SPECIFICATIONS

water by design
an initiative of
Healthy land & water

Specifications for bioretention filter media

Version 1.0

Version history

#	Date	Title	Contributors
1.0	September 2023	*Specifications for bioretention filter media*	Technical content by Paul Dubowski and Ben Penhallurick. Reviews provided by Paul Dubowski, Ben Penhallurick, Nicole Ramilo, Jonas Larsen, Dr Kylie Drapala and Dr Andrew O'Neill. Images provided by Paul Dubowski.

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Purpose

This document provides specifications for filter media as well as advice and options to improve and maintain healthy plants in bioretention systems.

About Water by Design

Healthy Land & Water's Water by Design initiative works with individuals and organisations to identify and fill knowledge gaps and facilitate the uptake of improved practices in sustainable water management. For more information visit www.waterbydesign.com.au.

About Healthy Land & Water

Healthy Land & Water is the peak environmental group for South East Queensland. For over 20 years it has been dedicated to investing in and leading initiatives to build the prosperity, liveability, and sustainability of our future region. Healthy Land & Water is focused on delivering an environment for future generations to thrive.

We are experts in research, monitoring, evaluation, and project management. Our team has led many thousands of projects to restore receiving waters and landscapes, improve native habitats, manage weeds, protect native species, inform policy, and educate communities on the best ways to improve and protect the environment.

Working in partnership with Traditional Owners, government, private industry, utilities and the community, Healthy Land & Water delivers innovative and science-based solutions to challenges affecting the environment. Through a combination of scientific expertise and on-ground management works, Healthy Land & Water lead and connect through science and actions that will preserve and enhance our natural assets and support resilient regions long into the future.

Traditional Owner acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Nations' Peoples for tens of thousands of years. We believe the spiritual, cultural, and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

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Queensland Government

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List of abbreviations and acronyms

CEC	Cation exchange capacity
CRCSWC	Cooperative Research Centre for Water Sensitive Cities
FAWB	Facility for Advancing Water Biofiltration
SOM	Soil organic matter
TOC	Total organic carbon (sometimes referred to as soil organic carbon)
WSUD	Water sensitive urban design

1 INTRODUCTION

The specifications presented in this document seek to incorporate the best available science since the publication of the FAWB guidelines (2009) while also addressing the issue of plant dieback in bioretention systems observed across Australia. A range of other benefits are also expected, as discussed in Section 3 of *Improving the biology of bioretention systems* (Water by Design 2023).

The specifications are based primarily on *Guidelines for Filter Media in Biofiltration Systems* (FAWB 2009) and *Adoption Guidelines for Stormwater Biofiltration Systems* (CRCWSC 2015). The three most notable exceptions are the specifications for organic matter content, hydraulic conductivity and particle size distribution, which have been changed. Each of these are discussed in greater detail in Section 3 of *Improving the biology of bioretention systems* (Water by Design 2023). Other minor amendments have also been made regarding specification parameters and media testing, which have been derived from recent work by Blacktown City Council (2021).

This document has been released with the specific intent to further capitalise upon emerging science and practice with a view to enhance the specifications over time.

We have enabled a 12 month feedback period on this document to ensure it is fit for purpose and captures end user experience. We welcome your feedback and encourage you to submit all comments to info@hlw.org.au by 1 September 2024.

2 SPECIFICATIONS

This document covers specifications for bioretention filter media, compost, transition layer and drainage layer materials. The bioretention filter media and compost specifications have been based on the above discussion and review of the best available scientific literature, specifications and standards. Ideally, these specifications will be validated through future monitoring and research.

However, given the pragmatic need to improve plant establishment and survival in bioretention systems, and as these specifications are based on the best available science, they are encouraged to be used prior to further validation. It is expected that these specifications will be revised as new monitoring and research data becomes available.

The transition layer and drainage layer specifications remain generally consistent with previous Water by Design guidance and the FAWB (2009) and CRCWSC (2015) specifications. They are included here for the sake of completeness.

Refer to the *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design 2022) for guidance on testing and chain of custody requirements.

Table 2.1 Essential bioretention filter media specifications.

Parameter	Range/limit	Testing method
Material	Must be free draining, non-toxic, structurally stable and support plant growth. Must comply with bioassay requirements in *AS 4419:2018* for landscape soils (on grade) (i.e. >60 mm or or ≤20% worm avoidance)	*AS 4419:2018 Appendix I*
Hydraulic conductivity	100 – 750 mm/hour	*ASTM F1815-11(2018)*
Total nitrogen (TN)	<1000 mg/kg	*AS 4454-2012 Appendix C* (Induction Furnace or Wet Chemical)
Available phosphate (Colwell)	<80 mg/kg	*AS 4419 Appendix F* (Colwell)
Total organic carbon (TOC)	After mixing with compost, 2 – 3% (w/w)*	*AS 1289.4.1.1* as referenced in *AS 4419:2018*
pH	5.5 – 7.5 (pH 1:5 in water)	*AS 4419:2018 Appendix D*
Electrical conductivity (EC)	<1.2 dS/m	*AS 4419:2018 Appendix D*
Cation exchange capacity (CEC)	3 cmol$^+$/kg ECEC as per *AS 4419:2018*	*Per Soil Chemical Methods – Australasia* (Rayment & Lyons 2011, CSIRO Publishing)
Water holding capacity (WHC)	>20% at 30 cm suction	*AS 3743-2003 Appendix B*
Acid sulphate soils	Filter media must be free from actual and potential acid sulphate soils	*AS 4969* and/or the *Queensland Laboratory Methods Guidelines*
Water repellence	≤60 s (water) or rating of ≤5 (ethanol)	*AS 4419:2018 Appendix C*
Bioassay	>60 mm root growth or ≤20% worm avoidance	*AS 4419 Appendix I*

* Feedstock for TOC should be consistent with acceptable feedstock provided in the compost specifications below. Acknowledging that organic carbon content and density vary between feedstocks and even stockpiles of the same feedstock, 2 – 3% w/w TOC is expected to equate to approximately 10 – 30% organic matter by volume.

Table 2.2 provides optional filter media specifications. Particle size distribution should be considered flexible as long as hydraulic conductivity is within the range/limit in Table 2.1.

Table 2.2 Optional bioretention filter media specifications.

Parameter	Range/limit*	Testing method*
Particle size distribution (PSD)	The filter media should be well-graded and should have all particle size ranges present from the 0.075 mm to the 4.75 mm sieve as defined by *AS 1289.3.6.1* Clay and silt (<0.05 mm): 2 – 5% Clay, silt and very fine sand (<0.15 mm): <10% Compost: <20% of compost may have particle sizes >16 mm, large particles (>20 mm) must be <2%	*ASTM F1632-03(2018)* (USGA Method)

* Values may vary widely.

2.2 Compost

Table 2.3 provides the essential compost specifications. This should be used for the compost mixed into the bioretention filter media to make up the TOC and the compost layer on the surface as indicated in Figure 2.1. The types of feedstock listed below the table must be used to make up the compost.

Table 2.3 Essential compost specifications.

Parameter	Range/limit*	Testing method
Material on top of filter media (compost layer)	100% (w/w) 100% organic 'mature compost' as defined by *AS 4454-2012*. Refer to Table 3.1(A) of AS 4454-2012 and *MRTS16 Form G*	*AS 4454-2012*, *MRTS16 Form G*, and labile carbon test (permanent oxidizable carbon (POXC))
Material mixed into filter media	Prior to mixing with filter media. 100% organic 'mature compost' as defined by *AS 4454-2012**. Refer to Table 3.1(A) of *AS 4454-2012* and *MRTS16 Form G*	*AS 4454-2012*, *MRTS16 Form G*, and labile carbon test (permanent oxidizable carbon (POXC))

* The value adopted here accounts for TOC of the bioretention filter media specified in Table 3.1 of *Improving the biology of bioretention systems* (Water by Design 2023).

A suitable organic matter with a low nutrient leaching potential must be used.

The following types of feedstock are acceptable:
- Composted green waste.
- Composted pine bark.
- Coconut coir (This may offer additional benefits to water quality performance. Tota-Maharaj and Cheddie (2015) demonstrated up to 90% removal of nitrate, phosphorous, and faecal indicator bacteria by coconut products from natural stormwater runoff).
- Composted wood chip fines.
- Sugar cane bagasse.
- Composted saw dust.

A combination of these feedstocks is also acceptable. It is recommended that the compost layered on top of the filter media is 100 mm deep.

High nutrient composts from feedstocks such as biosolids, manures, food waste, cooking oil/grease, mushroom compost, commercial/industrial waste, and vermicast have a high nutrient leaching potential and are not suitable to be used in bioretention systems. Peat should also not be used as a source of compost because it is non-renewable. Peatlands are an important store of soil carbon and their harvesting and use releases carbon dioxide, the major greenhouse gas driving climate change.

There is no suggested upper limit for labile carbon in the compost at this stage. The labile carbon content is expected to be limited by the use of 100% organic ‘mature compost’ (consistent with *AS 4454-2012*) and the use of acceptable feedstocks. Nevertheless, understanding how much labile carbon goes into filter media will help build industry knowledge over time.

As WSUD practitioners become familiar with how much labile carbon can be expected in a compliant mature compost, the labile carbon test will become an indicator of whether or not a compost is indeed sourced from an appropriate feedstock. Undertaking the permanganate-oxidizable carbon (POXC) test therefore provides value which far outweighs the cost of the test.

2.2.1 Compost installation

Several studies have found that layering the compost rather than mixing it through the filter media has resulted in less nitrate leaching, at least for the first flush (Hsieh and Davis 2005; Wan *et al*. 2015; Logsdon and Sauer 2016). It is suggested that the compost which does not form part of the filter media is placed between the filter media and the mulch, as shown in Figure 2.1. In the same way that a mulch layer does not change how a bioretention system is modelled, the addition of a compost layer should not change how a bioretention system is modelled.

Further advice on mulching options is provided in the *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design 2022).

Mullane *et al*. (2015) and Xia *et al*. (2007) observed that an initial washout of nutrients can be an issue for composts. Consequently, it is also recommended that prior to delivery to site, all compost is soaked and rinsed to reduce nutrient leaching from the bioretention system. This also applies to the compost being mixed with the bioretention filter media by the supplier. All compost is to be soaked for at least 24 hours and then rinsed for at least two hours prior to mixing with bioretention filter media or layering on top of the filter media. Soaking and rinsing should be undertaken by the supplier, ensuring that the water is not discharged to the local stormwater network or waterways, as it will be high in nutrients and therefore an unlawful contaminant subject to regulatory enforcement.

Beyond the compost requirements outlined in these specifications, further surface amelioration (e.g. as outlined in the FAWB (2009) and CRCWSC (2015) guidelines) is not recommended.

It should be noted that mulching is required in addition to compost. Mulching on top of the compost can be undertaken in accordance with the *Guidelines for the construction and establishment of bioretention systems and wetlands* (Water by Design 2022).

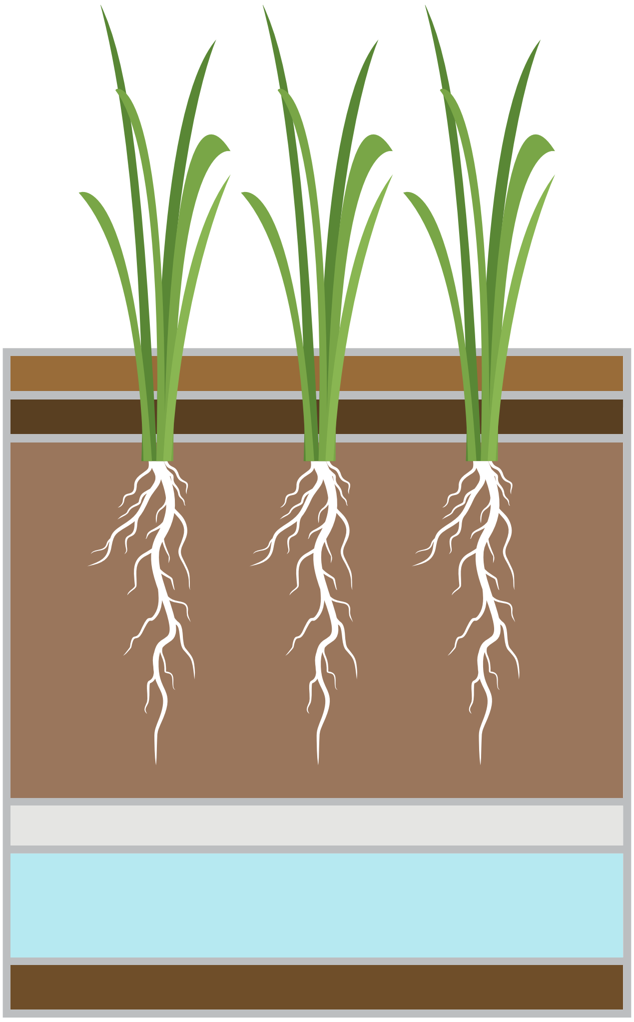

Figure 2.1 Layering of compost on top of filter media.

2.3 Transition layer

Table 2.4 provides essential transition layer specifications.

Table 2.4 Essential transition layer specifications.

Parameter	Range/limit*	Testing method
Material	Must be a clean, well-graded sand/coarse material. Use of a well-washed recycled glass is acceptable	
Hydraulic conductivity	>1.5 x hydraulic conductivity of filter media	*ASTM F1815-11(2018)*
Particle size distribution (PSD)	Clay and silt (0.05 mm): <2%	*ASTM F1632-03(2018)* (USGA Method)
Bridging criteria	D15 (transition layer) ≤5 x D85 (filter media)	*ASTM F1632-03(2018)* (USGA Method)

* Values may vary.

Bridging criteria is based on engineering principles that rely on the largest 15% of the filter media particles bridging with the smallest 15% of the particles. This results in smaller voids, which prevents the migration of filter media particles into the transition layer. The bridging criteria formula provided is taken from the VicRoads *Drainage of subsurface water from roads* (2004).

Where: D15 (transition layer) is the 15th percentile particle size in the transition layer material (i.e. 15% of the sand is smaller than D15 mm), and D85 (filter media) is the 85th percentile particle size in the filter media.

The transition layer can be omitted from the bioretention media provided the filter media and drainage layer meets the following criteria, as defined by VicRoads (2004):

- D15 (drainage layer) ≤ 5 x D85 (filter media).
- D15 (drainage layer) = 5 to 20 x D15 (filter media).
- D50 (drainage layer < 25 x D50 (filter media).
- D60 (drainage layer) < 20 x D10 (drainage layer).

These comparisons are best made by plotting the particle size distributions for the filter media and gravel on the same soil grading graphs and extracting the relevant diameters.

2.4 Drainage layer

Table 2.5 provides essential drainage layer specifications.

Table 2.5 Essential drainage layer specifications.

Parameter	Range/limit*	Testing method
Material	Clean gravel washed screenings (not scoria). Recycled concrete or brick products will not be accepted	
Particle size distribution	Clay and silt (0.05 mm): <2%	*ASTM F1815-11(2018)*
Bridging criteria	D15 (drainage layer) ≤5 x D85 (transition layer)*	*ASTM F1632-03(2018)* (USGA Wet Sieve Method)

* Values may vary.

Bridging criteria is based on engineering principles that rely on the largest 15% of the transition layer particles bridging with the smallest 15% of the particles. This results in smaller voids, which prevents the migration of transition layer particles into the drainage layer. The bridging criteria formula provided is taken from the VicRoads *Drainage of subsurface water from roads* (2004).

Where: D15 (drainage layer) is the 15th percentile particle size in the drainage layer material (i.e. 15% of the aggregate is smaller than D15 mm), and D85 (transition layer) is the 85th percentile particle size in the transition layer material.

2.5 Saturated zone

Saturated zones provide both improved stormwater quality outcomes and a source of water for plants. They could potentially be viewed as an alternative to the provision of compost if all the other benefits of compost described above are ignored. However, it will not always be possible to provide saturated zones in bioretention systems (e.g. where exfiltration is desired or where site constraints prohibit their use).

Equally, while the addition of compost to bioretention systems will improve water holding capacity, the use of compost may not be a replacement for saturated zones in every scenario. LeFevre *et al*. (2015) argue that:

- For true net nitrogen removal from stormwater to occur, a combination of biological denitrification and plant uptake with biomass harvesting is needed.
- Creation of anoxic zones by adding electron donors to the media and/or by maintaining saturation of the media during between flow events facilitates the necessary denitrification.

The use of compost and saturated zones should therefore be considered complimentary design responses to improve both stormwater quality and plant survival.

If saturated zones are used, they should consist of:

- 400 – 500 mm depth (but may be deeper depending on the specific application).
- 10 – 20 mm of clean gravel or coarse washed sand or small rocks of 50 mm diameter maximum.
- 2% by volume of a short-term carbon source (preferably fine straw).
- 4 – 6% by volume of a long-term carbon source (preferably 5 – 40 mm hardwood chips) to support the denitrification process.

The mixing of these media should be undertaken by the local supplier prior to delivery (preferred). If this is not feasible, it can be undertaken by civil contractors on site. For a more detailed description of saturated zone specifications, refer to Chapter 5 of the *Water Sensitive Urban Design Guidelines for the Coastal Dry Tropics (Townsville)* (Townsville City Council 2011).

It is also worth noting that Kim *et al*. (2003) identified newspaper as the best electron donor among the different organic and inorganic materials they investigated (including alfalfa, leaf mulch compost, newspaper, sawdust, wheat straw, wood chips, and elemental sulphur). Therefore, there may be scope to amend the above saturated zone specifications that recommend the use of straw.

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