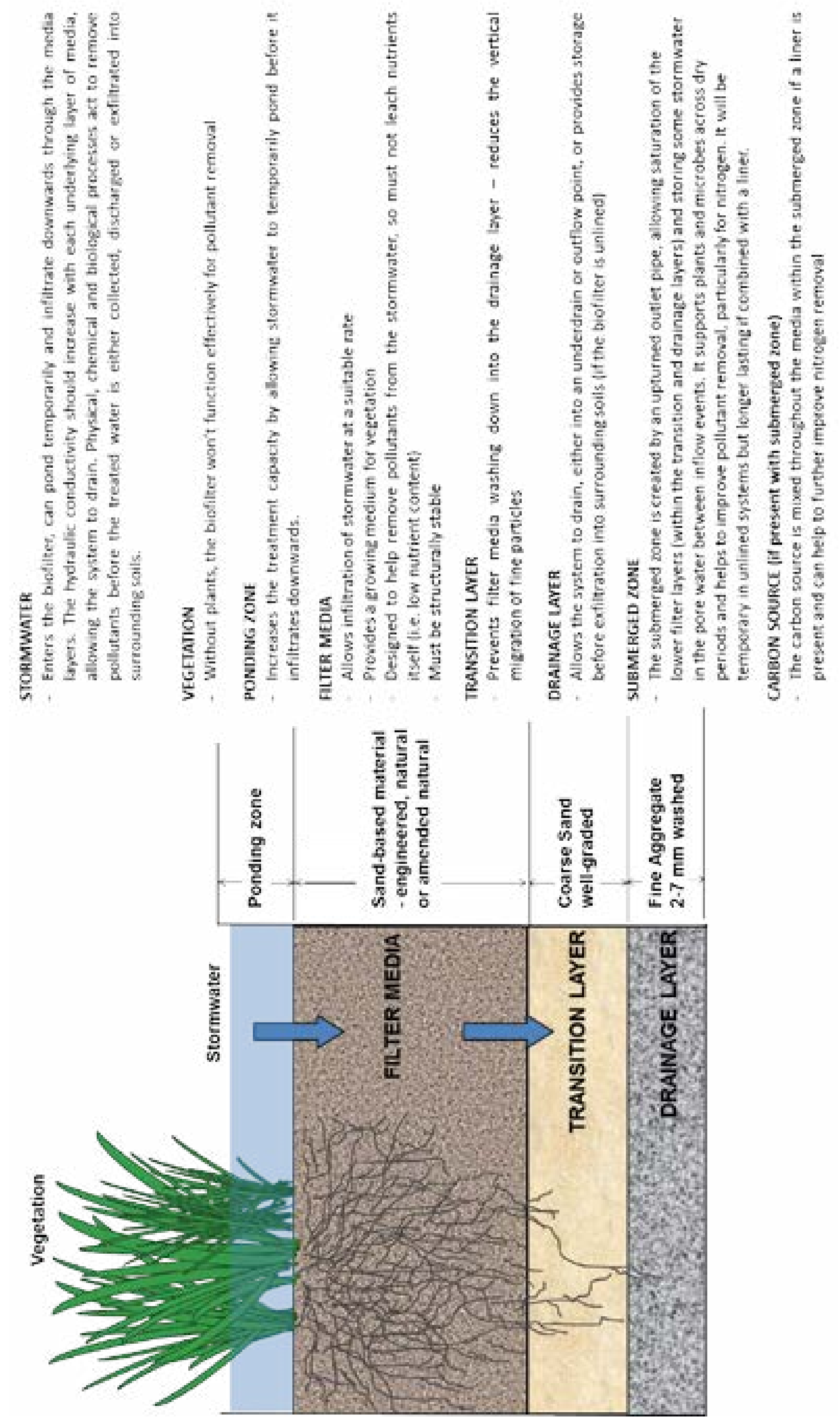

Figure 1. Layers within a biofilter and their function in the treatment of stormwater

Table 1. Essential and recommended media requirements

	Property	Specification to be met	Why is this important to biofilter function?
Filter Media (top layer/ growing media)			
ESSENTIAL SPECIFICATIONS	**Material**	Either an engineered material – a **washed, well-graded sand** – or naturally occurring sand, possibly a mixture	Media must be sand-based (and not a loam) to ensure adequate hydraulic conductivity, low nutrient content and structural stability
	Hydraulic conductivity	**100 – 300 mm/hr** (higher in tropical regions but must be capable of supporting plant growth). Determine using ASTM F1815-11 method	Provides adequate capacity to treat a higher proportion of incoming stormwater Testing method best represents field conditions
	Clay & silt content	**< 3% (w/w)**	Above this threshold hydraulic conductivity is substantially reduced. Too many very fine particles also reduce structural stability leading to migration and leaching
	Grading of particles	**Smooth grading** – all particle size classes should be represented across sieve sizes from the 0.05mm to the 3.4mm sieve (as per ASTM F1632-03(2010)	Provides a stable media, avoiding structural collapse from downwards migration of fine particles
	Nutrient content	**Low nutrient content** Total Nitrogen **(TN) < 1000 mg/kg** Available phosphate (Colwell) **< 80 mg/kg**	Prevents leaching of nutrients from the media
	Organic matter content	**Minimum content ≤ 5%** to support vegetation	Although some organic matter helps to retain moisture for vegetation and can benefit pollutant removal, higher levels will lead to nutrient leaching
	pH	**5.5 – 7.5** – as specified for 'natural soils and soil blends' in AS4419 – 2003 (pH 1:5 in water)	To support healthy vegetation over the long-term – without which the biofilter cannot function effectively
	Electrical conductivity	**< 1.2 dS/m** – as specified for 'natural soils and soil blends' in AS4419 – 2003	
	Horticultural suitability	Assessment by horticulturalist – **media must be capable of supporting healthy vegetation**. Note that additional nutrients are delivered with incoming stormwater	

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Table 1 Cont.

	Property	Specification to be met	Why is this important to biofilter function?
GUIDANCE	**Particle size distribution (PSD)**	Note that it is most critical for plant survival to ensure that the fine fractions are included (% w/w) Retained **Clay & silt < 3% (< 0.05 mm)** **Very fine sand 5-30% (0.05-0.15mm)** Fine sand 10-30% (0.15-0.25 mm) Medium sand 40-60% (0.25-0.5 mm) Coarse sand < 25% (0.5-1.0 mm) Very coarse sand 0-10% (1.0-2.0mm) Fine gravel < 3% (2.0-3.4 mm)	Of secondary importance compared with hydraulic conductivity and grading of particles, but provides a starting point for selecting appropriate material with adequate water-holding capacity to support vegetation. **Filter media do not need to comply with this particle size distribution to be suitable for use in biofilters**
GUIDANCE	**Depth**	400-600 mm or deeper	To provide sufficient depth to support vegetation Shallow systems are at risk of excessive drying
GUIDANCE	**Once-off nutrient amelioration**	Added manually to top 100 mm **once only** Particularly important for engineered media	To facilitate plant establishment, but in the longer term incoming stormwater provides nutrients
GUIDANCE	**Protective surface layer**	Include a surface layer 100-150 mm deep overlying the biofilter media. Use a coarser particle size than the media, generally commercially available sands.	Lab studies have successfully demonstrated the potential for this layer to delay clogging and improve treatment performance. Currently being tested in the field.
Transition sand (middle layer)			
ESSENTIAL SPECIFICATIONS	**Material**	**Clean well-graded sand e.g. A2 Filter sand**	Prevents the filter media washing downwards into the drainage layer
ESSENTIAL SPECIFICATIONS	**Hydraulic conductivity**	**Must be higher than the hydraulic conductivity of the overlying filter media**	To allow the system to drain and function as intended
ESSENTIAL SPECIFICATIONS	**Fine particle content**	**< 2%**	To prevent leaching of fine particles
ESSENTIAL SPECIFICATIONS	**Particle size distribution**	Bridging criteria – the smallest 15% of sand particles must bridge with the largest 15% of filter media particles (Water by Design, 2009) (VicRoads, 2004): **D_{15} (transition layer) ≤ 5 x D_{85} (filter media)** *<u>where</u>: D_{15} (transition layer) is the 15th percentile particle size in the transition layer material (i.e.,15% of the sand is smaller than D_{15} mm), and D_{85} (filter media) is the 85th percentile particle size in the filter media* The best way to compare this is by plotting the particle size distributions for the two materials on the same soil grading graphs and extracting the relevant diameters (Water by Design, 2009)	To avoid migration of the filter media downwards into the transition layer
ESSENTIAL SPECIFICATIONS		Bridging criteria **only in designs where transition layer is omitted** (Water by Design, 2009; VicRoads, 2004): D_{15} (drainage layer) ≤ 5 x D_{85} (filter media) D_{15} (drainage layer) = 5 to 20 x D_{15} (filter media) D_{50} (drainage layer < 25 x D_{50} (filter media) D_{60} (drainage layer) < 20 x D_{10} (drainage layer)	To avoid migration of the filter media into the drainage layer only in the case where a transition layer is not possible.

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Table 1. Continued

	Property	Specification to be met	Why is this important to biofilter function?
G.	**Depth**	≥ 100 mm	(as per above purpose)
Drainage layer (base)			
ESSENTIAL SPECIFICATIONS	**Material**	**Clean, fine aggregate - 2-7 mm washed screenings (not scoria)**	To collect and convey treated stormwater, protect and house the underdrain (if present), or provide a storage reserve as part of a submerged zone, or prior to exfiltration (in unlined systems).
	Hydraulic conductivity	**Must be higher than the hydraulic conductivity of the overlying transition layer**	To allow the system to drain and function as intended
	Particle size distribution	Bridging criteria D_{15} (drainage layer) ≤ 5 x D_{85} (transition media) *<u>where</u>: D_{15} (drainage layer) - 15th percentile particle size in the drainage layer material (i.e., 15% of the aggregate is smaller than D_{15} mm), and D_{85} (transition layer) - 85th percentile particle size in the transition layer material*	To avoid migration of the transition layer into the drainage layer
	Perforations in underdrain	Perforations must be small enough relative to the drainage layer material Check: **D_{85} (drainage layer) > diameter underdrain pipe perforation**	To prevent the drainage layer material from entering and clogging the underdrainage pipe (if present)
G.	**Depth**	Minimum 50 mm cover over underdrainage pipe (if present)	To protect the underdrain from clogging

2 General Description

3.1 Media layers

The biofiltration filter media guidelines require three layers of media: the filter media itself (400 600 mm deep or as specified in the engineering design), a transition layer (≥ 100 mm deep), and a drainage layer (≥ 50 mm cover over underdrainage pipe). The biofilter will operate so that water will infiltrate into the filter media and move vertically down through the profile. The material used for each of these layers must to meet essential specifications to ensure they serve their intended purpose (outlined in Table 1). For the system to drain appropriately, it is also important that the underlying transition layer has a higher hydraulic conductivity than the filter media, and in turn the drainage layer at the base should have the highest hydraulic conductivity. Importantly, the **use of geotextile fabrics between layer interfaces is not recommended** due to the risk of clogging. The **use of mulch across the biofilter surface is also not recommended** as it hinders maintenance for sediment removal, can restrict plant growth and spread, and clog the overflow.

3.2 Filter media properties

The filter media is required to support a range of vegetation types (from groundcovers to trees) that are adapted to freely draining soils with occasional wetting. This horticultural purpose is essential – without vegetation, the biofilter cannot serve its proper function for stormwater treatment. The material should be based on **natural or amended natural sands** or it can be **entirely engineered**; in either case, it can be of siliceous or calcareous origin.

Where there is not a locally available, natural sand-based material that complies with the properties outlined in Table 1, it is possible to construct an appropriate filter medium. A washed, well-graded sand with an appropriate hydraulic conductivity should be used as the filter medium. A mixture of engineered and natural materials may also be used. The engineered media should meet the same essential specifications given in Table 1. Suitable materials include those used for the construction of turf profiles (e.g. golf greens); these materials are processed by washing to remove clay and silt fractions. In large quantities (→20 m^3), they can be obtained directly from sand suppliers, while smaller quantities can be purchased from local garden yards.

Laboratory testing has shown that biofilters that contain an engineered filter medium will achieve essentially the same hydraulic and treatment performance as those containing a natural filter medium (Bratieres et al., 2009). However, it is recommended that a submerged zone be included in biofilters that utilise such a free draining filter medium to provide a water source for vegetation between rainfall events (Section 5). Biofilter media is deliberately designed to be a barren media as incoming stormwater provides a steady supply of nutrients to support plant growth. It is vital that **no additional soil-based materials are added outside of these specifications**, as this will compromise system function. The only acceptable amendment is a once-off application of ameliorant to aid initial plant establishment (Table 2). In general, the media will have an appropriately high permeability under compaction and be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/Acts), and must not be hydrophobic. The filter media will contain some organic matter for increased water holding capacity. Potential filter media can be assessed by a horticulturalist to ensure that they are capable of supporting a healthy vegetation community.

3.3 Infiltration capacity

Maintaining an adequate infiltration capacity is crucial in ensuring the long-term treatment efficiency of the system. The ability of a biofilter to detain and infiltrate incoming stormwater is a function of the filter surface area, ponding depth, and the hydraulic conductivity of the filter media (Figure 2). Most importantly, design of a biofilter must optimise the combination of these three design elements.

For a biofilter in a temperate climate with a ponding depth of 100 – 300 mm and whose surface area is approximately 2% of the connected impervious area of the contributing catchment, the prescribed hydraulic conductivity will generally be between 100 – 300 mm/hr in order to meet best practice targets (Figure 3). This configuration supports plant growth without requiring too much land space. In warm, humid (sub- and dry- tropical) regions the hydraulic conductivity may need to be higher and/or the surface area may need to be larger (approximately 4%) in order to achieve the required treatment performance (i.e., ensuring that the proportion of water treated through the media meets requirements). However, high hydraulic conductivities (→ 300 mm/hr) present challenging conditions for plant survival which need to be addressed by other aspects of the design (Table 2). It is important to also note that high hydraulic conductivity does not ensure protection against clogging in the long-term, but instead depends upon sediment inputs and the inclusion of pre-treatment devices for protection.

Where one of the design elements falls just outside the recommended range, the desired infiltration capacity of a biofilter can still be achieved by offsetting another of the design elements (Table 2). owever, problems can arise if properties deviate too far outside the recommended range – the likelihood of drought conditions, clogging and sediment accumulation, or a risk to public safety may increase. Some of the different design possibilities have been summarised in Table 2 and, if considered, should be investigated using a model such as MUSIC.

Table 2. Biofilter design – benefits, offsets and risks if designs stray outside the range of recommended specifications

Design property	Benefits or offsets in design	Risks
Undersized biofilter area	Greater inflows, reduced drought potential. Can help offset a high hydraulic conductivity or minimal ponding depth. Even more vital to include sediment pre-treatment to reduce clogging risk.	Reduces treatment capacity. Clogging and sediment accumulation occurs more rapidly, shortening lifespan. Plant drowning likely if clogging or blockage of outlet or overflow occurs, unless rectified quickly. Erosion and scouring from high inflows.
Oversized biofilter area	Increases treatment capacity. Reduced rate of sediment accumulation, increasing lifespan and reducing clogging potential. Can help to offset a slow hydraulic conductivity.	Increased drought potential due to low inflows, particularly in zones far from inlet/s. Greater need for inclusion of a submerged zone.
High hydraulic conductivity	Increases initial treatment capacity. Can help to offset a smaller biofilter area or reduced ponding depth. However, long-term clogging is driven by sediment accumulation, and more influenced by pre-treatment.	Low water holding capacity in media, drought-stress on vegetation more likely and plant survival may not be possible without additional watering or inclusion of a submerged zone.
Low hydraulic conductivity	Greater water holding capacity to support vegetation. Can help to offset an oversized biofilter area.	Reduces treatment capacity. Clogging more likely.
Deep ponding zone	Increases treatment capacity. Can help to offset low hydraulic conductivity or small biofilter area.	Must consider public safety depending upon biofilter location – risk of drowning and tripping hazard. Risks can be reduced with design of ledges, batter slopes or barriers/fencing, but otherwise may need to use reduced ponding depth. Risk of vegetation drowning if system clogs or outlet/overflow blocked.
Shallow ponding zone	Reduces safety risk to public.	Reduces treatment capacity.

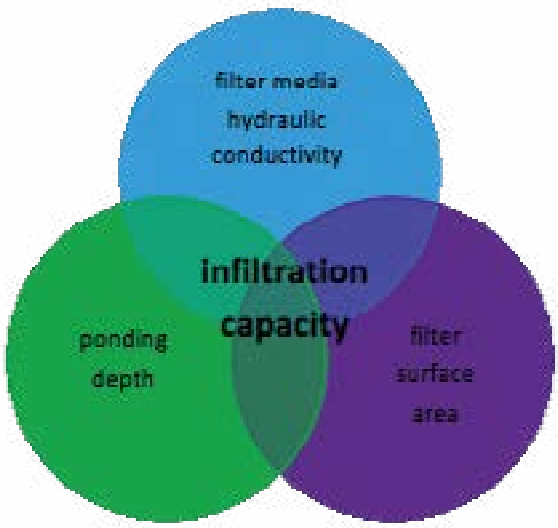

Figure 2. Design elements that influence infiltration capacity.

Figure 3. Recommended filter media hydraulic conductivity range and potential issues

The infiltration capacity of a biofilter will decline during the early part of the establishment phase (first 6 - 12 months of operation) as the filter media settles and compacts, but this will level out and then start to increase as the plant community establishes itself and the rooting depth increases. In order to ensure that the biofilter functions adequately at its eventual (minimum) hydraulic conductivity, a safety co efficient of 2 should be used: i.e., **designs should be modelled using half the prescribed hydraulic conductivity.** If a system does not perform adequately with this hydraulic conductivity, then the area and/or ponding depth should be increased. It may also be desirable to report sensitivity to infiltration rate, rather than simply having one expected rate. This is important when assessing compliance of constructed systems as systems should ideally meet best practice across a range of infiltration rates.

2.4 Designing to prevent clogging

As biofilters work to filter sediment and pollutants from stormwater they will inevitably accumulate fine particles over time. This gradually reduces the infiltration rate over time, eventually leading to clogging and greatly reduced treatment capacity. Most clogging happens in the surface layer and can be removed by scraping off and replacing the surface layer of media as required (discussed further in monitoring and maintenance, Section 4.3).

However, good design can also help to delay the onset of clogging, prolonging biofilter lifespan and improving stormwater treatment performance. Clogging is closely related to particle sizes within the biofilter media. Laboratory studies have found that **clogging can be significantly reduced by including two distinctly different layers of particle sizes, either in separate layers (with a coarse upper layer overlying media with finer particles) or a mixture of different size categories** (Kandra et al., 2014). Including this overlying layer with a coarser particle size leads to better performance, in terms of the volume of stormwater treated and sediment removed, compared to a single layer of media.

Recently, more laboratory trials have been carried out to assess the benefits of including a ‘protective layer’ of distinct particle size distribution and 100 mm thickness above the biofilter media. This protective layer comprises a commercially-available sand-based product (including engineered sands). Using accelerated dosing, these types of designs maintained significantly higher outflow rates in the longer-term relative to designs without a protective surface layer (Hatt et al. 2014). These designs are currently undergoing testing in the field, but the laboratory trials demonstrate the potential for a potential surface layer to prolong biofilter lifespan and reduce clogging.

3 Testing requirements

3.1 Determination of hydraulic conductivity

The hydraulic conductivity of potential filter media should be measured using the ASTM F1815-11 method. This test method uses a compaction method that best represents field conditions and so provides a more realistic assessment of hydraulic conductivity than other test methods. **Do not use AS4419-2003** as this generally leads to overestimation of the in situ hydraulic conductivity.

Note: if a hydraulic conductivity lower than 100 mm/hr is prescribed, the level of compaction associated with the ASTM F1815-11 method may be too severe and so underestimate the actual hydraulic conductivity of the filter media under field conditions. However, this test method is considered to be an appropriately conservative test, and it is therefore recommended even for low conductivity media.

3.2 Particle size distribution

An appropriate PSD is required to provide a stable media (i.e. does not migrate downwards through the biofilter profile), enough water holding capacity to support healthy vegetation, while also allowing a sufficient infiltration rate. The filter media should be well-graded i.e., it should have all particle size ranges present from the 0.05 mm to the 3.4 mm sieve (as defined by (ASTM F1632-03(2010)).

Clay and silt are important for water retention and sorption of dissolved pollutants, however they substantially reduce the hydraulic conductivity of the filter media. This size fraction also influences the structural stability of the material (through migration of particles to block small pores and/or slump). It is essential that the total clay and silt mix is **less than 3% (w/w)**.

Particle size distribution (PSD) is of secondary importance compared with hydraulic conductivity. Further, a material whose PSD falls within the following recommended range does not preclude the need for hydraulic conductivity testing i.e., it does not guarantee that the material will have a suitable hydraulic conductivity. The PSD should be assessed by a horticultural expert for its suitability as a growing medium. **If a material cannot be sourced that meets both the hydraulic conductivity requirement and the suggested PSD below, it may still be suitable**, provided the hydraulic conductivity range is met, it is structurally stable and a horticulturalist deems the media as appropriate to support vegetation. The following composition range (percentage w/w) provides **a useful guide** for selecting an appropriate material:

Clay & Silt	< 3%	(<0.05 mm)
Very Fine Sand	5-30%	(0.05-0.15 mm)
Fine Sand	10-30%	(0.15-0.25 mm)
Medium Sand	40-60%	(0.25-0.5 mm)
Coarse Sand	< 25%	(0.5-1.0 mm)
Very Coarse Sand	0-10%	(1.0mm-2.0mm)
Fine Gravel	< 3%	(2.0-3.4 mm)

4 Once-off initial amelioration

The filter media is designed to be low in nutrient content, as over time incoming stormwater and the turnover of plant roots will provide nutrients and organic matter to support plant growth. However, at the very beginning, the **top 100 mm of the filter medium** needs be ameliorated with appropriate organic matter, fertiliser and trace elements (Table 3). This amelioration is a once-off application to aid initial plant establishment and is designed to last four weeks. Beyond this point, the plants receive adequate nutrients via incoming stormwater and no further fertilisation is generally necessary. The ameliorants will be supplied separately to the media and applied to the surface layer on-site (e.g. using a rotary-hoe).

Testing of the media for its nutrient content and advice from a horticulturalist will indicate the required amendment to support initial plant establishment. However, a general guide for amelioration of the top 100 mm is provided in Table 3.

Table 3. Recipe for ameliorating the top 100 mm of sand filter media

Constituent	**Quantity (kg/100 m^2 filter area)**
Granulated poultry manure fines	50
Superphosphate	2
Magnesium sulphate	3
Potassium sulphate	2
Trace Element Mix	1
Fertilizer NPK (16.4.14)	4
Lime	20

5 Submerged zone and carbon source

The submerged zone (also referred to as a saturated zone) is created using an upturned outlet and use of a liner, which allows ponding in the lower layers of the biofilter (within the transition and drainage layers). Its inclusion is strongly recommended using an upturned outlet, with the moisture retention providing benefits in both unlined (creates a temporary submerged zone) and lined systems (longer-lasting submerged zone). It is particularly beneficial for systems that are unavoidably shallow or over-sized, when nitrogen or pathogen removal is a key objective, or in low rainfall areas. A submerged zone serves multiple roles in biofilter function, including provision of i.) a water supply to support plant and microbial survival across dry periods, ii.) benefits to nitrogen removal, particularly following extended dry periods, iii.) potential for anaerobic (low oxygen) conditions which allow denitrification (which removes nitrogen),and i.) prolonged retention for a volume of stormwater, which provides a longer processing time. For possible design configurations that include a submerged zone please see Section 3.5 of the 'Adoption Guidelines for Stormwater Biofiltration Systems' (Version 2; CRC WSC, 2015).

In lined systems the submerged zone often includes a carbon source mixed throughout the submerged layers. This provides electrons to drive denitrification (a key nitrogen removal process). The carbon source should decompose in the first one to two years of operation, while plant roots develop (which provide carbon over the longer term). The carbon source should comprise approximately 5% (v/v) and include a mixture of mulch and hardwood chips (approximately 6 mm grading), by volume. The **carbon source material needs to be low in nutrients;** appropriate materials include sugar cane mulch, pine chips (without bark) and pine flour ('sawdust'). High nutrient sources such as pea straw (derived from nitrogen-fixing plants) should be avoided as these are likely to leach nitrogen and phosphorus, negating the benefits of including a submerged zone. In addition, straw should not be used as a carbon source, due to reports of odours from some systems using straw. The carbon source is commonly provided separately to the media in bags, and it can be mixed in on site (e.g. using a rotary hoe).

6 Testing the media

In sourcing media for biofilters, test results for the specifications outlined in these guidelines should be sought from suppliers. If possible, it is best to source from experienced and trusted suppliers. This precludes the need for on-site testing; with the condition that a supplier must be able to provide recent test results from the specified source stockpile in their yard. It is important to note all media testing should be conducted in accordance with soil testing standards in this document, Careful consideration must be given to of the number of samples, their collection and the analytical testing method. Test results are only as reliable as the data collection and methodology; it should be recognised that there will be some variation in the stockpile thus collecting one sample from the surface of a stockpile will not provide representative nor useful results. In addition, once media has been delivered to site there is potential for cross-contamination with on-site soils if care is not taken (see Installation Section below), and if this has occurred then on-site testing of the media can place unreasonable liability on the supplier if the media properties no longer meet the specification.

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7 Installation

It is vital that when media is delivered to site it is either stockpiled on a hard surface or tipped directly into the biofilter trench/basin (taking care not to damage any underdrain pipes and ensuring the correct layering and compaction as described below). Otherwise, there is high potential for contamination with on-site soils during earthmoving works. Even a small amount of clay or silt can be severely detrimental to the long-term function of the biofilter and is likely to require expensive reinstatement works.

It is recommended that filter media be lightly compacted during installation to prevent migration of fine particles. In small systems, a single pass with a vibrating plate should be used to compact the filter media, while in large systems, a single pass with roller machinery (e.g. a drum lawn roller) should be performed. Under no circumstance should heavy compaction or multiple-passes be made. Filter media should be installed in two lifts unless the depth is less than 500 mm.

Following construction the plant establishment period is a crucial stage, with long-term success of the biofilter hinging on the development of healthy vegetation cover. It is vital to closely monitor the health of the seedlings and functioning of the new biofilter, and to provide additional watering to plants during this vulnerable stage. Further details can be found in the 'Adoption Guidelines for Stormwater Biofiltration Systems' (Version 2; CRC for Water Sensitive Cities, 2015) or Water by Design (2009).

8 Field testing

It is recommended that field testing, or sampling for laboratory testing, of hydraulic conductivity be carried out 1. in the second year of operation to assess the impact of inflow sediment and vegetation on hydraulic conductivity, 2. in mature systems (e.g. 8+ years) or 3. to investigate and diagnose problems in systems suffering from poor infiltration.

The hydraulic conductivity of the filter media should be checked at a minimum of three points within the system. The single ring, constant head infiltration test method (shallow test), as described by Le Coustumer et al. (2007), should be used for field testing. Alternatively, depending upon the resources and expertise available, samples of media can be collected (either in cores or grab samples). Samples may be combined (or composited) across the entire system or between zones in large systems (e.g. near inlet). The surface layer can be selectively sampled, as can deeper layers, to diagnose any problems within the profile. Further details on testing methodology can be found in Appendix I of the Biofilter Adoption Guidelines (CRC for Water Sensitive Cities, 2015).

Given the inherent variability in hydraulic conductivity testing and the heterogeneity of the filter media, the laboratory and field results are considered comparable if they are within 50% of each other. However, even if they differ by more than 50%, the system will still function if both the field and laboratory results are within the relevant recommended range of hydraulic conductivities.

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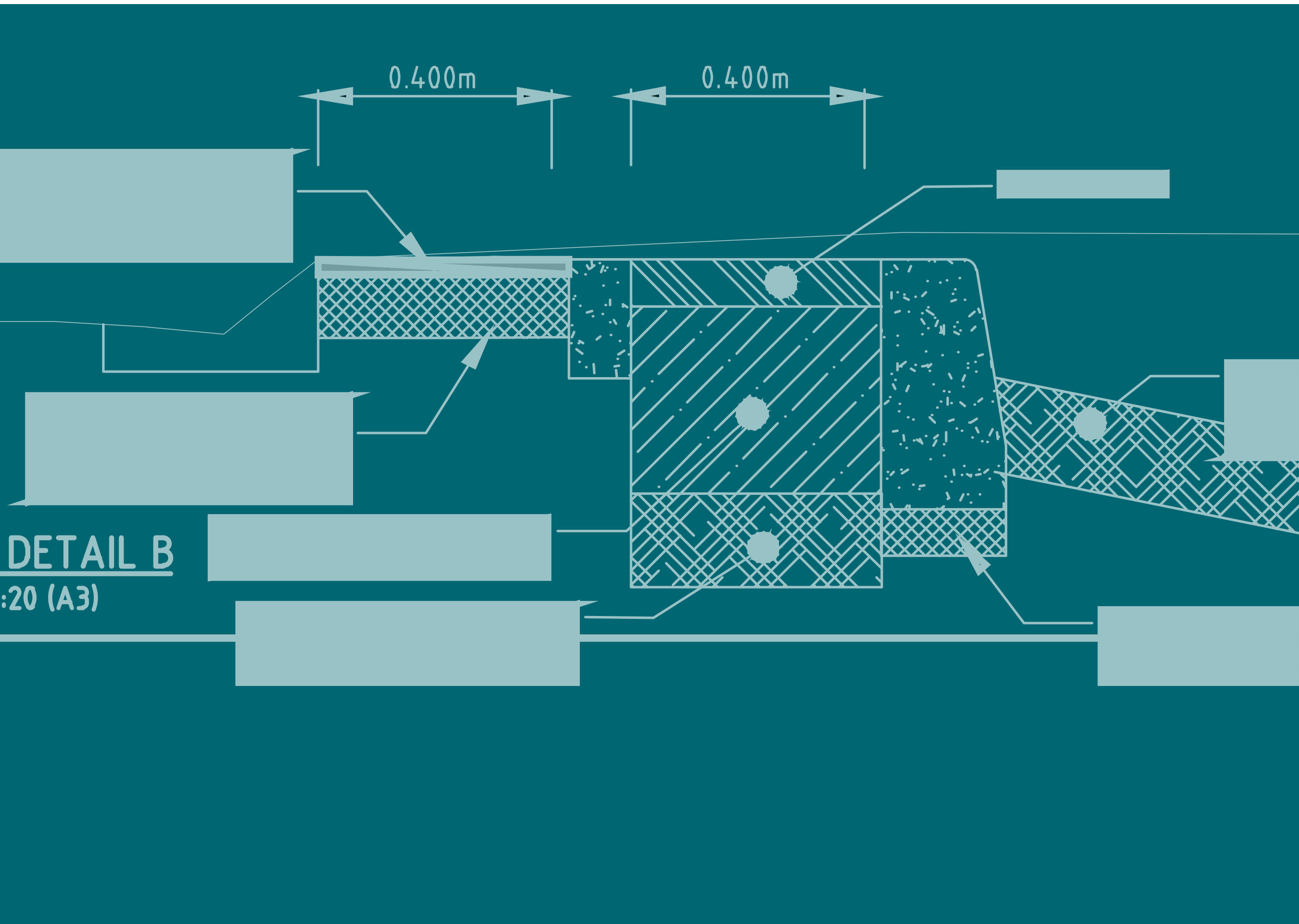
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