RESIDENTIAL DWELLING DEVELOPMENT

LOT 79 DP752017

79 KUMARNA STREET

DUFFYS FOREST. NSW. 2084

STORMWATER QUALITY ASSESSMENT

Prepared by SOWDES
25 October 2019

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Drawing No. 0030616-01SW Stormwater Management Site Plan. (A1 Plan)	Loose

This report is supported by two separate *MUSIC* models – one for the water quality assessment and the other for the hydrological assessment. Refer to the electronic submission of the development application for a copy of the relevant sqz files.

STORMWATER QUALITY ASSESSMENT

Introduction.

SOWDES has been commissioned by the proponents of a residential dwelling development to be established on a portion of land identified as Lot 79 DP752017 – 79 Kumarna Street at Duffys Forest. NSW. 2084 to undertake an assessment of the proposed development relating to the management and treatment of stormwater quality, and the discharge of stormwater to natural receiving systems.

This report and its recommendations have been compiled with reference to and consideration of the Warringah Council Control Plan (2011, and as amended 2097), 'Northern Beaches Council – WSUD & MUSIC Modelling Guidelines (June 2016)', PL850 – Water Management Policy (July 2017), relevant Australian and industry standards and guidelines, the development site layout as proposed in the Stormwater Management Site Plan prepared by SOWDES Ref: 0030616-01C, proposed stormwater and sewer drainage infrastructure, neighbouring developments and all existing site conditions.

Where practical and appropriate, the recommendations, constraints and conditions from the above listed reports and documents have taken precedence in the design process such that any water quality issues, environmental concerns and matters pertaining to public amenity have been addressed. The proponents through their appointed representatives have been involved throughout the design and recommendation process by contributing to the information source and providing general commentary on the overall system outcomes.

The basis of this report and its recommendations are derived from information obtained by the requesting and/or developing party. Changes pertaining to location, orientation, size and/or design may render the contents of this report inappropriate and hence invalid. Any such occurrence is beyond the control of the author and hence responsibility for accuracy and validity is passed. Further, data and input parameter values associated with any modelling program and are understood to be current and valid at the time of compiling the report, hence any changes to these protocols is beyond the reasonable control of the author and with such, the recommendations contained in this report are construed in good faith.

1. DEVELOPMENT DETAILS		
#	***DESCRIPTION***	***DETAIL***
1.1	Property details	Lot 79 DP752017
1.2	Address	79 Kumarna Street, Duffys Forest. NSW. 2084
1.3	Land zoning	'RU4' Primary Production Small Lots (Warringah Local Environmental Plan 2011 - Land Zone Map 002)
1.4	Development details	The development proposal is for the construction of a new residential dwelling and ancillary infrastructure which includes driveways and paths, detailed landscaping, horse stable complex, covered sand arena, round exercise yard, and a private swimming pool.
1.5		The development property is not serviced by a gravity sewer drainage system or inter-allotment stormwater drainage thereby requiring the development be self-sufficient in the provision of these services.
1.6		It is further noted that the site is not readily able to connect to the reticulated water supply with advice from Sydney Water being that the likelihood of connection is prohibitive due to flow and pressure restrictions from the existing mains system which is located approximately 150 metres from the southeastern boundary of the property.
1.7		It is proposed that the development will harvest rainwater from all roof catchment areas in suitable storage tanks to meet the demands of all potable, animal husbandry, and external applications.
1.8		The proposed dwelling will be located in the southern half of the allotment with the stables complex, covered sand area, round yard and rainwater storage tanks to be located along the southwestern boundary.
1.9		The northwestern third of the site which represents the lower elevations of the site and which is presently set to open grasslands will be partitioned into several grazing paddocks
1.10		The northern and eastern portions of the site are set to stands of variable quality Duffys Forest EEC and will not be disturbed or impacted by the development.
1.11		An assessment of the onsite management of effluent has been prepared by SOWDES as a separate document titled 'Wastewater Management Assessment' which has also considered the impact on water quality and the protection of environmentally sensitive areas, and therefore wastewater management as a potential source of stormwater quality pollution will not be addressed specifically within the scope of this report.

2. EXISTING SITE CONDITIONS		
#	***DESCRIPTION***	***DETAIL***
2.1	Area	The development property covers an area of approximately 2.011 hectares and is essentially rectangular in shape with the block rotated such that the diagonal length is almost in a north – south alignment.
2.2	Access	Access to the development property is from the Kumara Street road corridor which junctions off Mallawa Road to the south and on paper junctions with Cullamine Road to the north.
2.3		Kumarna Street is for the most part an unformed road with a meandering gravel track amongst forested vegetation formations providing access to the development property, however beyond the property entrance the road is basically formed as a narrow walking track.
2.4	Slope / topography	The terrain throughout the development property is highlighted by a small hillock located in the southern third with falls shedding in all directions, however the majority of the site falls from the crest of the hillock toward the northwest at an average grade of 8°.
2.5		There is a clearly formed ridge line that links the front entrance of the site to the residential development precinct with all the terrain on the southeastern side of the ridge being largely undeveloped tending to slope toward the east.
2.6		There are several rocky outcrops evident across the site, predominantly in the northern portion of the site where the Duffys Forest EEC is located and along the crest of the hillock in the southern half.
2.7	Site stormwater drainage	The development property is not serviced by an inter-allotment stormwater drainage system and is thereby required to manage all stormwater runoff on the site.
2.8		At present stormwater runoff follows the natural shape of the terrain with the majority exiting the property approximately midway along the northwestern boundary as unconcentrated sheet flows.
2.9		The site is not burdened by any defined drainage depressions or dams with the nearest mapped drainage corridor being located approximately 330 metres to the north of the property within the Kur-Ring-Gai Chase National Park which is a small tributary that forms part of the upper catchment of the Cowan Creek and Hawkesbury River systems
2.10	Vegetation	The vegetation formations throughout the property are set a blend of Duffys Forest EEC and non-threatened plant communities on the northwestern, northern, eastern and

		southern aspects, with managed lands in the neighbouring properties to the east, south, and southwest.
2.11		The northwestern quarter of the site has historically been cleared of forested vegetation formations and is subsequently set to a blend of open grassland paddocks and scattered native trees.
2.12	Soils	As a general description the soils are derived of a sandstone parent material and comprise a silty/sandy loam topsoil to 300mm followed by a sandy loam to sandy clay loam at depths of around 700mm and deeper.
2.13		There are several rocky outcrops evident across the site, predominantly in the northern portion where the Duffys Forest EEC is located and along the crest of the hillock in the southern half.
2.14	Constraints / other matters	The development property is not serviced by an inter-allotment stormwater drainage system thereby requiring all stormwater runoff to be directed to the lower elevations of the site for discharge to the natural landscapes below the northwestern boundary.
2.15		The transformation of surface finishes from greenfield to various hardstands will require all stormwater runoff to be treated through passive measures prior to discharge from the site to ensure that there is a beneficial effect on water quality.
2.16		Stormwater runoff from the roofed areas will be harvested to supply all potable, animal husbandry and external applications, including firefighting provisions.
2.17		As the site does not discharge stormwater to a formal 'pit and pipe' system there is a requirement to ensure that discharges are not concentrated and that they comply with Council's stormwater policy for 'level spreaders'.

Table 1. Summary of the different hardstand surface and types identified in the post-development conditions and the associated pollutant parameter within the MUSIC model. All figures are expressed in m². Refer to the accompanying Stormwater Management Site Plan – Ref: 0030616-01C for location details of the catchment areas.

Description of Surface	Area (m²) and Pollutant Parameter		
	Roofs 100% impervious (Roof)	Decomposed Granite 50% impervious (Unsealed roads)	Sand 50% impervious (Unsealed roads)
Dwelling	600		
Stables complex	430		
Covered sand arena	1360		
Driveway sections			
C-01		180	
C-02		380	
C-03		470	
C-04		350	
C-05		480	
C-06		100	
C-07		900	
C-08		380	
C-09 - Open stable yards			290
C-10 - Round exercise yard			200
Column Totals	2390	3240	490
Development Totals (m²)	6120		

3. *MUSIC* MODELLING & STORMWATER DRAINAGE DETAILS

#	*DESCRIPTION*	*DETAIL*	
3.1	Model Version	6.3.1	
3.2	Rainfall data	Sydney Observatory – pluviograph data at 6-minute time steps from 1st January 1981 to 31st December 1985	
3.3	Reduction targets	Total Suspended Solids	≥85%
		Total Phosphorus	≥65%
		Total Nitrogen	≥45%
		Gross Pollutants	≥90%
3.4	Modelling assumptions / settings	The development property covers an area of 2.011 hectares which for descriptive purposes in the pre-development conditions is deemed to be vacant and undeveloped lands	
3.5		The proposed development will form a 'development precinct' of approximately 11350m² of which 6120m² will be formed into a mix of hardstand areas of varying nature that will generate runoff, with the remaining 5230m² to set to purpose-design landscaping.	
3.6		Only the 6120m² deemed to be hardstand in the post-development scenario has been included within the model as it assumed the transformation of existing vacant land to purpose-designed landscaped will have a neutral effect on water quality.	
3.7		The directly connected impervious areas generating runoff have been divided into several smaller sub-catchments which are summarised in Table 1.	
3.8		The roofed areas of the residential dwelling, the stables complex, and the sand arena will direct rainwater runoff to rainwater tanks as follows: • Residential dwelling – 100,000 litre inground water tank to be located on the northwestern aspect of the development precinct – below the proposed pool. Water will be reused at the nominal rate of 1,200 litres per day for all domestic and potable applications. The figure of 1,200 litres per day is determined in accordance with the design calculations associated with the Wastewater Management Assessment. • Stables complex – a bank of at least three 22,500 litre rainwater tanks (ST-1, ST-2, ST-3) to be located at the rear of the sand arena. The tanks will be plumbed 'in-series' so that the standing water level across all tanks will rise and fall equally. Water will be reused at the nominal rate of 400 litres per tank per day which is to supply external applications such as animal husbandry, external irrigation, cleaning and washing cars and external areas, and topping the pool systems.	

		• Sand arena – a bank of at least three 22,500 litre rainwater tanks (SA-1, SA-2, SA-3) to be located at the rear of the sand arena. The tanks will be plumbed 'in-series' so that the standing water level across all tanks will rise and fall equally. Water will be reused at the nominal rate of 200 litres per tank per day which is to supply external applications such as animal husbandry, external irrigation, cleaning and washing cars and external areas, and topping the pool systems.
3.9		The rainwater tank efficiency for the residential dwelling when run through the hydrological model suggests that the 100,000 litre rainwater tank will satisfy 89% of supply demands, whilst the stable complex and sand arena tanks systems will satisfy 100% of the supply demands.
3.10		It is noted that the hydrological model suggests that only 56% of rainwater runoff from the roof area of the residential dwelling will be retained with the remainder lost to overflows which would be associated with rainfall occurring when the tank is close to full at commencement of the event, or when the duration is long enough to more than fill the tanks
3.11		The stable complex and sand arena have load reductions in the order of 29% and 9% respectively.
3.12		It is proposed that the inground tank servicing the residential dwelling will have a low-level float set at approximately 25% of the tank's capacity that will activate a transfer of water from the rainwater tanks at the rear of the sand arena to raise the level to 50% of capacity.
3.13		This transfer system will ensure that there is adequate harvesting and storage capacity in the residential tank for subsequent rain events, and also for the banks of tanks at the rear of the sand arena structure.
3.14		Overflow from the residential rainwater tank will be directed through a 225Ø uPVC stormwater line to the site's discharge point located along the northwestern boundary of the site
3.15		The overflow from the separate banks of rainwater tanks at the rear of the sand arena will be directed to a fourth tank to be used for temporary detentions purposes, with the low-level and high-level outlets of the detention tanks connected to a separate 225Ø uPVC stormwater line that will also drain to the site's discharge point along the northwestern boundary of the site the – refer to Items 3.20 – 3.22 for further details.
3.16		The remaining hardstand areas of the developed site such as driveways, pathways and unsealed trafficable areas have been

		divided into small sub-catchment areas that will effectively generate runoff with entrapped pollutant loadings.
3.17		The landscaping plan prepared for the development has nominated that all driveway and pathways will be a compacted decomposed granite material which has been attributed a 50% impervious value in the model
3.18		The proposed open yards at the rear of the stables complex and the round yard in the southwest corner are designated a sand base but have also been attributed a 50% impervious fraction in the model
3.19		These identified areas have been designated a biofiltration raingarden system as a passive form of water quality treatment
3.20		In total there are 12 separate biofiltration treatment devices, all of varying surface area size but with the same construction characteristics for ease of installation
3.21		Within the accompanying Stormwater Management Site Plan (Ref: 0030616-01C) the individual catchment areas are allocated an identification number which will match to a corresponding biofiltration raingarden system – for example 'C-01' (catchment area 1) will correspond with 'BF-01' (biofiltration raingarden 1)
3.22		Three separate and small sections of proposed pathways – two around the sand arena and one adjacent to the round yard in the northwest corner of the site that have a combined area of 380m² will not be actively treated in a biofiltration raingarden device, and these have been identified with a separate numbering sequence beginning with 'UC' – which stands for 'untreated catchment'.
3.23		Whilst these three small areas have not been given any direct water quality treatment it is recognised that some level of treatment may be achieved through buffering effects and overland flow through vegetated and ground covers that would be beneficial.
3.24		The total surface area of all hardstand surface areas excluding roofed catchments is 3730m² whilst the total surface area of the biofiltration raingarden systems is 240m².
3.25		Filtered water from the individual biofiltration raingardens will be collected in stormwater drainage pipes and directed to the site's stormwater drainage point along the northwest boundary.
3.26		The site's stormwater discharge point will be formed as a broad rock-lined energy dissipator that is 10 metres long and 1.5 metres wide.
3.27		The two ends of the energy dissipator will be 3 metres in length and be raised by 300mm to ensure that the majority of flows are confined to the central 4 metre section of the system.

3.28		The energy dissipator will be approximately 500mm thick and keyed into the surface by approximately 250mm with rocks averaging 150 to 200mm in diameter.
3.29		The invert level of the incoming pipes will be same as the finished level of the central portion of the energy dissipator with pipes entering from the sides of the system to be installed through the raised end sections.
3.30	'Peak Discharge' and 'On-Site Stormwater Detention'	It is difficult to effectively model a peak discharge flow rate for the scope of the development given the combination of roof and hardstand areas that are directed to various water quality treatment devices and rainwater tanks, and that are also affected by the roughness of various landscaping and ground covers.
3.31		The complexity of modelling such a development inclusive of water quality treatment devices in a software program such as *DRAINS* or similar is too subjective to generate a reliable peak discharge outcome that could be considered robust for pre-development and post-development comparison purposes.
3.32		It is considered that the most likely source of rapid discharge from the site will be associated with the roofed sections and the overflow from the rainwater tanks - the driveway and path areas will be directed as general overland flows through the biofiltration systems and associated outlet pipes which will tend to absorb and/or attenuate peak flows.
3.33		As a means of providing an degree of stormwater detention and attenuation of peak discharge it is proposed that a fourth 'detention tank' of 22,500 litres will be added to each bank of tanks servicing the stables complex and the sand arena that will collect the overflow from each bank and then discharge gradually to the stormwater drainage system via a small orifice outlet at the base of the tank – nominally 40mm.
3.34		The detention tanks will still be connected to the stormwater system via the normal high-level outlet provisions to control discharges in large storm events.
3.35		All stormwater gathered in piped drainage system will be directed to the level spreader at the discharge point along the northwestern boundary and will be gradually discharged as a broad and unconcentrated flows
3.36		It is noted that the stormwater discharge point is located adjacent to Cullamine Road which is unformed, and that the outflows from the site will drain passively into the Kur-Ring-Gai Chase National Park located on the other side of the road reserve - therefore not burdening any neighbouring property owners or developments.

Table 2. Base flow pollutant concentrations used in the pre-development and post development stormwater model.

Concentration (mg/L-log$_{10}$)						
	Suspended solids		Phosphorus		Nitrogen	
Surface type	mean	std. dev	mean	std. dev	mean	std. dev
Roofs	1.20	0.17	-0.85	0.19	0.11	0.12
Unsealed Roads	1.20	0.17	-0.85	0.19	0.11	0.12

Table 3. Storm flow pollutant concentrations used in the pre-development and post development stormwater model.

Concentration (mg/L-log$_{10}$)						
	Suspended solids		Phosphorus		Nitrogen	
Surface type	mean	std. dev	mean	std. dev	mean	std. dev
Roofs	1.30	0.32	-0.89	0.25	0.30	0.19
Unsealed Roads	3.00	0.32	-0.30	0.25	0.34	0.19

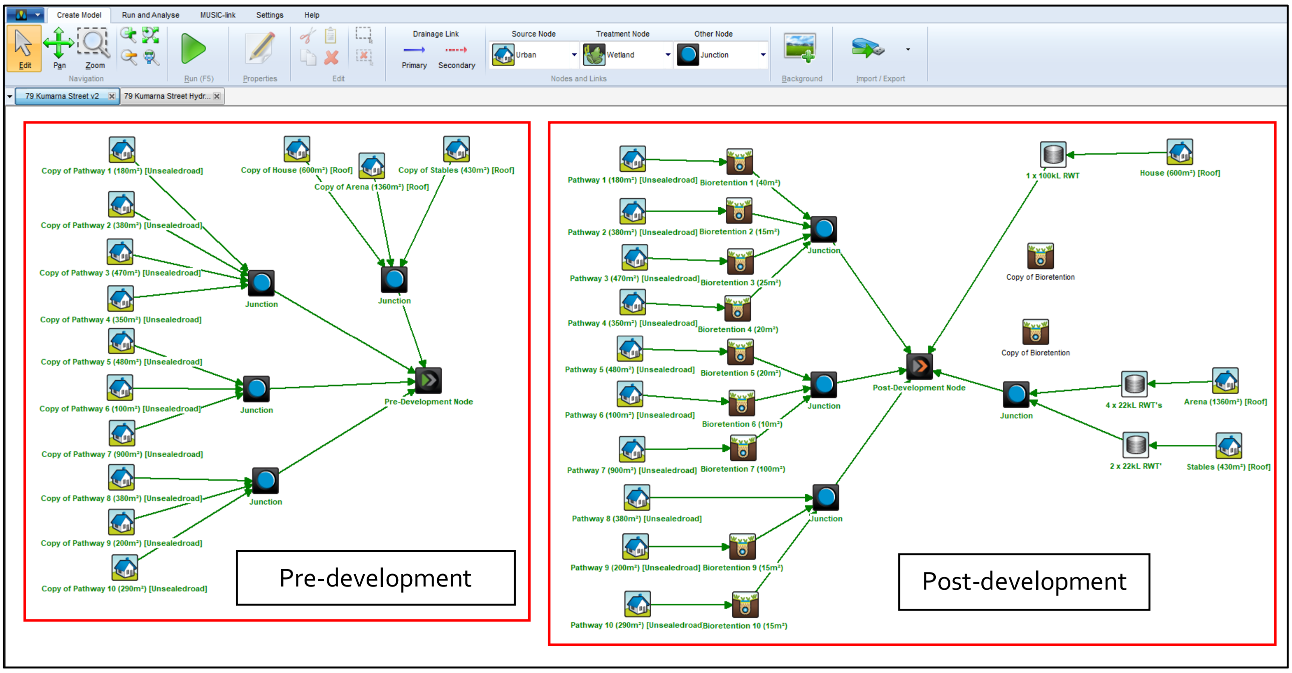

Figure 1. Layout of the source, treatment and receiving nodes in the stormwater model.

4. SUMMARY OF THE STORMWATER TREATMENT MEASURES	
#	***DETAIL***
4.1	Rainwater runoff from the roof area of the residential dwelling will be directed into a 100,000 litre inground water storage tank to be located on the lower northwestern side of the dwelling precinct
4.2	Overflow from the rainwater tank will be directed through internal stormwater drainages to the site's stormwater discharge point midway along the northwestern boundary
4.3	Rainwater will be reused at the nominal rate of 1,200 litres per day for all potable and non-potable internal applications
4.4	Rainwater runoff from the stables complex will be directed to a bank of 3 x 22,500 litre water tanks to be located at the rear of the sand arena structure – identified in the accompanying plan as tanks ST-1, ST-2 and ST-3.
4.5	Overflow from the bank of rainwater tanks will be directed to a separate 22,500 litre tank – identified as ST-OF in the accompanying Stormwater Management Site Plan – Ref: 0030616-01C which will be used for the temporary detention of stormwater and gradually discharged to the stormwater system via a 40mm diameter low-level outlet
4.6	In the event of large rain events the normal high-level overflow pipe from the detention tank will be connected to the internal stormwater drainage system
4.7	Rainwater from the bank of tanks ST-1 to ST-3 will be used at the nominal rate of 400 litres per day to meet the demands of external irrigation, animal husbandry, pool filling, and other general external uses.
4.8	Rainwater runoff from the sand arena complex will be directed to a bank of 3 x 22,500 litre water tanks to be located at the rear of the sand arena structure – identified in the accompanying plan as tanks SA-1, SA-2 and SA-3.
4.9	Overflow from the bank of rainwater tanks will be directed to a separate 22,500 litre tank – identified as SA-OF in the accompanying Stormwater Management Site Plan – Ref: 0030616-01C which will be used for the temporary detention of stormwater and gradually discharged to the stormwater system via a 40mm diameter low-level outlet
4.10	In the event of large rain events the normal high-level overflow pipe from the detention tank will be connected to the internal stormwater drainage system
4.11	Rainwater from the bank of tanks SA-1 to SA-3 will be used at the nominal rate of 400 litres per day to meet the demands of external irrigation, animal husbandry, pool filling, and other general external uses.
4.12	The proposed driveways, paths and other uncovered hardstand areas will be formed to encourage surface water runoff that will flow toward the designated biofiltration raingarden systems distributed throughout the development precinct as nominated in the accompanying Stormwater Management Site Plan – Ref: 0030616-01C.
4.13	The outlet and overflow provisions from each biofiltration raingarden device will be connected to the internal stormwater drainage system and be directed to the site's discharge point along the northwestern boundary

4.14	Each of the biofiltration raingardens will have a surface area as noted in the accompanying Stormwater Management Site Plan – Ref: 0030616-01C with the following construction characteristics: • Extended detention depth of 200mm • Filter media depth of 400mm • A drainage layer depth of 200mm • Saturated hydraulic conductivity of 200mm/hour • Total nitrogen content of 600mg/kg • Orthophosphate content of 30mg/kg • Vegetated with effective nutrient removal plants • 100Ø slotted draincoil underdrain at the rate 1 per 500mm width of biofiltration media • 100mm layer of 20 to 40mm diameter rock mulch over the entire surface area Typical characteristics of the filter media to be used in the biofiltration devices is included within Section 7 for reference
4.15	Each of the individual biofiltration raingarden devices will have 65Ø slotted draincoil pipes installed just under the layer of rock mulch to act as distribution laterals. The number of distribution laterals will be equal to the number of underdrains in the same system. Each distribution lateral will be fitted to the side walls of the inlet control pit at the appropriate invert level and will extend for the length of the system. The use of distribution laterals will alleviate scouring and preferential wetting around the location of the inlet pit whilst also ensuring even distribution of the rainwater across the entire surface area of the system
4.16	The inlet and outlet control pits within each of the biofiltration treatment devices will be fitted with grated lids and set at the nominated finished height equal to the top of the extended detention depth to allow ponded water in excess of the extended detention volume to rapidly drain away during intense rain events. In the base of each outlet control pit will be a solid wall pipe joined directly to the stormwater drainage system under the biofiltration device to allow stormwater during intense rain events to drain rapidly. A high-level pipe can also be installed inside the inlet control pit that finishes at the same level as the grated lid – refer to the cross section drawing of the biofiltration system in the Stormwater Management Site Plan Ref: 0030619-01C for details.
4.17	The site discharge point will be formed with a 10-metre-long by 1.5-metre wide energy dissipator that will be 500mm thick and filled with ballast rock at an average diameter of 150 to 200mm.
4.18	The two ends of the energy dissipator will be 3 metres in length and be raised by 300mm to ensure that the majority of flows are confined to the central 4 metre section of the system.
4.19	The invert level of the incoming pipes will be same as the finished level of the central portion of the energy dissipator with pipes entering from the sides of the system to be installed through the raised end sections.
4.20	A separate erosion and sediment control plan will need to be prepared for the construction of site's stormwater discharge system and all stormwater drainage along the northwestern boundary by the appointed civil / hydraulic contractors and approved by Council prior to commencing practical works.

4.21	The proposed biofiltration raingardens are designed to form part of the site's overall landscaping undertakings and are therefore intended to be planted with a range of species that are both suitable for wet and dry soil conditions, but also sympathetic to the general landscaping theme. A sample of a typical raingarden is included in the following image.

Examples of biofiltration raingardens with a rock mulch layer over the filter media and various grass plantings.

5. The Results.

The stormwater quality treatment measures are deemed compliant when the post-development site conditions with treatment are compared to the post-development site without treatment and the following reductions are achieved:

- Total suspended solids – 85%
- Total phosphorus – 65%
- Total nitrogen – 45%
- Gross pollutants – 90%

The results in Table 4 demonstrate that the proposed collection, conveyance and treatment measures achieves these target reduction objectives.

Table 4. Comparison of the post-development pollutant reductions between no-treatment and with-treatment

	Annual pollutant loading (kg/year)			
	TSS	TP	TN	GP
Post-development – no treatment	3040	1.85	12.4	143.0
Post-development – with treatment	437	0.536	6.12	11.3
Reduction %	85.63	71.03	50.65	92.10
	✓	✓	✓	✓

6. Conclusion.

Measures to ensure the protection of the proposed stormwater treatment devices, in particular the biofiltration 'raingarden' devices from mechanical and physical damage - particularly during their construction phase as well as into the future is an important part of the overall effectiveness and investment in stormwater quality improvements. As a means of ensuring the long-term viability and efficacy of the proposed stormwater treatment measures an 'Operational Environmental Management Plan' (OEMP) aimed at producing effective understanding and maintenance of the individual stormwater quality improvement devices (SQID's) has been prepared and is included within this document. A copy of the OEMP should be retained on site to be included within an ongoing Management Plan for the site that includes recommended regular maintenance programs and directions for remedial actions in the event of component or system failure.

The proposed biofiltration raingarden treatment devices to be located throughout the development precinct should not be installed until construction of the internal driveways, paths and other uncovered hardstand areas has been undertaken to limit the potential for physical damage. Sowing of the plant species for the individual biofiltration raingarden devices should be undertaken as soon as practical once the individual driveway, paths and other hardstand areas are completed. The long-term efficiency and viability of the biofiltration raingarden devices is largely dependent upon the regular input of rainwater to the system to ensure viability of the filter media and the supporting vegetation. This is unlikely to occur if the infrastructure is not present to direct the stormwater runoff into the respective biofiltration raingarden systems.

The design of the stormwater conveyance, quality and treatment measures recommended within this report are based on a thorough assessment of the site including all known and associated features and constraints. The proponents of the development proposal have been consulted throughout the design process and have constantly provided feedback with respect to the proposed stormwater treatment measures and the viability of those measures within the scope of their development aspirations. The outcomes delivered by adopting these design recommendations satisfy the 'Water Sensitive Urban Design' principles as defined and required by the Northern Beaches Council.

The stormwater quality objectives are one of several design elements to be considered within the scope of this development. The ensuing sections address the installation and ongoing management and maintenance of the stormwater treatment devices.

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Graduate Diploma Bush Fire Protection (UWS)
Graduate Certificate Engineering – Water (UTS)
25 October 2019

7. Maintenance of Stormwater Quality Improvement Devices (SQID's)

One of the principle measures of stormwater treatment proposed within the context of this stormwater quality assessment is the use of the biofiltration system (raingarden) within the development precinct. The importance of installing these systems correctly is pivotal to the overall success of the stormwater quality outcomes. To aid in the correct installation of the bioretention systems a series of checklists for the various stages of the their respective constructions is included for use on the site and should be completed during construction and commissioning and submitted with the final documentation to Council prior to receiving the final occupancy certificate. The construction checklist is a generic style checklist designed to cover many different types of possible development and site situations and should be completed as appropriate for the site. The checklist is also a useful tool for reading prior to the construction of the bioretention raingardens as the sequence of lists follows a structured approach to the general construction requirements and will assist the installer to know what has to be installed, the requirements of that material and a process for checking along the way.

Following on from the construction checklist is a detailed description relating the requirements of the filter media material which is not simply the loamy garden variety of material that is readily available from most landscape supply centres. There are very specific requirements for the filter media material and the information provided will assist the supplier in achieving the correct grade of constituents to ensure compliance with the requirements. It may be a condition of the development consent and concurrence requirements that the construction of the bioretention systems be certified by a recognised consultant in which case the correct filter media material must be supplied and certified as such by the supplier. The information in this section will be very useful for the filter media material supplier as there are only a few known local sources that to date have can supplied to the required standards.

Following the construction checklists and the filter media material descriptions is an Operational Environmental Management Plan (OEMP) which includes a description of the main components and purpose of each type of water quality treatment device along with a maintenance table and maintenance checklist. The maintenance table and checklist for the each of the stormwater quality improvement devices (SQID's) are to be used on a regular basis as indicated to ensure the long-term efficiency and efficacy of the individual devices. Poor maintenance or checking may lead to imminent failure of the individual devices in turn leading to potentially detrimental environmental impacts. The individual items in the following tables and checklist are to be used as applicable as all items may not necessarily be a component of the individual stormwater quality treatment devices. In particular, the following tables and checklists will be appropriate to use during the establishment and construction phases of the development until such time as each system is operating properly which would include the establishment of healthy and vigorous plantings. It is anticipated that a register of the completed checklists would be retained on site for future reference and inspection purposes.

BIORETENTION SYSTEM CONSTRUCTION & ESTABLISHMENT SIGN-OFF FORMS					
Project No:		DA No:			
Project Site Address:					
Catchment Area:		(m²)	Number of Bioretention Systems:		
Bioretention System Identifier:					
Bioretention System Identifier:					
Reference Drawing No:		Landscape Drawing No:			
ROLE / STAKEHOLDER	**COMPANY**	**CONTACT NAME**	**CONTACT DETAILS**		
Developer					
Site Superintendent (civil)					
Site Superintendent (landscape)					
Bioretention Designer					
Civil Engineer					
Landscape Architect					
Civil Contractor					
Landscape Contractor					
Council Compliance Officer					

CHECKLIST OF SIGN OFF FORMS			
Sign-off Form	Date Completed	Name of Signatory & Role	Signature
Pre-Start Meeting			
Form A: Earthworks & Functional Services			
Form B: Under Drainage			
Form C: Bioretention Media			
Form D: Finished Levels			
Form E: Coarse Sediment Forebay			
Form F: Protective Measures			
Form G: Landscape Installation			
Form H: Landscape Establishment			

PRE-START MEETING List Pre-Start meeting attendees who are to sign indicating they have attended the meeting and understand the design intent, construction and establishment process			
Location of Meeting:			
Date:			
ROLE / STAKEHOLDER	**COMPANY**	**CONTACT NAME**	**CONTACT DETAILS**
Developer			
Site Superintendent (civil)			
Site Superintendent (landscape)			
Bioretention Designer			
Civil Engineer			
Landscape Architect			
Civil Contractor			
Landscape Contractor			
Other			
Other			
Other			
Comments (attach and refer to additional pages as necessary):			
Actions (attach and refer to additional pages as necessary):			

Bioretention System Identifier:				
FORM A - EARTHWORKS AND FUNCTIONAL HYDRAULIC STRUCTURES Purpose: To ensure earthworks bulking out, trimming and profiling and the key levels of functional (hydraulic) structures are in accordance with design drawings and specifications. The earthworks and structures dictate the movement of stormwater through the bioretention system and are a critical element in the function of the system.				
Items	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
As constructed survey complete and attached to this form				
Photos taken and attached to this form				
Set-out of system is correct				
Base levels are at correct elevation (±50mm)				
Base at correct grading (0.5%)				
Punch out holes in overflow pit are correct size, correct level and above invert level of outlet pipe (±25mm)				
Overflow pit is correct size and crest and invert is at correct level (±25mm)				
Outlet pipe invert levels are correct (upstream & downstream)(±25mm)				
Outlet pipe is free draining				
Overflow weir (if required) is correct length and at correct level (±25mm)				
Overflow weir (if required) is keyed into bund				
Bunds / embankments surrounding the system are correct levels or above				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM B - UNDER DRAINAGE Purpose: To ensure under drainage is installed correctly before the bioretention media is installed.				
Items	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Base of system free from debris				
Liner (typically filter cloth) correctly installed (if required)				
There is no 'fabric sock' around the draincoil				
Correct draincoil has been supplied and slotted at 2mm or smaller				
Draincoil pipes are laid at the correct spacing (small bioretention systems 1.5 metres, large system 2.0 metres) Required grade verified using level or string line				
Draincoil pipes laid at required grade (verified using level or string line to achieve design level ±25mm and 0.5% grade)				
Overflow pit is correct size and crest and invert is at correct level (±25mm)				
All junctions and connections have been appropriately sealed				
Outlet pipe is free draining				
Top of clean-out points at design level (i.e. approximately 50 - 150mm above filter media level)				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM C - BIORETENTION MEDIA Purpose: To ensure that the media placed in the system meets the required specifications and that there is a record of the media being delivered to site. To ensure media layers are installed correctly and meet the design and specification requirements				
Sourcing, Testing and Supplying Bioretention Media				
Drainage Layer	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Meet the specifications				
Meets the required hydraulic conductivity (180mm/hour)				
Delivery supply docket certifies that the material delivered is the material tested (delivery docket attached)				
Transition Layer Supply	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Meets the specifications				
Supplier certification provided (certification attached)				
Delivery supply docket certifies that the material delivered is the material tested (delivery docket attached)				
Filter Media Supply	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Meets the FAWB's guideline: *Biofiltration Filter Media Guidelines, Appendix C* (June 2009) (copy attached)				
Meets the required hydraulic conductivity (180mm/hour)				
Supplier certification provided (certification attached)				
Delivery supply docket certifies that the material delivered is the material tested (delivery docket attached)				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Bioretention System Identifier:				
FORM C - BIORETENTION MEDIA - (continued)				
Installation of Bioretention Media				
	Checked (Date)	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Base of the system is free from debris				
Drainage layer (fine gravel) installed to correct depth (±25mm)				
Transition layer (coarse sand) installed to correct depth (±25mm)				
Placement of filter media completed to avoid compaction of media and using at least two lifts whilst being installed				
Filter media installed to correct depth				
Light and even compaction applied to remove air gaps (e.g., light roller or single pass with pozitrack bobcat)				
Spreader bar used to flatten surface of filter media				
Sediment fences in place				
INSPECTION: Superintendent and Bioretention designer inspection and sign-off to occur while installation of media is occurring. Photos must be taken by the superintendent, bioretention designer or the installer.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM D - FINISHED LEVELS Purpose: To ensure finished levels of the system surface and bunds are correct and meet the design.				
Items	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Landscaping topsoil applied to surrounding bunds to achieve design levels				
As-constructed survey of the system surface and surrounding bunds completed				
Final constructed levels are consistent with the design levels				
Under drainage clean-outs extended 50 - 150mm above finished filter media level				
Under drainage pipes are flushed to remove any sediment accumulation ingress during construction				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM E - COARSE SEDIMENT FOREBAY Purpose: To ensure the coarse sediment forebay is constructed correctly.				
Items	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Extent of coarse sediment forebay correctly set out				
Rocks to be used to line the base of the forebay are correct size and shape				
Base of the constructed forebay is flat and set at the correct level below the surface of the filter media				
Rocks placed for energy dissipation are of appropriate size and in correct location				
Interface between the forebay and filter media is structurally sound and not prone to collapse				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM F - PROTECTIVE MEASURES Purpose: To ensure protective measures are correctly installed to protect the bioretention system while building is occurring in / and around the catchment area of the bioretention system.				
Protection Option Adopted (choose 1, 2 or 3)				
Option 1: Surface Protection During Building Phase	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Continuous sediment fences are installed around the perimeter of the filter media and top of batter				
Where landscape works are not to commence immediately then cover batters with filter cloth				
Protective covering (filter cloth + 25mm topsoil + turf) installed across the entire filter media area of the system				
Option 2: Bypass and Early Establishment	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Continuous sediment fences are installed around the perimeter of the filter media and top of batter				
Where landscape works are not to commence immediately then cover batters with filter cloth				
Temporary bund installed (where required) to prevent stormwater run-off from entering bulk of system. Bund keyed into batters of bioretention system and crest level higher than pits and weirs				
Temporary protective covering (filter cloth + 25mm topsoil + turf) installed within the bunded area				
Comments (attach and refer to additional pages as necessary):				

Bioretention System Identifier:				
FORM F - PROTECTIVE MEASURES - (continued) Purpose: To ensure protective measures are correctly installed to protect the bioretention system while building is occurring in / and around the catchment area of the bioretention system.				
Option 3: Sediment Basin and Bioretention Function	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Continuous sediment fences are installed around the perimeter of the filter media and top of batter				
Sediment basin installed upstream of bioretention system in accordance with Chapter 2 of NSW Landcom's *Soil and Construction: Managing Urban Stormwater* (2004) manual - the "Blue Book", and shall be to the satisfaction of Council				
Suitable access provided to sediment basin for clean out				
Bioretention system installed downstream of sediment basin				
Protective covering (filter cloth + 25mm topsoil + turf) installed across the entire filter media area of the basin				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM G - LANDSCAPE INSTALLATION Purpose: To ensure the correct plants are supplied, installed and established				
Items	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Correct mulch has been supplied				
Mulch applied at correct depth and secured				
Supplied plants are correct species				
Supplied plants are in correct pot sizes at maturity (e.g., minimum 300mm pots)				
Plants have been installed at the correct planting density (refer to the list entitled 'Plant Species for Bioretention Systems' for planting density specifications)				
As constructed drawings marked with final plant species and densities				
Mulch is clear of the plant stems by approximately 50mm				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

Bioretention System Identifier:				
FORM H - LANDSCAPE ESTABLISHMENT Purpose: To ensure the correct plants are supplied, installed and established				
Items	**Checked (Date)**	**Satisfactory**	**Action (If Unsatisfactory)**	**Initials**
Weeds being removed as required				
Watering occurring as required				
Re-planting occurring as required to replace desiccated plants				
Plants successfully established, plant propagation is occurring. Measures of successful establishment include: - survivorship greater than 90% - 80% coverage of bioretention system by plants - preferably more than one species per macrophyte zone - at least 5 plants/m² (preferably 6 - 10 plants/m²) - plant height at least 50% - propagation is occurring (evident by new stems seeding) Growth and maturity should be recorded every three months, using photos as logs of development				
HOLD POINT: Superintendent and Bioretention designer inspection and sign-off before proceeding.				
Comments (attach and refer to additional pages as necessary):				

Signed by Superintendent		Signed by Bioretention Designer:	
Print Name:		Print Name:	
Date:		Date:	

GUIDELINES FOR FILTER MEDIA IN BIOFILTRATION SYSTEMS (Version 3.01)
June 2009

The following guidelines for filter media in biofiltration systems have been prepared on behalf of the
Facility for Advancing Water Biofiltration (FAWB) 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 FAWB guideline specifications (published in 2006 (Version 1.01), 2008 (Version 2.01)). It attempts to provide a simpler and more robust guideline for both soil-based and engineered filter media. FAWB acknowledges the contribution of 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.

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1 GENERAL DESCRIPTION

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 minimum cover over underdrainage pipe). The biofiltration system will operate so that water will infiltrate into the filter media and move vertically down through the profile.

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. The material should be based on **natural or amended natural soils** or it can be **entirely engineered**; in either case, it can be of siliceous or calcareous origin. In general, the media should have an appropriately high permeability under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/Acts), and should not be hydrophobic. The filter media should contain some organic matter for increased water holding capacity but be low in nutrient content. In the case of natural or amended natural soils, the media should be a **loamy sand**.

Maintaining an adequate infiltration capacity is crucial in ensuring the long-term treatment efficiency of the system. The ability of a biofiltration system to detain and infiltrate incoming stormwater is a function of the filter surface area, extended detention (ponding) depth, and the hydraulic conductivity of the filter media (Figure 1). Most importantly, design of a biofiltration system should optimize the combination of these three design elements.

For a biofiltration system in a temperate climate with an extended detention 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 2). 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 in order to achieve the required treatment performance using the same land space (i.e., ensuring that the proportion of water treated through the media meets requirements).

Where one of these design elements falls outside the recommended range, the infiltration capacity can still be maintained by offsetting another of the design elements. For example, a filter media with a lower hydraulic conductivity may be used, but the surface area or the extended detention depth would need to be increased in order to maintain the treatment capacity. Similarly, if the available land were the limiting design element, the system could still treat the same size storm if a filter media with a higher hydraulic conductivity were installed. Where a hydraulic conductivity greater than 300 mm/hr is prescribed, potential issues such as higher watering requirements during the establishment should be considered. Biofiltration systems with a hydraulic conductivity greater than 600 mm/hr are unlikely to support plant growth due to poor water retention, and may also result in leaching of pollutants. However plant survival might be possible if the outlet pipe were raised to create a permanently submerged zone.

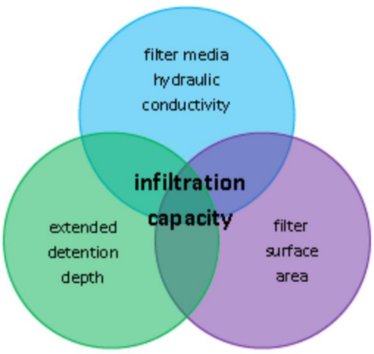

Figure 1. Design elements that influence infiltration capacity.

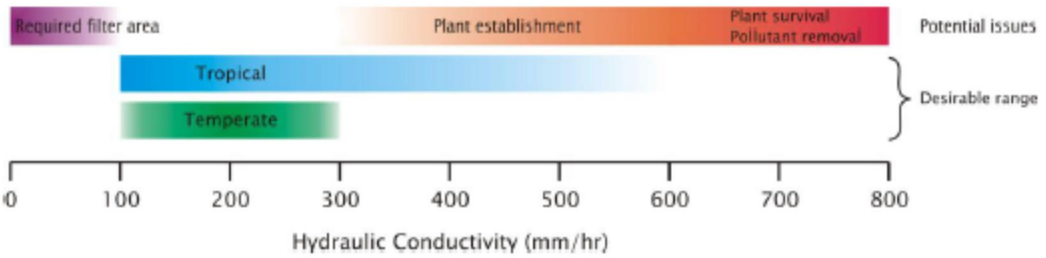

Figure 2. Recommended filter media hydraulic conductivity range and potential issues

The infiltration capacity of the biofiltration system will initially decline during the establishment phase 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 system 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 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 TESTING REQUIREMENTS

2.1 Determination of Hydraulic Conductivity

The hydraulic conductivity of potential filter media should be measured using the ASTM F1815-06 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.
Note: if a hydraulic conductivity lower than 100 mm/hr is prescribed, the level of compaction associated with this test method may be too severe and so underestimate the actual hydraulic conductivity of the filter media under field conditions. However, FAWB considers this to be an appropriately conservative test, and recommends its use even for low conductivity media.

2.2 Particle Size Distribution

Particle size distribution (PSD) is of secondary importance compared with hydraulic conductivity. 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. However, 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 to Coarse Sand	40-60%	(0.25-1.0 mm)
Coarse Sand	7-10%	(1.0-2.0 mm)
Fine Gravel	<3%	(2.0-3.4 mm)

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)** to reduce the likelihood of structural collapse of such soils.

The filter media should be well-graded i.e., it should have all particle size ranges present from the 0.075 mm to the 4.75 mm sieve (as defined by AS1289.3.6.1 - 1995). There should be no gap in the particle size grading, and the composition should not be dominated by a small particle size range. This is important for preventing structural collapse due to particle migration.

2.3 Soil-Based Filter Media: Properties

The following specifications are based on results of extensive treatment performance testing conducted by FAWB as well as recommendations made by AS4419 – 2003 (Soils for Landscaping and Garden Use). Filter media must be tested for the following; media that do not meet these specifications should be rejected or amended:

i. Total Nitrogen (TN) Content – <1000 mg/kg.
The specified TN content for this project is ~600mg/kg
ii. Orthophosphate (PO_4^{3-}) Content – <80 mg/kg
The specified orthophosphate content for this project is ~30mg/kg
Soils with total phosphorus concentrations >100 mg/kg should be tested for potential leaching. Where plants with moderate phosphorus sensitivity are to be used, total phosphorus concentrations should be <20mg/kg.

iii. Organic Matter Content – at least 3% (w/w). An organic content lower than 3% is likely to have too low a water holding capacity to support healthy plant growth. In order to comply with both this and the TN and PO_4^{3-} content requirements, a low nutrient organic matter will be required.
iv. pH – as specified for 'natural soils and soil blends' 5.5 – 7.5 (pH 1:5 in water).

v. Electrical Conductivity (EC) – as specified for 'natural soils and soil blends' <1.2 d^S/m.

Optional testing:

vi. Dispersibility – this should be carried out where it is suspected that the soil may be susceptible to structural collapse. If in doubt, then this testing should be undertaken. Potential filter media should generally be assessed by a horticulturalist to ensure that they are capable of supporting a healthy vegetation community. This assessment should take into consideration delivery of nutrients to the system by stormwater. Any component or soil found to contain high levels of salt (as determined by EC measurements), high levels of clay or silt particles (exceeding the particle size limits set above), or any other extremes which may be considered retardant to plant growth should be rejected.

3 ENGINEERED FILTER MEDIA

Where there is not a locally available soil-based material that complies with the properties outlined in Sections 2.1 - 2.3, 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. 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 m3), they can be obtained directly from sand suppliers, while smaller quantities can be purchased from local garden yards. The **top 100 mm of the filter medium** should then be ameliorated with appropriate organic matter, fertiliser and trace elements (Table 1). This amelioration is required to aid plant establishment and is designed to last four weeks; the rationale being that, beyond this point, the plants receive adequate nutrients via incoming stormwater.

Table 1. Recipe for ameliorating the top 100 mm of sand filter media

Constituent	Quantity (kg/100 m2 filter area)
Granulated poultry manure fines	**50**
Superphosphate 2	**2**
Magnesium sulphate 3	**3**
Potassium sulphate 2	**2**
Trace Element Mix 1	**1**
Fertilizer NPK (16.4.14) 4	**4**
Lime 20	**20**

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 soil-based filter medium (Bratieres *et al.*, 2009). However, it is recommended that a submerged zone be included in biofiltration systems that utilise such a free draining filter medium to provide a water source for vegetation between rainfall events.

4 TRANSITION LAYER

The transition layer prevents filter media from washing into the drainage layer. Transition layer material shall be a clean, well-graded sand material containing <2% fines. To avoid migration of the filter media into the transition layer, the particle size distribution of the sand should be assessed to ensure it meets 'bridging criteria', that is, the smallest 15% of the sand particles bridge with the largest 15% of the filter media particles (Water by Design, 2009; VicRoads, 2004):

D_{15} (transition layer) ≤ 5 x D_{85} (filter media)

where: 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.

A dual-transition layer, where a fine sand overlays a medium-coarse sand, is also possible. While it is acknowledged that this can increase the complexity of the construction process, testing indicates that a dual-transition layer produces consistently lower levels of turbidity and concentrations of suspended solids in treated outflows than a single transition layer. Therefore, it is recommended that this design be specified for stormwater harvesting applications (to enable effective post-treatment disinfection) and where minimising the risk of washout during the establishment period is of particular importance.

The transition layer can be omitted from a biofiltration system provided the filter media and drainage layer meet the following criteria as defined by the Victorian Roads *Drainage of Subsurface*
Water from Roads - Technical Bulletin No 32 (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 (Water by Design, 2009).

5 DRAINAGE LAYER

The drainage layer collects treated water at the bottom of the system and conveys it to the underdrain pipes. Drainage layer material is to be clean, fine gravel, such as a 2 – 5 mm washed screenings. Bridging criteria should be applied to avoid migration of the transition layer into the drainage layer (Water by Design, 2009; VicRoads, 2004):

D15 (drainage layer) ≤ 5 x D85 (transition layer)
where: D15 (drainage layer) is the 15th percentile particle size in the drainage layer material (i.e., 15% of the gravel is smaller than D15 mm), and
D85 (transition layer) is the 85th percentile particle size in the transition layer material.

Note: The perforations in the underdrain pipes should be small enough that the drainage layer cannot fall into the pipes. A useful guide is to check to that the D85 (drainage layer) is greater than the pipe perforation diameter.

Geotextile fabrics are **not recommended** for use in biofiltration systems due to the risk of clogging. An open-weave shade cloth can be placed between the transition layer and the drainage layer to help reduce the downward migration of smaller particles if required, however this should only be adopted where there is insufficient depth for transition and drainage layers.

6 INSTALLATION

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

7 FIELD TESTING

It is recommended that field testing of hydraulic conductivity be carried out at least twice: 1. One month following commencement of operation, and 2. in the second year of operation to assess the impact of vegetation on hydraulic conductivity.

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. 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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TYPICAL ANALYSIS OF MEDIA USED IN BIOFILTRATION DEVICES

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Web: www.sesl.com.au

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Certified System Quality ISO 9001

Batch Nº: 21713A Sample Nº: 1 Date Received: 15/3/12 Report Status: ○ Draft ◉ Final

Client Name:	Benedict Industries	Project Name:	FAWB Analysis
Client Contact:	David Connor	Location:	M165 Standard Testing
Client Job Nº:		SESL Quote Nº:	
Client Order Nº:		Sample Name:	M165
Address:	PO Box 431 FRENCHS FOREST NSW 1640	Description:	Soil
		Test Type:	PSA US, HC-USGA, Olsen P

Particle Range (mm)	Fraction	% Retained by mass	Target Range
>3.35	Gravel	0.3	-
2.0 - 3.35	Fine Gravel	0.2	< 3.0 %
1.0 - 2.0	Very Coarse Sand	0.6	7 - 10 %
0.25 - 1.0	Medium to Coarse Sand	78.2	40 - 60 %
0.15 - 0.25	Fine Sand	14.1	10 - 30 %
0.05 - 0.15	Fine to Very Fine Sand	3.3	5 - 30 %
<0.05	Silt and Clay	3.1	< 3.0 %
Physical Performance	**Unit**	**Result**	
Hydraulic Conductivity			
Predicted based in PSA		839	
Actual ASTM F 1815-06		457	> 100 mm/hr
Soil Properties			
Organic Matter	% dry weight	1.2	≥ 3.0 %
pH in H_2O (1:5)	pH unit	7.4	5.5 - 7.5
Electrical Conductivity (1:5)	dS/m	0.16	< 1.2 dS/m
Phosphorus (Olsen)	mg/kg	9.3	< 80 mg/kg
Total Nitrogen	mg/kg	600	< 1000 mg/kg

Commentary from SESL not requested.

Consultant: Scott Fraser

Authorised Signatory:

Methods
<[illegible]2 mm by hydrometer sedimentation (Reference Black et al (1965) Method 43-5)
<[illegible]53> [illegible]2 mm by wet sieve analysis
>[illegible]53 mm by dry sieve analysis. (Reference ASTM F1632-03 modified)
Hydraulic conductivity to ASTM F 1815-06.
Soil Properties were assessed in accordance with AS4419-2003 (Soils for Landscaping and Garden Use). The Biofiltration Filter Media Guidelines (Version 3.01), Prepared by the Facility for Advancing Water Biofiltration (FAWB), June 2009 was used for the interpretation in this test.

Date of Report: 05/03/2012

END OF REPORT

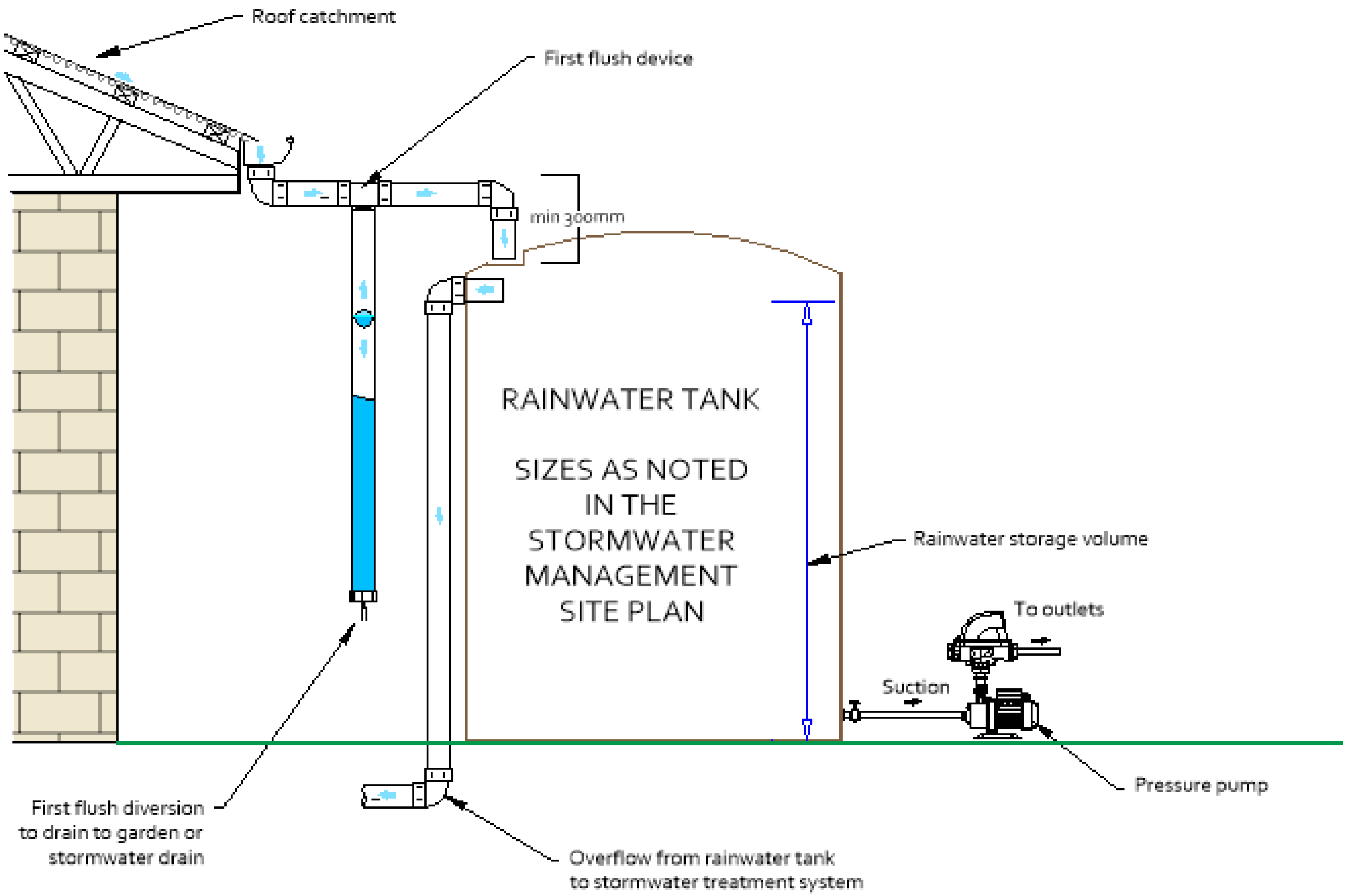
Total No Pages: 1/1

IF YOU ARE READING THIS PAGE PLEASE REFER TO THE ACCOMPANYING ELECTRONIC VERSION OF THE A3 DRAWING SHOWING THE SCHEMATIC SECTIONS OF TYPICAL BIOFILTRATION DEVICES.

8/. OPERATIONAL ENVIRONMENTAL MANAGEMENT PLAN - (OEMP)

Description of Stormwater Quality Improvement Devices (SQID's)		
Name	Description / purpose	Typical components
Rainwater tanks	Rainwater tanks allow for the storage of a certain volume of rainwater for later reuse in the form of internal applications (toilet flushing and laundry) and external uses such as garden watering and car washing. Storage of the rainwater in rainwater tanks essentially attenuates stormflow to help reduce peak flow concentrations during intense and prolonged rain events.	• volume of storage below overflow pipe • surface area • overflow pipe diameter • re-use options (expressed as daily, monthly or annual demands) often supplemented with a 'town water top-up' device to maintain a minimum volume of water (normally 20%) of the tank's capacity
Biofiltration systems (Raingardens)	Biofiltration systems (either as small scale Lot devices [raingardens] or larger scale sub-catchment stormwater quality systems) promote the filtration of stormwater through a prescribed filter medium. The type of filter medium determines the effectiveness of the pollutant removal, with material of lower hydraulic conductivity providing the most efficient pollutant removal.	• extended detention depth • surface area • filter medium area • filter medium depth • filter medium particle diameter • saturated hydraulic conductivity • depth and grade of underdrain pipes • vegetation cover and density

Rainwater tanks.



Typical arrangement for rainwater tanks with town water top-up system (some variations may be encountered)

Rainwater tanks.

Inspection and monitoring.

For rainwater tanks the following items should be inspected:

- clogging and blockage of the first flush device
- clogging and blockage of the tank inlet leaf / litter screen
- depth of accumulated sediment within the base of the tank
- town water top-up system operating properly and within set parameters (if installed)
- pressure pumps cut in and out as required (if installed)

Maintenance.

The following maintenance activities will be required with inspection frequencies as indicated in the Rainwater Tank Maintenance and Inspection Checklist:

- first flush device to be cleaned out
- leaves and debris to be removed from the inlet leaf / litter screen
- removing leaves and debris from the roof gutter system
- sediment and debris to be removed from the base of the rainwater tank

Adequate first flush systems and mesh screens on rainwater tank inlets should reduce the amount of accumulated sediment and debris entering the tank and thereby rendering de-silting to approximately a 10 year cycle. Further information regarding the use and maintenance of rainwater and rainwater tanks can be found in the Commonwealth Government publication titled "Guidance on use of Rainwater Tanks" via the following link:

http://www.health.gov.au/internet/main/publishing.nsf/Content/0D71DB86E9DA7CF1CA257BF0001CBF2F/$File/enhealth-raintank.pdf

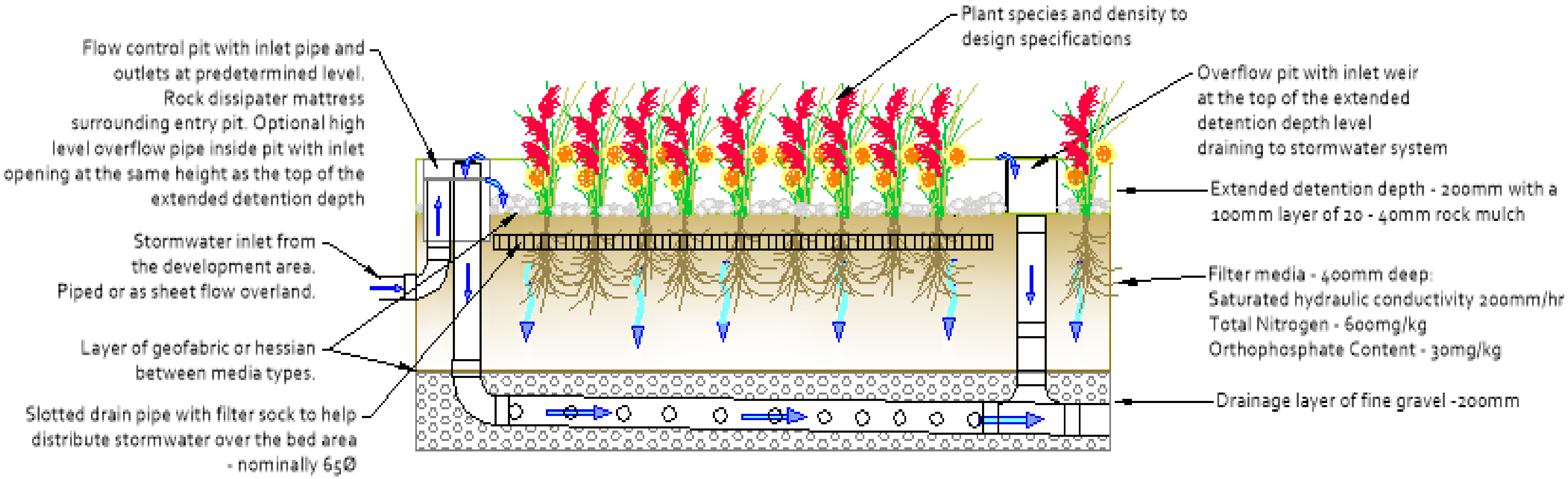
Rainwater Tank Maintenance and Inspection Checklist

Items Inspected	Checked		Maintenance needed		Inspection frequency **After all rainfall events, or**
	Yes	No	Yes	No	
FIRST FLUSH DEVICE					Monthly
First flush device clear of debris and not blocked					
DEBRIS CLEANOUT					6 months
Tank base surface clear of debris					
Inlet area and inlet screens and pipes clear of debris					
Overflow clear of debris					
ROOF GUTTERS					6 months
Leaves and debris in gutters					
SEDIMENT LEVEL IN TANK					2 years
Sediment level					
TANK STRUCTURE					
Check for corrosion or fatigue					
Check footings (if applicable)					
OUTLET PIT					Annual
Pipe condition					
Evidence of blockage					
TOWN WATER TOP-UP SYSTEM (as applicable)					6 months
Check proper function within established operating parameters					
PRESSURE PUMP (as applicable)					3 months
Check for correct 'cut in' and 'cut out' performance					
Check for leaks					

Checklist Summary

Maintenance and Inspection Checklist	Date Inspection Performed	Date Corrective Action Performed
• **Rainwater tanks**		
Comments		
Name (print)		
Signature		
Date		

Biofiltration Systems (including Raingardens)



Typical arrangement for biofiltration raingardens for the Residential Developments (some variations may exist)

Biofiltration Systems (including Raingardens)

Inspection and monitoring.

Following construction biofiltration systems should be inspected every 1 to 3 months (or after each significant rainfall event) for the initial establishment period to determine whether or not the biofiltration zone requires maintenance or the filter media requires replacement. The following critical items should be monitored:

- ponding, clogging and blockage of the filter media
- establishment, density and integrity of vegetation cover
- weed infestation
- blockage of the outlet from the biofiltration system

After the initial establishment period (typically 1 to 2 years) inspections may be extended to the frequencies nominated in the Biofiltration System Maintenance and Inspection Checklist.

Maintenance.

If the biofiltration system is not maintained frequently the entire filter media may need to be replaced due to clogging of the drainage layer with fine particles, failure of the plants to establish or scouring and collapse of the filter media. This can result in frequent maintenance being more cost effective in the long term. The following Maintenance Table summarises the individual maintenance items to be addressed whilst the required inspection frequencies are shown in the Biofiltration System Maintenance and Inspection Checklist.

Maintenance Table Detailing Maintenance Items, Purpose, Performance Targets and Rectification Measures

Item to be monitored	Purpose of monitoring	Performance target	Schedule maintenance or investigation	Immediate action required	Maintenance action required
Structures	- Inlet structures, pits, grates and channels - Overflow pipes, junction pits, underdrains and outlet pipes. Control the flow of stormwater in the system.	Clear and undamaged	Partially blocked, observed damage	Mostly blocked, severe damage	Organise removal of debris, inspect for associated erosion and scour damage within the raingarden and organise repair work as required
Erosion	Erosion will affect the distribution of flow across the raingarden. If left untreated small sites of erosion can quickly spread over large areas becoming costly to repair. Surface area of system to be covered with a rock mulch to reduce erosion.	Erosion absent. 100% cover of rock mulch over surface area	Erosion damage visible but structure functional	Severe erosion. Damage impairing function of the raingarden. Rock mulch missing.	Schedule investigation into cause of the erosion. Replace lost soils Replace any damaged plants to meet the design plant schedule. Replace lost rock mulch to ensure 100% cover

Item to be monitored	Purpose of monitoring	Performance target	Schedule maintenance or investigation	Immediate action required	Maintenance action required
Sediment and debris build up	The accumulation of sediment is part of the prescribed function of a raingarden. However, sediment must be regularly removed when accumulated to ensure that the sediment trapping performance of this system is sustained.	Sediment absent	Sediment build up appears excessive	Sediment build up to more than 10% of surface area	Undertake investigation to identify sediment source. Remove accumulated debris. Replace any damaged plants to meet the design plant schedule
Weeds	Weeds should be removed from the sedimentation basin: - Weeds compete with the desirable plants for the available soil moisture - Weeds compromise the visual amenity of the raingardens	No weeds present	Weeds present	Noxious or environmental weeds present, or weeds cover more than 25%	Hand removal or targeted herbicide treatment with registered chemicals. General spraying should not be undertaken as overspray will kill the desirable plant species.
Plant condition	Plants are crucial to the performance, function and visual amenity of the raingardens. The raingardens become as much a feature of the development as the buildings themselves.	Healthy vegetation	Poorly growing or visually stressed	Die back / dead plants	Investigate possible causes of observed changes in plant health; eg, due to inappropriate soil moisture content, disease, competition by weeds, poison containment. Once the problem has been rectified infill re-planting may be required if more than 10% of plants are affected which must be as per the original design planting schedule.
Litter - organic	Organic litter can provide an additional source of nutrients and introduce weed species which can compete for soil moisture and reduce raingarden efficacy. Accumulated organic matter and litter can affect the visual amenity of the raingardens	No litter visible	Litter visible	Litter blocking structures or detracting from visual amenity	Identify the sources of organic litter and address with appropriate response action. All litter must be removed from the raingarden.
Litter - anthropogenic	Litter can potentially block the inlet and outlet structures resulting in flooding, as well as detract from the visual amenity	No litter visible	Litter visible	Litter blocking structures or detracting from visual amenity	Identify and address the sources of rubbish generating within the development eg, overflow from rubbish bins, dumping or wind blown from nearby sources.
Oil slicks	Oil spills / inflows are better trapped and isolated within a raingarden than allowed to flow to enter the stormwater system	No visible oil	Persistent but limited visible oil	Extensive or localised thick layer of oil visible	It is better that the oil is contained within the system rather than allowed to flow to the downstream waterway. Once contained and 'mopped up' remove affected section of raingarden and replace with same as original filter media and plant species.

Biofiltration System Maintenance and Inspection Checklist

Items Inspected	Checked		Maintenance needed		Inspection frequency **After all rainfall events, or**
	Yes	No	Yes	No	
SEDIMENTATION & DEBRIS CLEANOUT					6 months
Surface clear of sedimentation and debris					
Inlet area clear of sedimentation and debris					
Overflow clear of sedimentation and debris					
TRENCH SURFACE VEGETATION					6 months
Vegetation condition					
Vegetation trimming / maintenance					
Weed infestation					
Evidence of erosion					
DEWATERING					6 months
Trench surface dewatering between storm events					
Evidence of ponding					
Topsoil layer require replacing					
Surface ponding or siltation present					
Entire planting media require replacing					
OUTLET / OVERFLOW CHANNEL OR PIT					Annual
Pit / grate condition					
Evidence of cracking or spalling of concrete structures					
Evidence of erosion in downstream channels					
Check protection devices (eg; bollards, wheel-stops)					

Checklist Summary

Maintenance and Inspection Checklist	**Date Inspection Performed**	**Date Corrective Action Performed**
• **Biofiltration Systems (including Raingardens)**		
Comments		
Name (print)		
Signature		
Date		