City of Sydney WSUD Technical Guidelines

October 2014

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1 Introduction

The WSUD technical guidelines outlined in this document have been developed for the City of Sydney as part of the review of its Raingarden (WSUD) Policy. The technical guide includes a range of design information:

- Key local design considerations including soil types and acid sulphate soils.
- Identification and summary of WSUD elements appropriate to meet the WSUD targets of the City of Sydney. This includes sizing of WSUD elements.
- MUSIC Modelling Guideline including MUSIC modelling input parameters for the City of Sydney including rainfall data, Soil Characteristics, Pollutant Generation and Key parameter values/acceptable parameter ranges for treatment nodes
- Description and cross sections, as well as design information on appropriate location, design considerations, soil and vegetation, sizing, maintenance and where to find further information
- Review and comments on the current typical drawings prepared by the City of Sydney and inclusion of other elements WSUD elements which can meet the City of Sydney targets.
- A review in the form of tracked changes of the City of Sydney technical specification including updated information on soils, vegetation, Construction hold points, material selection and sourcing for WSUD elements.

The guideline can be used by both Council and developers in implementing WSUD through the City.

2 City of Sydney Environment

The WSUD strategy for a development should be informed by the local environment at the site of the proposed development as well as downstream of the site.

2.1 Soil landscapes

The soil landscapes within the City of Sydney are shown in Figure 1 and described in Table 1. The soil conditions at the site will affect the generation of runoff (for MUSIC modelling) and the ability of water to exfiltrate from stormwater treatment systems. Infiltration systems are only appropriate at sites where a deep sandy soil is found and where there will be no impacts on adjacent infrastructure. Whilst the information provided in Figure 1 and described in Table 1 provides an indication of the expected conditions, basic site investigations will be required to confirm whether infiltration will be possible. Site investigation should include a site specific physical investigation of the soil types by hand auger or equivalent to a depth of at least 2m and a field or lab hydraulic conductivity test undertaken by a suitably qualified person.

The following soil landscapes are generally the most likely to be suitable for infiltration:

- Tuggerah

The following soil groups may also be suitable for infiltration depending on site conditions:

- Deep Creek
- Hawkesbury
- Gymea

The following soil groups are unlikely to be suitable for infiltration:

- Blacktown
- Lucas Heights
- Disturbed terrain

As part of this project, the Project Team has contacted the NSW Office of Water to determine if there are any regulations relating to the infiltration of treated stormwater into the Botany Sand Aquifer. At present much of the Botany Sand Aquifer is covered by an exclusion zone, within which residents are banned from extracting groundwater. Preliminary feedback from the NSW Office of Water indicated that the infiltration of treated stormwater from raingardens could be considered as an activity that is covered by the Aquifer Interference Policy (NSW Office of Water, 2012). Whilst the Aquifer Interference Policy primarily relates to gas and mining projects, it includes requirements for groundwater impact assessment and approval by the Office of Water.

Whilst small infiltration systems are not likely to create significant risks, a WSUD program to encourage broad infiltration across the wider area could require a detailed assessment to confirm that there would not be any adverse impacts and that the groundwater system would be protected. The assessment may need to demonstrate compliance with the Australian Managed Aquifer Recharge guidelines. Further information should be sought from the Office of Water prior to implementing infiltration systems.

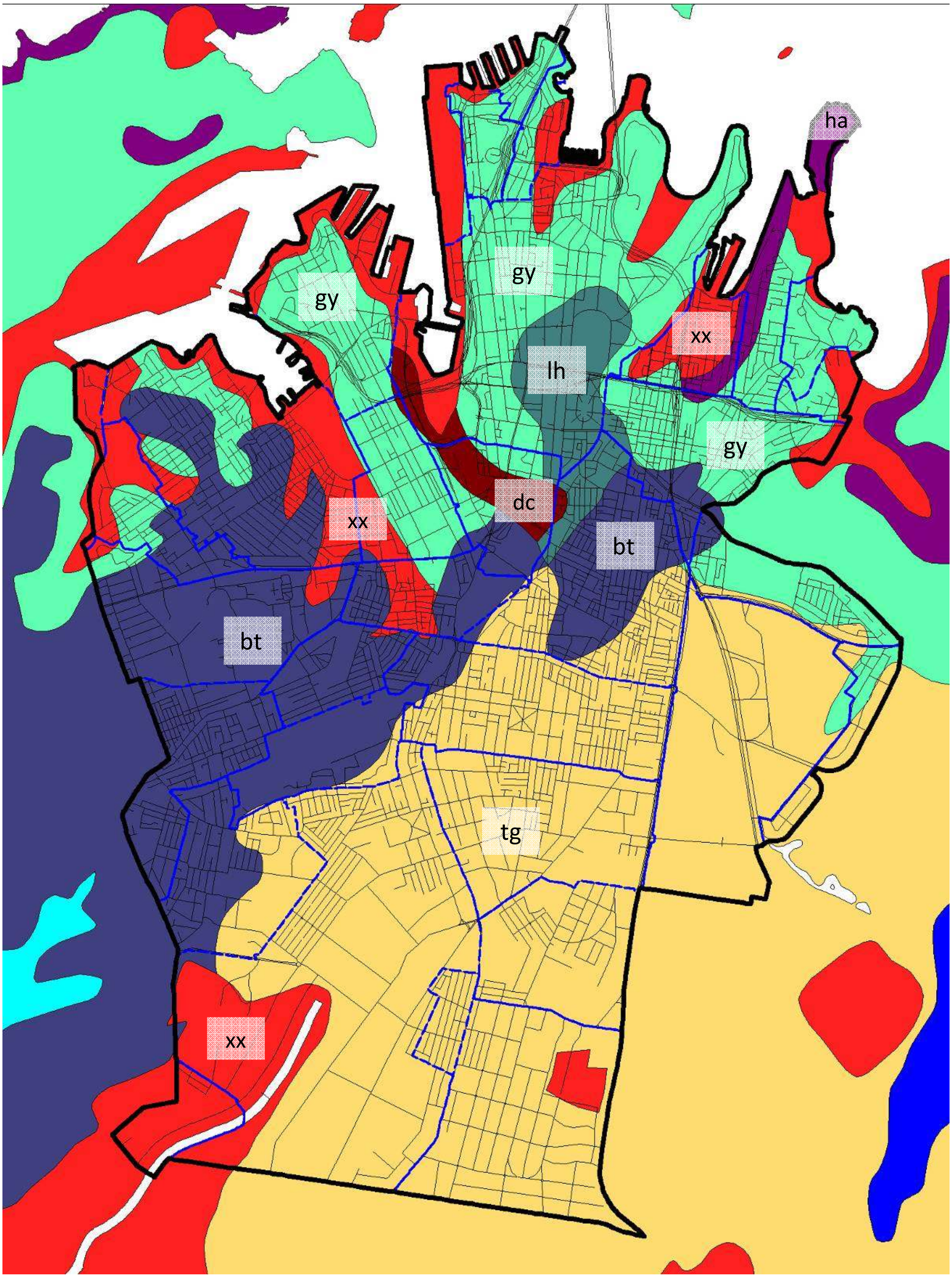


Figure 1: City of Sydney soils, with roads and suburb boundaries

Table 1: Soil Landscapes (Chapman and Murphy 1989)

Code	Name	Process	Description
bt	Blacktown	Residual	Shallow to moderately deep *Red* and *Brown Podzolic Soils* on crests, upper slopes and well drained areas; deep *Yellow Podzolic Soils* and *Soloth*s on lower slopes and in areas of poor drainage.
dc	Deep Creek	Alluvium	Deep *Podzols* on well drained terraces, *Silliceous Sands* on current floodplain and *Humus Podzols* in low lying areas.
gy	Gymea	Erosional	Shallow to moderately deep *Yellow Earths* and *Earthy Sands* on crests and inside of benches; shallow *Siliceous Sands* on leading edges of benches; localised *Gleyed Podzolic Soils* and *Yellow Podzolic Soils* on shales lenses; shallow to moderately deep *Siliceous Sands* and *Leached Sands* along drainage lines.
ha	Hawkesbury	Colluvial	Shallow discontinuous *Lithosols/Siliceous Sands* associated with rock outcrop; *Earthy Sands*, *Yellow Earths*, and some *Yellow Podzolic Soils* on inside of benches and along joints and fractures; localised *Yellow and Red Podzolic Soils* associated with shale lenses; *Siliceous Sands* and secondary *Yellow Earths* along drainage lines.
lh	Lucas Heights	Residual	Moderately deep, hardsetting *Yellow Podzolic Soils* and *Yellow Soloths*; *Yellow Earths* on outer edges of crests.
tg	Tuggerah	Aeolian	Deep *Podzols* on dunes and *Podzol*/*Humus Podzol* intergrades on swales.
xx	Disturbed Terrain	Disturbed Terrain	Fill areas commonly capped with up to 40cm of sandy loam or up to 60cm of compacted clay over fill or waste materials.

2.2 Acid Sulphate Soils

Acid Sulphate Soils (ASS) must be taken into consideration in designing for stormwater treatment systems. The ASS mapping for the City of Sydney is shown in Figure 2.

Generally any development sites located within Class 1 or Class 2 ASS are unlikely to be appropriate for infiltration. Sites within Class 3, Class 4 or Class 5 areas may be appropriate for infiltration depending on local conditions (such as elevation and depth to the water table) and site specific investigations should be carried out to confirm whether there is any risk of ASS issues including site soil testing for Potential ASS and actual ASS.

Deep excavation for treatment systems should also generally be avoided in ASS areas, where the excavation is likely to expose potential or actual acid sulphate soils. In these areas the WSUD strategy will need to consider appropriate treatment system measures which have the least disturbance to ASS.

2.3 Endangered Ecological Communities

The City of Sydney includes several Endangered Ecological Communities (EECs):

- Sydney Turpentine Ironbark Forest, at Orphan School Creek, Forest Lodge and St John’s Anglican Church, Glebe
- Coastal Saltmarsh at Bicentennial, Federal and Jubilee Parks, Glebe
- Coastal swamp/alluvial forest at Royal Botanic Gardens and Lewis Hoad Reserve, Glebe (City of Sydney, 2013)

Any proposed developments that drain to these EECs must take particular care to ensure that there are no impacts from stormwater runoff. For these sites the WSUD strategy must address how stormwater runoff volumes will be managed to ensure the EECs will not be impacted.

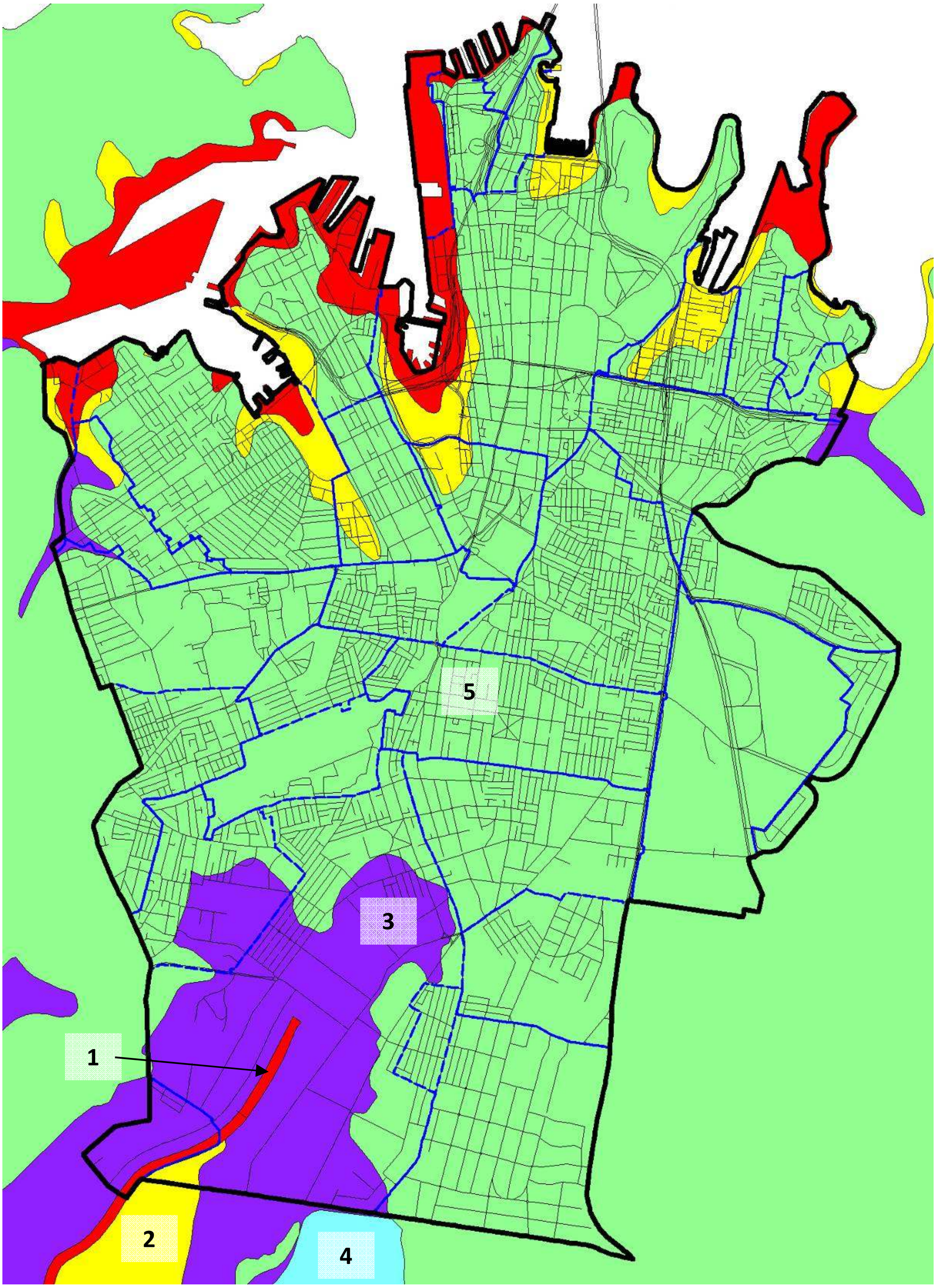


Figure 2: City of Sydney ASS map, with roads and suburb boundaries (ASS data taken from NSW OEH)

3 WSUD Options for the City of Sydney

WSUD can be applied at all scales and in all types of urban development and redevelopment to meet the targets identified in Part A of this project. Elements of WSUD can also be retrofitted to existing buildings and incorporated into upgrades or replacements of existing infrastructure including council projects such as city centre, road, laneway and park upgrades. WSUD can be used to provide stormwater harvesting at council parks, passive irrigation of vegetated areas, and has added benefits of improving biodiversity, amenity and micro-climate.

The suite of WSUD elements can be applied at varying development scales and are outlined in Table 2. Key WSUD elements which can be applied in the City of Sydney include gross pollutant traps, porous or permeable paving, green roofs/walls, bioretention systems and wetlands. A description of these systems is provided in the following sections. Further information on WSUD elements is available in the South East Queensland Conceptual Design Guidelines for WSUD (Water by Design 2009) and the South East Queensland Technical Design Guide (Water by Design 2007). Both of these guidelines are considered the National benchmark for WSUD practitioners.

Table 2: The application of WSUD elements at varying scales (after Engineers Australia 2006)

WSUD Element	Allotments	Streets, Public Open Space and Precincts	Regional elements
Water Conservation	3★ WELS or above fixtures & appliances	Water use education	Water use education
Landscaping	Landscaping (local indigenous)	Landscaping (local indigenous)	Landscaping (local indigenous)
Stormwater Reuse	Rainwater tanks	Ponds and storage for reuse	Ponds and storage for reuse
Wastewater reuse	Greywater reuse	Greywater / Reclaimed water reuse	Reclaimed water reuse
Stormwater Quality Treatment	On-site infiltration	Precinct infiltration	
	Vegetated swales	Vegetated swales	Rehabilitated waterways
	Raingardens / Bioretention systems	Bioretention systems	Bioretention systems
	Permeable / Porous Paving	Wetlands	Wetlands / Urban forest
Stormwater Quantity Treatment	On-site detention	Retarding basins	Retarding basins

3.1 Gross Pollutant Traps

Gross pollutant traps (GPTs) target gross pollutants including litter, leaves and other vegetative matter. Many GPTs will also capture significant loads of coarse suspended solids. GPTs are often the first treatment measure in a treatment train, for example they can be used upstream of wetlands and other water bodies to protect them from gross pollutants. GPTs are available in a range of different types and sizes, suitable for a wide range of applications. Examples of GPTs are shown in Figure 3.

Pollutant capture efficiency of coarse material varies between different types of GPTs, however most GPTs cannot remove fine sediments, nutrients or other pollutants to any significant degree. Therefore GPTs are not recommended as a sole treatment system if a project is seeking to meet the WSUD targets identified by Council.

Issues when installing GPT’s include consideration of their efficiency in trapping pollutants which will affect the frequency and magnitude of cleanouts, and the volume of waste material that must be disposed. It should be noted that some GPTs store captured pollutants in a drained state, while others hold them in stagnant water. Anaerobic conditions in wet sumps can lead to odours, and wet pollutants may be more difficult to clean out and dispose of than dry pollutants.

Figure 3: GPT in Centennial Park (left), inlet basket (right) (Photos: Alluvium)

3.2 Bioretention Systems / Raingardens

Bioretention systems, also known as raingardens, are commonly constructed in Sydney to meet stormwater quality targets such as those identified by Council. They are suitable in hard urban areas found in the City of Sydney, and can be implemented at a range of scales.

Bioretention systems are vegetated soil filters. Stormwater runoff is treated by draining vertically through a vegetated filter media (typically a sandy loam). Treated stormwater is then collected by a perforated underdrain and directed to the downstream stormwater drainage system. A schematic of a typical bioretention system is shown in Figure 4.

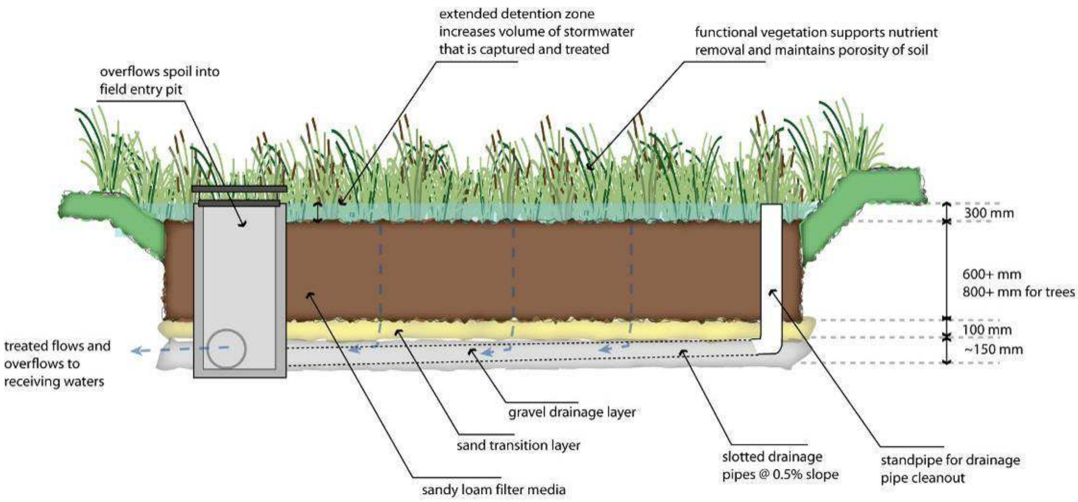


Figure 4: Schematic section through a typical bioretention system

Bioretention systems have a temporary ponding depth (extended detention) of between 100-300mm above the filter media surface to temporarily store stormwater thereby increasing the volume of runoff treated through the filter media.

Vegetation plays a key role in bioretention systems. The surface is densely planted with ground level grasses, sedges, and also some selected tree and shrub species. The agitation of the surface of the bioretention caused by movement of the vegetation and the growth and die off of root systems helps to prevent sediments from clogging the filtration media. Beneath the surface, vegetation provides a substrate for biofilm growth within the upper layer of the filter media. Vegetation facilitates the transport of oxygen to the soil and enhances soil microbial communities which enhance biological transformation of pollutants.

Bioretention systems can be implemented in almost any size and shape, in many different locations including street trees in the footpath, or road or traffic calming devices within streetscapes. It is important to have sufficient depth (normally at least 0.8 m) between the inlet and outlet of a bioretention system, therefore they may not be suitable at sites with major underground services, shallow bedrock or other depth constraints, however they are otherwise a very flexible and effective treatment measure for both suspended and dissolved pollutants.

Bioretention systems can be constructed without a liner, to allow some of the treated stormwater can infiltrate into the underlying ground, if conditions are appropriate. These systems still require underdrainage to ensure that the hydraulic conductivity through the filter media is maintained.

The outlet structure for bioretention systems may also be constructed to create a saturated zone, where the system is not free drainage but rather the standing water level is allowed to be kept within the filter drainage layer or filter media. These systems have been found to promote better establishment of the vegetation and improved nutrient removal. The saturated zone requires a carbon source (such as hardwood chips) to gain full effect of the denitrification process.

Bioretention systems are able to meet the meet the stormwater treatment targets identified in the City of Sydney DCP and are typically sized to be approximately 1-2.5% of the catchment draining to the treatment system. This is shown by the expected bioretention performance for roads in Figure 5, and typical development in Figure 6, both derived from MUSIC modelling.

Based on the curves in Figure 5, a streetscape bioretention system treating only road runoff needs to be at least 1.6% of the catchment area to meet the TSS target of 85% load removed. Based on the curves in Figure 6, a bioretention system for a typical development needs to least 2.2% of the catchment area to meet the TSS target of 85% load removed.

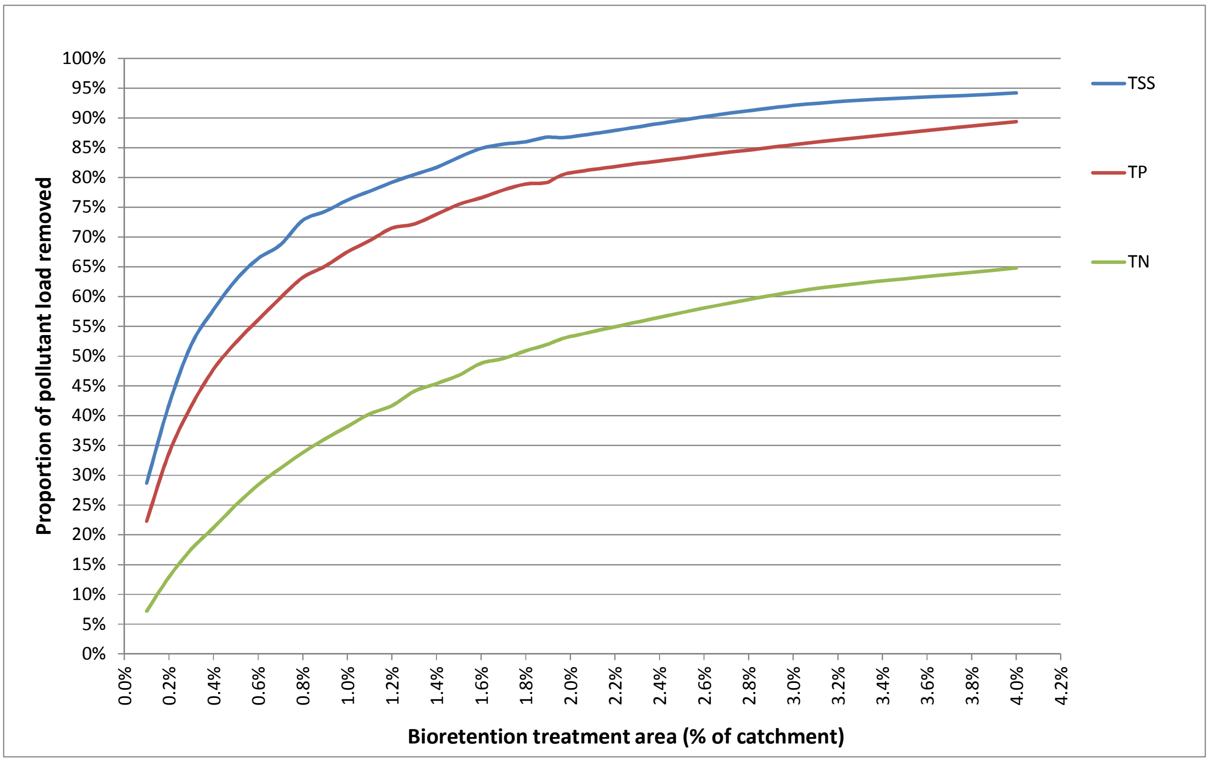


Figure 5: Bioretention Performance – 100% road catchment

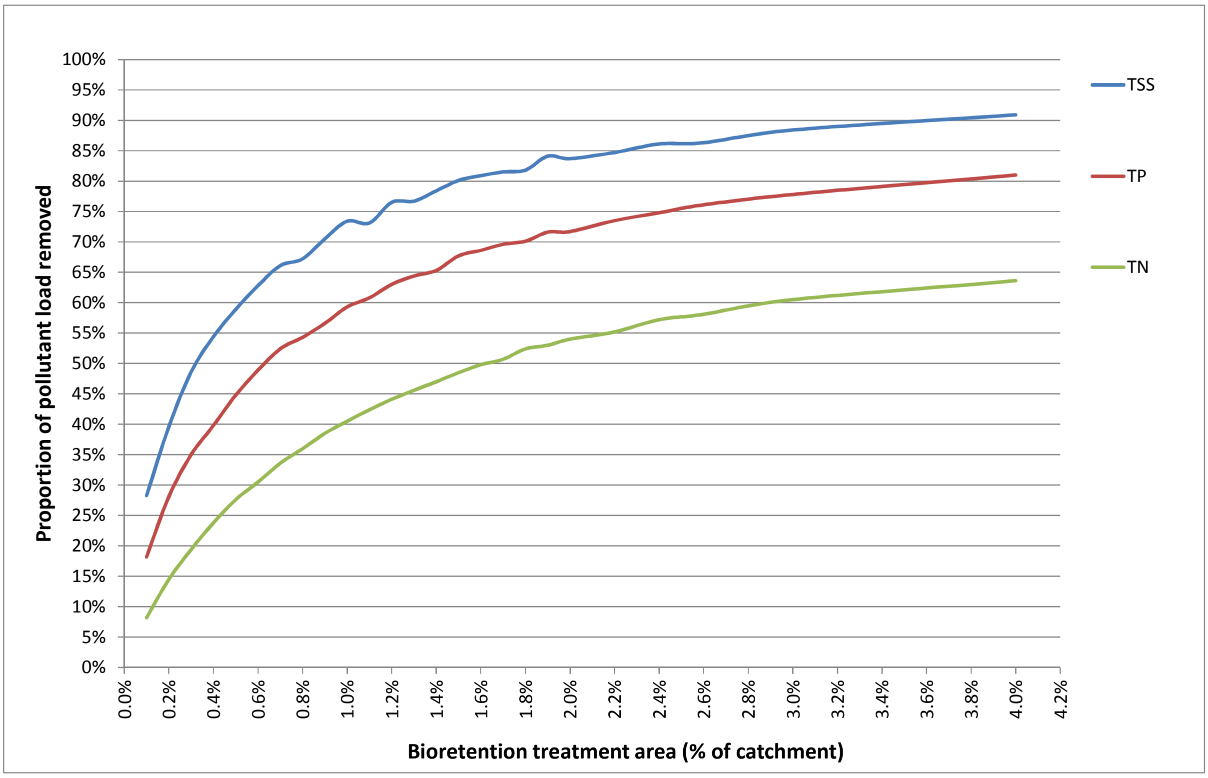


Figure 6: Bioretention Performance – 60% roof catchment, 20% road and 20% pervious

Note that the bioretention systems were modelled with the following parameters:

- Extended detention depth – 200 mm
- Saturated Hydraulic conductivity – 100 mm/hr
- Filter Depth 0.6 m
- TN content of the filter media – 800 mg/kg
- Ortho-phosphate content of the filter media = 40 mg/kg
- Exfiltration – 0 mm/hr (i.e. assuming the system would be fully lined)
- Vegetation with Effective Nutrient Removal plants.

The pollutant removal performance will change with each of these parameters.

3.3 Rainwater and Stormwater Harvesting

Rainwater or stormwater harvesting can reduce stormwater flows (and pollutant loads) discharging to waterways as well as minimising the demand for imported potable water. Within the City of Sydney there is a number of harvesting projects including stormwater harvesting for parks and rainwater harvesting for buildings.

Throughout the City of Sydney there is a significant opportunity to harvest stormwater however a major constraint is the delivery of harvested water to locations where there is a demand for reuse. Demands for harvested and treated stormwater can include irrigation, cooling towers and internal demands such as toilet flushing and hot water supplies.

Stormwater harvesting can achieve pollutant removal by preventing a proportion of stormwater flows from reaching the downstream environment, instead reusing the water for irrigation (which is then evaporated with suspended solids and nutrients going to the soil and plants) or internal demands (with the suspended solids and nutrients removed by treatment or directed to the sewer). The effectiveness of stormwater harvesting as a pollutant load reduction tool depends on the size and type of the catchment, the tank storage volume, and the demand for treated water. The higher the demands, the greater the potential pollutant load reduction.

A series of typical rainwater harvesting curves have been prepared for a City of Sydney building with a 500 m^2 roof area. These have been prepared to illustrate a typical scenario, however the results from these curves can easily be scaled to other roof areas, where buildings are smaller or larger.

Figure 7 shows results for a range of scenarios:

- Rainwater demands were varied from 0.5 to 10 kL/day (182-3,650 kL/year)
- Tank sizes were varied from 25 to 500 kL

Note that typical water demands for typical Sydney commercial buildings (Sydney Water 2007) are within the following range (measured according to the net lettable area):

- Office buildings: 0.4-1.0 $kL/m^2/year$
- Shopping centres: 1.35-1.70 $kL/m^2/year$

Lower demands are achieved by well-managed buildings with no cooling towers, while the higher demands represent median market practice with no leaks. Note that a large proportion of water demands in commercial buildings are for non-potable uses including toilet flushing, cooling towers, cleaning, etc.

A building with a 500 m^2 roof area could have a net lettable area ranging from less than 500 to more than 10,000 m^2, depending on the number of floors. Therefore the range of demands presented in Figure 7 is a wide range, to represent a wide range of different building types.

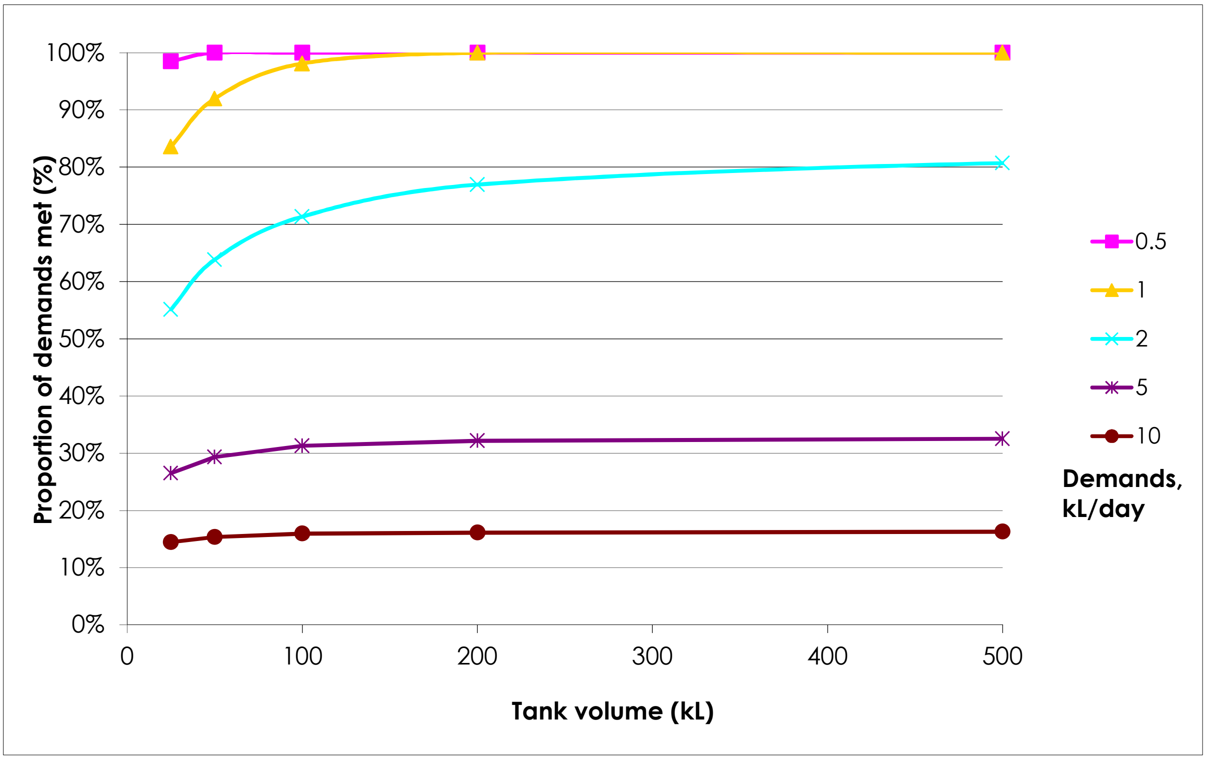


Figure 7: Rainwater tank efficiency curves for a City of Sydney building with 500 m² roof area

Figure 7 shows that a 500 m^2 building with low water demands (0.5 kL/day) can potentially meet all, or a high proportion of, these demands with rainwater. Buildings with larger demands can only meet a small proportion of the total, however the potential total water savings are more significant. Figure 8 translates the results into water savings in ML/year. This shows that for a fixed tank volume, water savings increase as the demands increase, up to a point where the tank volume becomes the limiting factor.

Figure 9 translates water savings into TN load removal in kg/year. These curves follow the same profile as those in Figure 8. For every megalitre of rainwater harvested from the roof, this removes the following pollutant loads:

- 26 kg TSS
- 0.15 kg TP
- 2.2 kg TN

This highlights and helps to quantify the potential role of rainwater harvesting in meeting pollutant load reduction targets for the CBD. If a "typical" building of 500 m^2 roof area and 1400 m^2 net lettable area has total water demands of 1000 kL/year, of which 70% are non-potable (2.0 kL/day), then it can meet approximately 70% of these demands with a 100 kL rainwater tank. This equates to water savings of 0.5ML/year and TN removal of 1.1 kg/year. This sounds small, however the demands are sufficient to remove 90% of the flows and of the pollutant load from the roof.

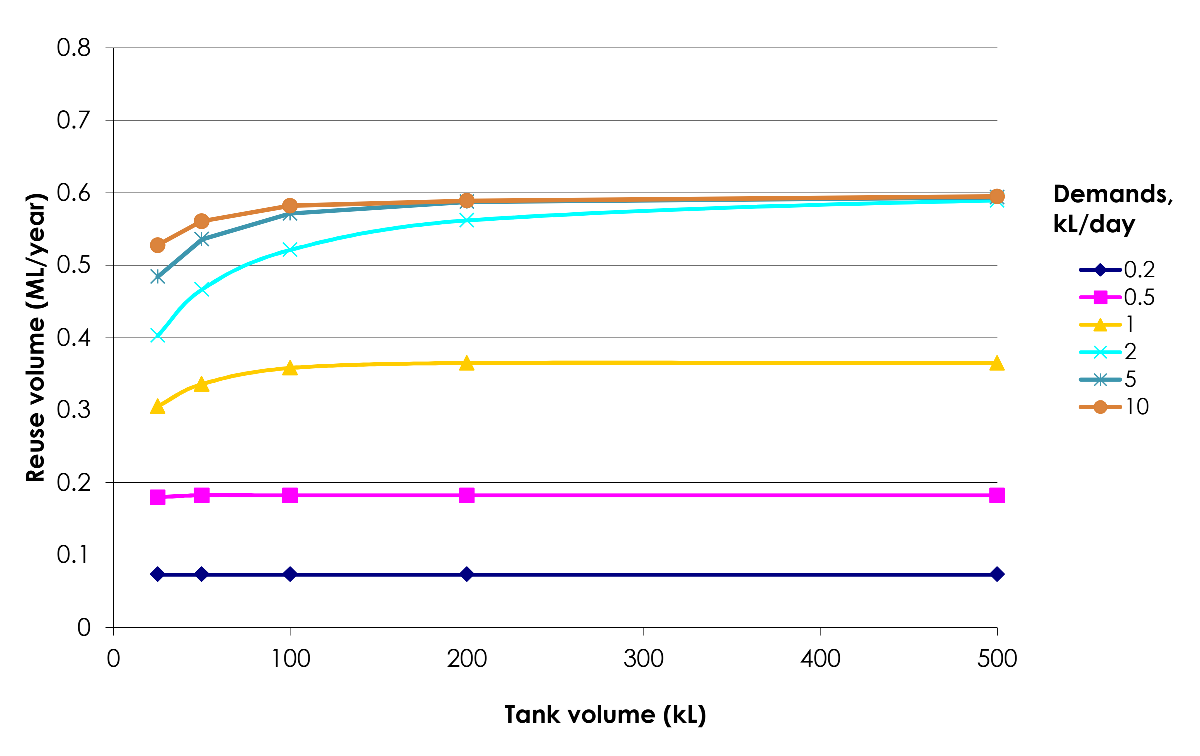


Figure 8: Rainwater tank water reuse curves for a City of Sydney building with 500 m² roof area

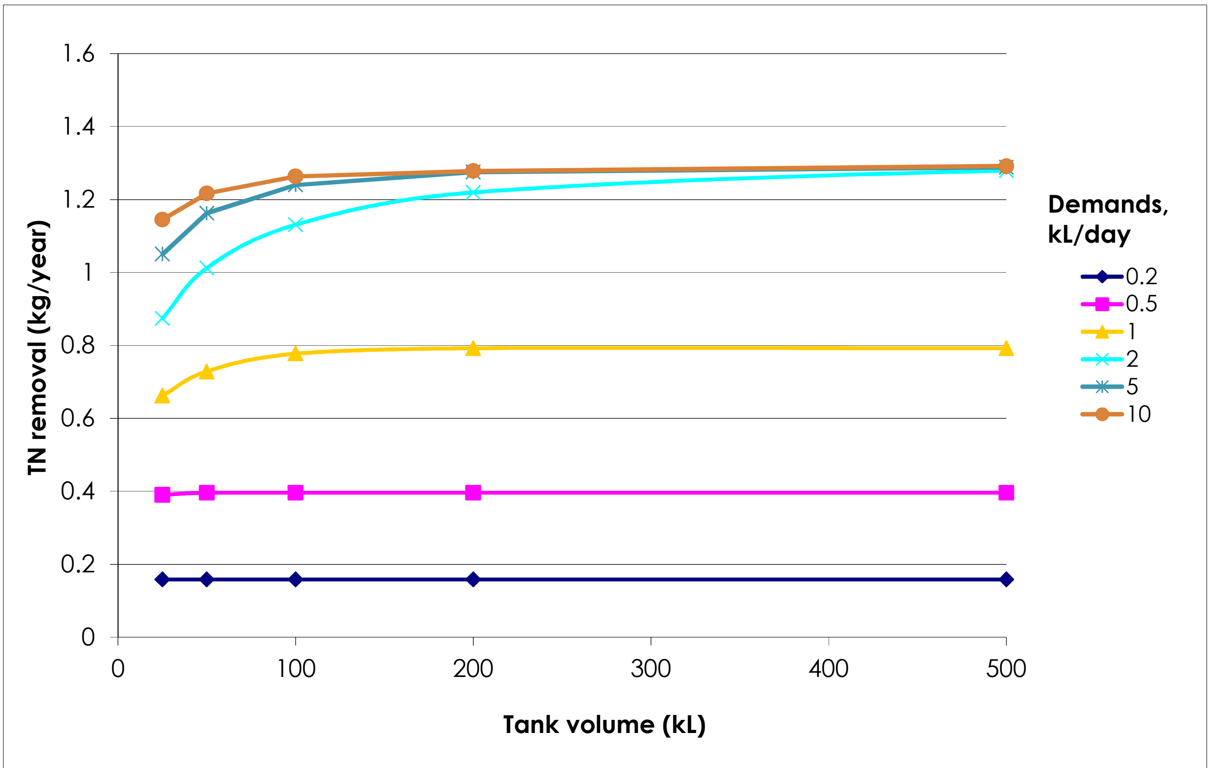


Figure 9: Rainwater tank TN removal curves for a City of Sydney building with 500 m² roof area

3.4 Recycled Water

The City of Sydney also has a recycled water program, as outlined in Part A per the Decentralised Water Master Plan. There will be recycled water precincts where recycled water mains can supply non-potable uses in private buildings. In these precincts developments will be able to connect to a recycled water supply. Proponents should refer to the City of Sydney (Sustainability group) to check if their development is within a recycled water precinct.

Advanced decentralised blackwater (sewage) or greywater treatment plants are also able to be included in new developments where the ongoing operation and maintenance can be adequately managed. Note that these systems are subject to other regulatory requirements.

Note that the use of recycled water contributes to minimising potable water demand and wastewater generation but does not aid in the reduction of stormwater pollutant loads. So whilst there may be benefits for BASIX and Greenstar these systems do not provide any benefit in terms of the water quality targets.

3.5 Permeable Paving

Porous paving (or permeable paving) can replace paved, concrete or bitumen footpaths and roads, and seek to infiltrate stormwater into an aggregate layer or other bedding material beneath the surface. Porous pavements are available from commercial suppliers and include various forms which either infiltrate through the whole media, or through spacing joints in pavers. The main types are:

- Gravel-filled lattice (see Figure 10) – these also allow infiltration in gaps within the lattice
- Open jointed pavers (see Figure 11) – these allow infiltration in gaps between the paving stones
- Porous concrete pavers (see Figure 12) – these pavers themselves are porous, made from a “no fines” concrete that allows infiltration
- Porous asphalt or porous concrete pavements (see Figure 13) – these are continuous surfaces made from porous asphalt or porous concrete. Both are similar, made from large, single sized aggregate with no fines, which leaves large pore spaces for infiltration

Note that “grass pavers”, which allow grass to grow within a concrete or plastic matrix (similar to the gravel-filled lattices pictured in Figure 10), are also available and commonly used in Europe and North America; however these tend to be inappropriate in hot, dry Australian conditions. Grass struggles to survive in these conditions.

Permeable paving is a means of reducing runoff from hard surfaces. It can be used in the place of ordinary paving; however permeable paving is typically only appropriate for footpaths, parking areas or very low speed, low traffic roads or laneways.

Figure 10: Gravel-filled lattices – heavy duty plastic (left) and concrete (right). (Photos: by Damien McGarry, Sunshine Coast Regional Council, as published in the Water by Design *Concept Design Guidelines for Water Sensitive Urban Design).*

Figure 11: Open jointed porous pavers at Darlinghurst (Photo: Equatica)

Figure 12: Porous concrete pavers at Rose Bay Promenade, Woollahra (Photos: Equatica)

Figure 13: Porous asphalt (left) and porous concrete (right) pavements (Photos: http://www.christensen-construction.com/Porous Asphalt.html and http://www.perviouspavement.org/pervious_paths.htm)

Porous pavers can replace regular paving stones in pedestrian areas and sites with low traffic, such as parking bays. Gravel-filled lattices are commonly used for parking bays. Porous pavements (i.e. Figure 13) can be designed for higher traffic loads such as a parking lot or cycleway.

All types of porous paving are at risk of clogging, as the small pore spaces (either in the concrete/asphalt itself or in the aggregate in the gaps between open jointed pavers) are easily blocked by accumulated sediment. Unlike a bioretention system, there is no natural process to maintain porosity of the filtration media. Porous pavements can be cleaned by vacuuming or with a high pressure hose, however this is a time-consuming maintenance task. From an operational perspective most councils would prefer that cleaning is required less frequently. Therefore porous paving is most effective when it is used in the following situations:

- In areas with low sediment loads,
- Where the porous paving receives runoff only from its own catchment (runoff from upstream areas should not be directed onto the porous paving, as the increased loading rate will accelerate clogging),
- Where clogging will not cause nuisance flooding,
- Where cleaning can be undertaken effectively.

It is also important to consider where water will go after it is conveyed beneath the pavement surface. In areas with permeable sandy soils, it may be appropriate to allow infiltration; however in areas with clayey, impermeable soils or in locations next to structures, infiltration is unlikely to be feasible or appropriate. Therefore water will need to be collected at the base of the pavement and conveyed into the stormwater drainage system.

Porous paving therefore has limited applicability as a stormwater treatment measure. It is useful as a source control device, to reduce peak flows, velocities and pollutant loads from paved surfaces. Porous paving reduces peak flows and velocities by providing some detention storage capacity in the underlying media. Where infiltration is possible, runoff volumes can also be reduced. Porous paving also provides some removal of sediment and other pollutants by infiltration; however its capacity is limited due to the tendency for clogging, as discussed above. As such it is recommended that porous paving be designed to function as part of a treatment train, upstream of stormwater treatment systems such as bioretention systems (Water by Design 2009).

Unlike a bioretention system, permeable paving cannot treat a large upstream catchment area, as the various paving systems have limited infiltration capacity and can easily clog. Permeable paving is also not recommended to replace areas which would otherwise be vegetated. However in place of ordinary paving, permeable paving can reduce stormwater runoff and associated pollutant loads.

Permeable paving can contribute to a reduction in stormwater pollution, by reducing the runoff of pollution from road/parking catchments that would typically be impervious.

3.6 Green Roofs and Green Walls

Green roofs can be an effective measure to reduce impervious surfaces in urban areas, however they are not suitable in all situations. Green roofs are expensive to construct, as they require the roof structure to support an increased load (increasing the cost of the roof as a whole), and specialist materials are required for waterproofing, drainage and planting media. Green roofs can also be expensive to maintain and require regular maintenance to sustain vegetation. However green roofs can provide other benefits including thermal insulation to buildings, air quality improvement, amenity, habitat and biodiversity, and they should be considered in context with these benefits as well.

Roofs are particularly important in terms of nitrogen loads, because most nitrogen is deposited from atmospheric sources, and in town centres, there are relatively few additional sources at ground level. Therefore a roof can contribute as high a nitrogen load as a road or other impervious surface.

Green roofs typically cannot treat external stormwater catchments (there may be a few cases where a higher level roof can be treated on a lower level), but they can be used as a means to reduce impervious surfaces and therefore reduce stormwater runoff and pollutant loads if constructed appropriately. Given that green roofs generally include the direct connection of drained soil products to the stormwater system it is important to ensure that the soils have low nutrient concentrations and that fertilisers are not used.

Most green walls provide little benefit in terms of stormwater treatment and may leech nutrients into the stormwater system if consideration is not given to the soil media used. Green walls can also have significant water demands (for irrigation) and therefore have an overall negative impact on the water cycle. Where green walls are proposed in the CBD, they should be designed to minimise potable water demands, and utilise rainwater or treated stormwater for irrigation, so that they make some contribution to reducing stormwater runoff and pollutant loads. As with green roofs, green walls can provide benefits such as thermal insulation, air quality improvement, amenity, habitat and biodiversity, therefore these considerations may encourage their use, even in the absence of water cycle benefits.

Further information on green roofs including a resource manual is available at:
http://www.cityofsydney.nsw.gov.au/vision/sustainable-sydney-2030/sustainability/greening-the-city/green-roofs-and-walls

3.7 Wetlands

Constructed surface flow wetland systems use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. They generally consist of:

- An inlet zone (such as a sediment basin or GPT)
- A macrophyte zone (a shallow heavily vegetated area to remove fine particulates and take up soluble pollutants), and
- A high-flow bypass channel (to protect the macrophyte zone).

Wetland systems can incorporate open water areas. Wetland processes are engaged by slowly passing runoff through heavily vegetated areas where plants filter sediments and pollutants from the water. Biofilms that grow on the plants absorb nutrients and other associated contaminants. While wetlands can play an important role in stormwater treatment, they can also have significant community benefits. They provide habitat for wildlife and a focus for recreation, such as walking paths and resting areas. They can also improve the aesthetics of new developments and can be a central landscape feature. Examples of wetlands are shown in Figure 14.

Wetlands need to be lined with an impermeable liner, which can either be a layer of compacted clay or a strong plastic liner. Wetlands should include at least 200-300 mm good quality topsoil to support the vegetation.

Figure 14: Wetland at Sydney University (left), and in a Marrickville Residence (right) (Photos: Equatica)

3.8 Summary of Appropriate WSUD elements in the City of Sydney

A summary of WSUD elements and their appropriateness for different locations is provided in Table 3. Table 3 is based on the information presented in the section above, and shows that bioretention systems and wetlands are able to meet the best practice WSUD targets identified in the City of Sydney DCP.

- A streetscape bioretention system treating runoff from a road catchment (only) needs to be at least 1.6% of the catchment area draining to the system to meet the TSS target of 85% load removed.

- Bioretention systems for a typical development need to be approximately 2.2% of the catchment area draining to the system to meet the TSS target of 85% load removed.

- A wetland needs to be approximately 5-8% of the catchment to meet the targets.

Several systems such as GPTs, harvesting need to be modelled on the specific project design to determine the extent to which it may meet the targets. Green roofs and permeable paving are not able to meet the targets.

Table 3 identifies where the WSUD elements may be used buildings, street-scapes, or parklands. It is noted that while infiltration systems are appropriate in some soils types in the southern section of the City, when applied in parklands and developments site specific assessments need to be undertaken to determine the appropriateness of infiltration in these areas.

Table 3: WSUD treatment system summary

WSUD Element	Meet the TSS Target	Meet the TP/TN target	Scale		
			Building/ Development	Streetscape	Parklands
GPT	?	X	Y	Y	Y
Bioretention (lined)	Y	Y	Y	Y	Y
Bioretention (unlined - infiltration)	Y	Y	Site specific assessment required	Site specific assessment required	Site specific assessment required
Stormwater harvesting	?	?	Y	n/a	Y
Rainwater Harvesting	?	?	Y	n/a	Y
Permeable Paving	X	X	Y	Y	Y
Green Roofs	X	X	Y	n/a	n/a
Wetlands	Y	Y	Y	N	Y

4 Supporting Information for Preparation of a WSUD Strategy

It is recommended that DA proponents prepare a WSUD Strategy to support their application to meet the WSUD targets. A WSUD Strategy is a written report detailing potable water savings and stormwater quality control measures that are to be implemented on a proposed development site, and would include:

- Proposed development description
- WSUD objectives applicable
- Water conservation measures
- Stormwater quality control measures and modelling
- Integration of WSUD with the urban design
- Costs for WSUD
- Checklist

Table 4 outlines the detail required under each of the headings and provides links to supporting information and key resources and tools available to assist in the preparation of the WSUD Strategy. The supporting information is contained both within this document as well as in external documents which are available on the internet.

4.1 WSUD Strategy Development stage

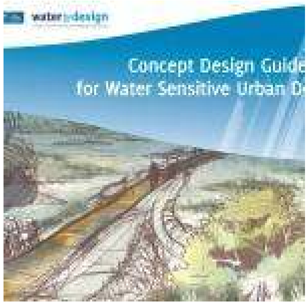
When preparing a Development Application a proponent is required to employ the services of appropriately qualified and experienced practitioners for the development of an appropriate WSUD strategy for their site. The following information should be referred to when developing that strategy.

1. MUSIC Model – MUSIC, the Model for Urban Stormwater Improvement Conceptualisation, derives default water quality parameters for a range of pollutants generated from various land use types. As presented in Australian Runoff Quality (Engineers Australia)[1] most verified and published Australian water quality research has been synthesised and incorporated into MUSIC. The latest version of MUSIC is Version 6 (2013), and is available for purchase at eWater. The MUSIC model includes a modelling guideline which should be referred to when using the MUSIC software.

2. MUSIC Modelling guide – the development of a MUSIC model requires specific inputs and parameters. For proposed developments in the City of Sydney key parameters for undertaking any MUSIC modelling are outlined in Section 5 of this document. Further information on MUSIC modelling is available in the *Draft NSW MUSIC Modelling Guideline*.

[1] Engineers Australia (2006), Australian Runoff Quality, Melbourne, Australia.

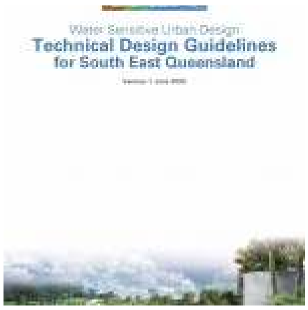
3. WSUD Conceptual Design Information – information on specific WSUD elements (such as rainwater tanks, bioretention and wetlands) and where they are appropriate is available in the South East Queensland's (SEQ) 'Water by Design' Program's Concept Design Guidelines for WSUD. This document provides an industry standard and seeks to assist multi-disciplinary teams conceptualise and develop design solutions that integrate best practice sustainable urban water management within the urban form. The Sydney Metropolitan Catchment Management Authority has produced an Interim Reference Guideline that replaces Queensland references with Sydney specific alternatives available.

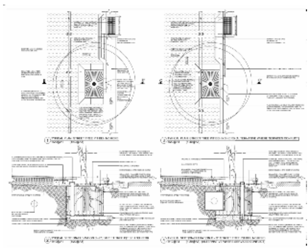


4.2 Further Information beyond the Development Application stage

The following resources outline further information which can be used by proponents when developing detailed design / construction drawings and undertaking construction.

4. Technical Design Manual – the 'Water by Design' Program's WSUD Technical Design Guidelines for South East Queensland describe appropriate methods for the detailed design of some common structural stormwater management measures.





5. Typical Drawings – the Sydney Metropolitan CMA has released typical drawings for a series of WSUD elements, including bioretention systems at steep or flat sites, in footpaths or roadways.

6. Construction and Establishment for Swales, Bioretention Systems and Wetlands – the South East Queensland 'Water by Design' Program has produced Construction and Establishment Guidelines, providing guidance on common construction and establishment issues associated with the delivery of vegetated WSUD elements, assisting practitioners to avoid common faults and potential failure at the delivery and design stage. The Sydney Metropolitan Catchment Management Authority has produced an Interim Reference Guideline that replaces Queensland references with Sydney specific alternatives.

Table 4: Contents of a WSUD Strategy, and tools and resources available

<table>
<tr><th>Outline contents</th><th>Details to be provided in the WSUD Strategy</th><th>Supporting Information</th></tr>
<tr><td>Proposed Development</td><td>Summarise any background information available on the site, including previous studies, a description of the existing site conditions and details of the proposed development – layout, size, catchments, topography, landuse, roof areas, etc.</td><td>Proponent's development layout</td></tr>
<tr><td>WSUD objectives</td><td>This section should identify the WSUD objectives which apply to the development including water conservation and stormwater quality objectives.</td><td>The City of Sydney DCP</td></tr>
<tr><td>Water conservation</td><td>Identify how water saving fittings, fixtures and appliances can be integrated into the development, or if the development is within a recycled water precinct and will be connected, to meet the water conservation targets. Water balance modelling (for harvesting and reuse systems) should include:
Rainfall data
Water demands
Other parameters and assumptions</td><td>Concept Design Guidelines for WSUD (external link Section 4.1)
Standard MUSIC parameters for the City of Sydney (Section 5 of this document)</td></tr>
<tr><td>Stormwater quality
Demonstrate how the stormwater quality targets will be met. Including:
stormwater quality (MUSIC) modelling results
Identify the location, size and configuration of stormwater treatment measures proposed for the development.
Including details of which sub-catchments are directed to which treatment measure.</td><td>Establish a stormwater quality (MUSIC) model for the proposed development to predict expected stormwater pollutant loads generated from development and to develop a strategy to achieve the stormwater quality targets.

The information submitted with the WSUD Strategy should include:
Location, size and configuration of stormwater treatment elements.
Summary of MUSIC results demonstrating compliance with the targets
Details of MUSIC modelling, with the MUSIC parameters and assumptions outlined in an appendix to the WSUD Strategy. Parameters to be reported include:
rainfall (rain station, time step and years of rainfall) and evapotranspiration
source nodes (catchment areas, impervious fractions, soil parameters and pollutant mean and standard deviation values), and
treatment nodes, with the following parameters reported:
bioretention systems - hydraulic conductivity, extended detention depth and filter depth
ponds and wetlands - inlet pond size, permanent pool depth, extended detention depth and notional detention time</td><td>MUSIC modelling software

Standard MUSIC parameters for City of Sydney (Section 5 of this document)

NSW MUSIC Modelling Guide (external link Section 4.1)

WSUD Conceptual Design Information (Section 3 and external link Section 4.1)</td></tr>
</table>

	▪ swales - slope and vegetation heights ▪ where treatment nodes vary from k-c*, values for all pollutants and rationale for non-standard pollutants • Any variation from the recommended MUSIC parameters must be reported and justified.	
Integration with the urban design The WSUD Strategy should outline how WSUD elements will integrate with other elements of the urban design.	This may include: • Site plans (and cross-sections, where relevant) including WSUD elements • List of plant species to be used in vegetated stormwater treatment measures • Drawings to illustrate conceptual layout of WSUD elements within the context of other site features	*Concept Design Guidelines for WSUD (external link Section 4.1)*
Costs Prepare capital and operation and maintenance cost estimates of proposed water cycle management measures.	Both typical annual maintenance costs and corrective maintenance or renewal/adaptation costs should be included. Develop a maintenance plan.	*Concept Design Guidelines for WSUD (external link Section 4.1))*
Checklist	Checklist of the WSUD aspects of the development	*Section 8*

5 MUSIC Modelling Parameters for the City of Sydney

This section provides guidance on modelling parameters to be used when modelling WSUD elements in MUSIC. These guidelines are provided to ensure consultants, developers and Council have a consistent and uniform approach to stormwater quality and harvesting modelling within the City of Sydney local government area.

The parameters outlined in this section should be used at all times when developing a WSUD Strategy to meet the targets outlined in The City of Sydney Council's DCP. Further information on MUSIC Modelling is available in the *Draft NSW MUSIC Modelling Guideline*. The information contained herein is an adaption of the Draft NSW MUSIC Modelling Guideline and should be read in conjunction with the eWater MUSIC User Guide which is provided with the MUSIC software (2013).

This guideline provides specific guidance on rainfall and evaporation inputs, source node parameters, rainfall runoff parameters, pollutant generation parameters and stormwater treatment nodes. Any MUSIC models that are not consistent with this guideline must justify the differences in parameters and/or assessment methods.

5.1 Rainfall & evaporation inputs

The rainfall data recommended for MUSIC modelling for The City of Sydney is shown in Table 5.

Council requires all stormwater quality modelling to use the Sydney Observatory 6-minute rainfall data. A modelling period of 1/1/1982 to 31/12/1986 is recommended, as this period is representative of the long-term average annual rainfall of the City of Sydney, and also includes a number of wet and dry years.

For hydrologic modelling used for stormwater harvesting analysis and stormwater storage design (including rainwater tank sizing), continuous simulation for 50 years should be used at a daily time step for estimating supply reliability. Sydney Observatory daily data from 1925-1974 is recommended as it is representative of the long-term average annual rainfall of the City of Sydney.

Table 5: Recommended Rainfall Data for MUSIC modelling

Purpose	Time step required	Rainfall Station	Modelling Period
Water quality	6 minutes	066062 Sydney Observatory	1982-1986
Water quantity (including rainwater tanks, stormwater storages)	Daily	066037 Sydney Observatory	1925-1974

Average Sydney potential evapotranspiration (PET) data is suitable for use in modelling water quality and hydrology. The monthly PET values for The City of Sydney area are shown in Table 6.

Table 6: Monthly Evapotranspiration for Sydney Region

Month	J	F	M	A	M	J	J	A	S	O	N	D
PET (mm)	180	135	128	85	58	43	43	58	88	127	152	163

5.2 Source node inputs

Rainfall runoff parameters

MUSIC rainfall-runoff parameters have been derived for NSW from model calibration studies. Table 7 outlines the soil properties recommended for adoption in MUSIC modelling for The City of Sydney. The steps for setting up the rainfall runoff parameters are described below:

Step 1: Divide site into sub-catchments based on topography and land use types – all subcatchments (to be designated as separate source nodes) should be classified as Roads, Roofs, and Other impervious and Pervious areas and entered into the model at appropriate locations.

Step 2: Estimate Fraction Impervious for each sub-catchment (source node) – A calculation of the impervious fraction for each sub-catchment (source node) should be made based on the proposed land-uses (eg road, roof, carpark, landscape area etc).

The total impervious area for the site should be consistent with Council's planning controls, including minimum landscaping area, maximum building envelopes, floor space ratios and road design guidelines. For the City of Sydney some of these controls include minimum open space requirements and minimum percentage of deep soil area (refer City of Sydney DCP).

Step 3: Set Soil Properties – For all source nodes, the soil characteristics shown in Table 7 should be adopted in MUSIC based on the location of the site in the soils map (Figure 1). These parameters have been derived based on typical soils found in the City of Sydney LGA. Use of different soil parameters must be justified.

Table 7: Soil properties for MUSIC Source Nodes

Parameter	Unit	Recommended values		
Impervious area parameters				
Rainfall Threshold (mm)	mm	1.5 (for roads/paths etc.) 0.3 (for roofs)		
Pervious area parameters				
		Sand (tg)	**Sandy loam** (dc, ha, gy)	**Clay** (bt, lh, xx)
Soil Capacity (mm)	mm	350	195	187
Initial Storage (%)	%	30	30	30
Field Capacity (mm)	mm	144	135	127
Infiltration Capacity Coefficient a		360	250	135
Infiltration Capacity Coefficient b		0.5	1.3	4.0
Groundwater Properties				
Initial Depth (mm)	mm	10	10	10
Daily Recharge Rate (%)	%	100	60	10
Daily Baseflow Rate (%)	%	50	45	10
Deep Seepage (%)	%	0	0	0

Pollutant generation parameters

The development of the MUSIC software included a comprehensive review of stormwater quality in urban catchments, which forms the basis for the default values of event mean concentrations for total suspended solids (TSS), total phosphorous (TP) and total nitrogen (TN). Table 8 presents the recommended stormwater quality parameters for various land use categories in MUSIC. Note that for all simulations the MUSIC model must be run with pollutant export estimation method set to "stochastically generated" as opposed to the "mean" estimation method.

Table 8: Stormwater Quality Parameters for MUSIC Source Nodes

Land-use category		**Log10 TSS (mg/L)**		**Log10 TP (mg/L)**		**Log10 TN (mg/L)**	
		Storm Flow	**Base Flow**	**Storm Flow**	**Base Flow**	**Storm Flow**	**Base Flow**
General urban (incl. public open space) / **Residential** / **Industrial** / **Commercial**	Mean	2.15	1.20	-0.60	-0.85	0.30	0.11
	Std Dev	0.32	0.17	0.25	0.19	0.19	0.12
Road Areas	Mean	2.43	---*	-0.30	---*	0.34	---*
	Std Dev	0.32	---*	0.25	---*	0.19	---*
Roof Areas	Mean	1.30	---*	-0.89	---*	0.30	---*
	Std Dev	0.32	---*	0.25	---*	0.19	---*

***** Base flows are only generated from pervious areas, therefore these parameters are not relevant to impervious areas

5.3 Treatment node inputs

To meet the site's stormwater quality objectives the development will need to incorporate an appropriate stormwater treatment process for the development, dependent on site constraints and opportunities.

The default parameters in MUSIC for the first order decay k-C* model used to define the treatment efficiency of each treatment device should be used unless local relevant treatment performance monitoring can be used as reasonable justification for modification of the default parameters. Reference should be made to the MUSIC User Manual.

Note: The following devices are not to be modelled within the MUSIC program: Natural waterways, Natural wetlands, Naturalised channel systems, Environmental buffers and ornamental Lake/Pond systems.

In order to avoid any confusion relating to treatment node implementation Council provides the following advice for modelling stormwater quality treatment systems within the City of Sydney LGA.

Table 9: Stormwater treatment parameters

Stormwater treatment measures	Selected key parameter values and design guidance
Bioretention systems (basins & swales) 	High flow bypass = generally 3-month ARI flow (to be calculated by consultant). Extended detention depth (for basins or raingardens) = 0.05 - 0.3 m (CoS standard drawing has 0.1m) Extended detention depth (for swales) = 0 Filter depth = 0.4-0.8 m (CoS standard drawing has 0.4m) Saturated hydraulic conductivity = 50-200 mm/hr Exfiltration rate = 0 mm/hr (if lined) TN content of filter media = >600mg/kg Orthophosphate content of filter media = >30mg/kg Note that a submerged (saturated) zone requires a specially designed outlet pit configuration.
Gross pollutant traps 	High flow bypass for the device = 3-month ARI peak flow. Gross pollutant removal should be obtained for the specific GPT type proposed from the supplier – preferably independently verified. Pollutant removal should be based on Appendix C of the MUSIC User Manual and the *Draft NSW MUSIC Modelling Guideline*.
Wetlands 	High flow bypass = 1 year ARI flow (to be calculated by consultant). Inlet pond volume calculated using: • Inlet pond surface area = 10% of macrophyte zone (storage surface) area • Inlet pond depth = 2.0 m recommended • Extended detention depth = 0.25 - 0.75 m based on outlet design Notional detention time target = 72 hours.
Swales 	Bed slope = 1-5% Vegetation heights of 0.05-0.5 m are acceptable, however MUSIC assumes that swales are heavily vegetated when modelling their treatment performance. Mown grass swales should not be expected to provide significant stormwater treatment and should not be modelled in MUSIC.
Rainwater tanks 	Only roofs should be connected. Given constraints due to gutter and downpipe arrangement, typically a maximum of 50% of the total roof area can be connected to one tank. If using stored water for irrigation, insert annual irrigation demand (kL/yr) and provide other irrigation estimation details. For a daily demand (kL/day), make estimation based on proposed building design with calculations of proposed demands to be connected (e.g. toilet flushing and/or washing machines).
Infiltration systems 	Infiltration is not a stormwater treatment measure and stormwater treatment should be provided upstream of infiltration basins. MUSIC pollutant removal parameters assume that the basin is vegetated and that stormwater is pre-treated to remove coarse sediment upstream of the retention/infiltration basin. If these assumptions are not true, then the basin should not be expected to meet the pollutant removal performance estimated in MUSIC.
Water quality ponds 	Permanent pool = 1.0-2.0 m Extended detention depth = 0.25-1.0 m. Parameters within the MUSIC model assume that stormwater is pre-treated to remove coarse sediment upstream of the pond, therefore ponds should never be designed without pre-treatment (such as a swale or sedimentation basin).
Sedimentation basins 	Permanent pool volume based on 2 m depth (e.g. with a surface area of $50m^2$ the PPV would be $100m^3$) Extended detention depth = 0.25-1.0 m

Stormwater treatment measures	**Selected key parameter values and design guidance**
Detention basins  Detention Basin	*On site detention basins are not to be modelled for water quality impacts.* Refer to Council's DCP for details on OSD requirements.
Buffers  Buffer	Buffer strips are only applicable where runoff is distributed across the whole buffer strip and the buffer strip slope is ≤ 5%
Media filtration systems (e.g. sand filters)  Media Filtration	As per bioretention systems (without vegetation)
Generic  Generic	For modelling a treatment device that is not a specific node within the program. This option should only be used is the user has sufficient data to model it effectively. Examples of applications include flow diversions, or sewer overflows.
Porous Paving	Whilst MUSIC does not include a treatment node specifically for porous paving, it can be modelled using an unvegetated bioretention treatment node. If using this method the void spaces in the paving area should be set as the 'filter area'. Refer to the *Draft NSW MUSIC Modelling Guideline* for details on modelling.
Permeable Pipes	Permeable pipes are to be modelled according to the manufacturer's recommendations. The flows treated by the permeable pipes must be according to the treatable flow rate for the proposed length of pipe and head achieved for infiltration.
ALL TREATMENT NODES	If infiltration is allowable based on a site specific investigation, seepage loss (exfiltration rate) should be as follows: - 36 mm/hr for sandy sites (within soil landscape zone tu) - 3.6 mm/hr for sandy clay loam (within soil landscape zones gy, ha, dc) If site specific hydraulic conductivity tests are carried out these can be used to set an alternative exfiltration rate. Evaporative loss should normally range from 75% of PET for completely open water to 125% of PET for heavily vegetated water bodies.
ALL "ADVANCED PROPERTIES" (k-C* values, orifice discharge and weir coefficients, void ratio, number of CSTR cells)	As per MUSIC default values

6 Bioretention Systems as WSUD Treatment

Bioretention systems are commonly used in Sydney to meet stormwater quality targets, and are further described in this section. Bioretention systems are vegetated soil media filters, which treat stormwater by allowing it to pond on the vegetated surface, then slowly infiltrate through the soil media. Treated water is captured at the base of the system and discharged via outlet pipes. A typical cross-section of a bioretention system is shown in Figure 15.

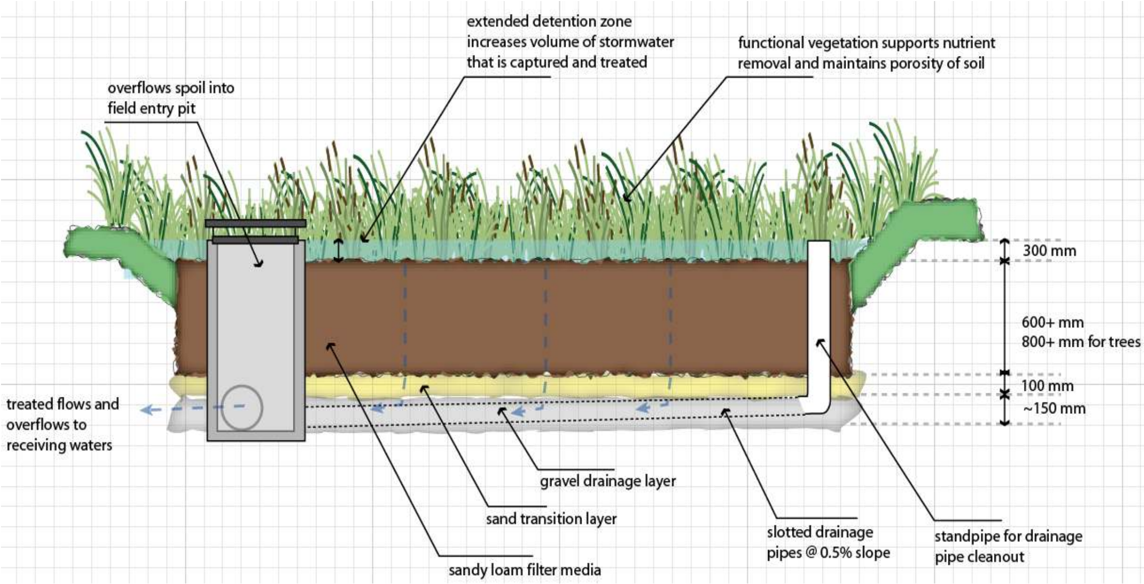


Figure 15: Bioretention system typical arrangement (Water by Design 2009)

Bioretention systems can be implemented in almost any size/shape in many different locations including street trees in the footpath, or road or traffic calming devices within streetscapes. It is important to have sufficient depth (normally at least 0.8 m) between the inlet and outlet of a bioretention system, therefore they may not be suitable at sites with shallow bedrock or other depth constraints, however they are otherwise a very flexible and effective treatment measure for both suspended and dissolved pollutants.

Bioretention systems are able to meet the meet the stormwater treatment targets identified in Council's DCP and are typically sized to have a filter area of approximately 2% of the catchment draining to the treatment element. This size will vary based on the imperviousness of the development and elements of the bioretention system such as extended detention depth and filter depth.

6.1 Street trees

Street tree bioretention systems are small systems that are incorporated into street tree plantings. These systems can be integrated into high-density urban environments and can take on a variety of forms. The filter media should be at least 0.8 m deep to allow for root growth of the tree, therefore substantial depth is required between the inlet and outlet. Examples of street tree bioretention systems are shown in Figure 16.

6.2 Bioretention Rain-gardens

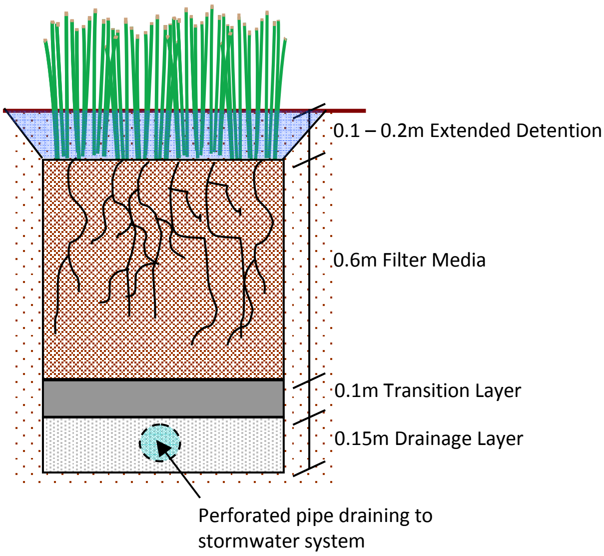
Rain-gardens can be incorporated in a range of locations, as they can be any shape and size. They are essentially small bioretention basin systems, with typical locations including pocket parks, traffic calming measures and between parking bays. Examples of rain-gardens in The City of Sydney are shown in Figure 16 and Figure 17.

Figure 16: WSUD in Street Tree pits – Redfern St (left), Sydney University (centre) and Pirrama Park, City of Sydney (right) (Photos: Alluvium).

Figure 17: WSUD rain-gardens in The City of Sydney LGA – Telopea St, Redfern (left), Pirrama Park, Pyrmont (right), (Photos: Alluvium).

6.3 Elements of a bioretention system

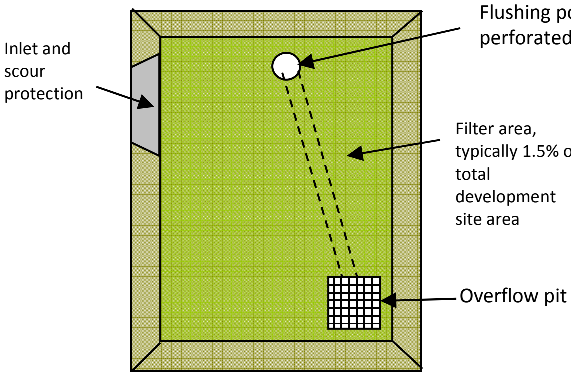
A bioretention system includes the following components:



- **Vegetation** prevents surface clogging and assists in pollutant removal via biological processes. Some plant species that can be used include:
  - *Banksia robur*
  - *Correa alba*
  - *Dianella caerulea 'King Alfred'* (Blue flax-lily)
  - *Dichelachne micrantha*
  - *Doryanthes excels*
  - *Imperata cylindrical* (Blady Grass),
  - *Isolepsis nodosa*
  - *Lomandra hystrix*
  - *Lomandra longifolia* (Matrush)
  - *Melaleuca thymifolia*
  - *Westringia fruiticosa*
  - *Acmena smithii*
  - *Callistemon sp*

  A minimum of 8 plants per square metre is recommended, which may be planted from 'hiko' cells, provided that there is adequate irrigation and maintenance during the establishment period. Shrubs or trees may also be included.

- **Extended detention** (or ponding depth) stores stormwater temporarily on the surface to buffer flows so that a greater volume can be treated.
- The **filter media** is the principal treatment zone. As stormwater passes through the filter media, pollutants are removed by filtration, adsorption and biological processes. The filter media should normally be 0.6 m deep, and 0.3 m is the minimum acceptable depth where the site is constrained. The filter media should be a loamy sand (refer technical specification for details) with a permeability of 200-400 mm/hr after gentle compaction and should be clean and free of weeds. The filter media should contain some organic matter (less than 5%) but be low in nutrient content. No fertiliser is to be added.
- A **transition layer** of clean well graded sand/coarse sand prevents the filter media from washing out of the system
- The **drainage layer** of clean fine gravel (2-5 mm) collects treated water at the base of the system and contains 90-100 mm perforated pipes to convey treated water out of the system
- An **impervious liner** may be required to prevent infiltration into surrounding soils, particularly if the treatment system is immediately adjacent to roads or buildings where infiltration may cause structural issues. Note that geotextile filters should not be used within the bioretention system, as they are prone to clogging. If perforated pipes come with a geotextile sock, this should be discarded before installation.
- An **inlet** for stormwater runoff. The inlet should be designed to protect the surface of the bioretention system from scour and erosion



- An **overflow pit** (or other controlled overflow point) to allow high flows, beyond the capacity of the treatment system, to escape to the stormwater drainage system in a controlled manner

- A **flushing point** connected to the perforated pipes, so they can be cleaned in the event of blockage

- **Edge treatment** (e.g. a raised kerb or series of bollards) may be required to protect the bioretention system from traffic
- **Pre-treatment** is recommended when sediment loads are likely to be high, or if there is a risk of spills. The simplest option is to incorporate a pit with a sump immediately upstream of the bioretention system.

7 Detailed design advice

7.1 Detailed Designs for Specific Sites

Design guidance in the form of typical drawings for bioretention systems at steep or flat sites, in footpaths or roadways, has been developed by the WSUD in Sydney program and is available at the following link - http://www.wsud.org/wp-content/uploads/SMCMA-WSUD-Standard-Drawings-Final.pdf.

Further detailed design guidance can be found in the *Water By Design* 'Bioretention Technical Design Guidelines', available at: http://waterbydesign.com.au/techguide/

Note that consultants designing WSUD in the public domain to be owned and maintained by the City of Sydney are required to use the City's specifications and standard WSUD drawings.

WSUD systems should be designed to ensure that they will require as minimal on-going maintenance as practical.

7.2 Construction and maintenance

It is essential that adequate construction supervision is provided and that all hold points are witnessed by an appropriately qualified person. The correct installation of drainage systems, media and planting are all crucial in making raingardens function properly and ensuring that they are visually appealing from early in their life.

During the construction phase, bioretention systems should be protected from high sediment loads associated with construction on site (erosion and sediment control measures should be in place to manage stormwater during this phase). The bioretention system should be connected at the end of the construction phase.

Regular maintenance is important to ensure the ongoing performance of bioretention systems. Maintenance requirements of bioretention systems include:

- Monitoring for scour and erosion, and sediment or litter build-up
- Weed removal and plant re-establishment
- Monitoring overflow pits for structural integrity and blockage

Further information is available in the Construction and Establishment for Swales, Bioretention Systems and Wetlands guidelines, is identified in Section 4.2. Further information on design checking tools and typical maintenance activities in contained in Sections 8 and 9 respectively.

8 Design Checking Tools

Design checklists have been adopted for the City of Sydney LGA for the following stormwater treatment elements:

- Bioretention systems
- Constructed wetlands

For sand filters and infiltration measures, the design checklists in the SEQ Guidelines are appropriate for the City of Sydney.

The checklists are provided on the following pages. The checklists present the key design features that are to be reviewed when assessing the design of stormwater treatment systems. These considerations include configuration, safety, maintenance and operational issues that need to be addressed during the design phase.

BIORETENTION SYSTEM DESIGN ASSESSMENT CHECKLIST

Asset I.D.		**DA No.**		
Basin Location:				
Hydraulics:	Minor Storm (m^3/s):	Major Storm (m^3/s):		
Area:	Catchment Area (ha):	Bioretention Area (m^2):		
Treatment			**Y**	**N**
Treatment performance verified from curves?				
Bioretention Media and Drainage Systems			**Y**	**N**
Design documents bioretention area and extended detention depth as defined by treatment performance requirements?				
Overall flow conveyance system sufficient for design flood event(s)?				
Where required, bypass sufficient for conveyance of design flood event?				
Where required scour protection provided at inflow point to bioretention?				
Specifications for filter, transition and drainage layers consistent with FAWB bioretention media specifications?				
Perforated pipe capacity > infiltration capacity of filter media?				
Liner provided to prevent infiltration (if required)?				
Will groundwater levels interact with bioretention system?				
Collection pipes extended to surface to allow inspection and flushing?				
*Overflow pit has set down of at least 50mm below kerb invert? (where conventional gully/lintel used downstream of bioretention then no overflow pit required)				
Surface Finishes			**Y**	**N**
Bioretention area and extended detention depth documented to satisfy treatment requirements?				
Extended detention level is min 50mm below inlet level				
Overflow pit crest set at top of extended detention?				
Maximum ponding depth will not impact on public safety?				
Maintenance access provided to surface of bioretention system (for larger systems)?				
Protection from coarse sediments provided (where required) with a sediment forebay?				
Protection from gross pollutants provided (where required)?				
Landscape			**Y**	**N**
Plant species selected can tolerate extended dry periods, periodic inundation and design velocities?				
Provision for irrigation or water storage in saturated zone?				
Bioretention design and plant species selected integrate with surrounding landscape or built environment design?				
Planting design conforms with acceptable sight line and safety requirements?				
Comments				

WETLAND DESIGN ASSESSMENT CHECKLIST

Asset I.D.		**DA No.**		
Wetland Location:				
Hydraulics:	Design operational flow (m^3/s):	Above design flow (m^3/s):		
Area:	Catchment Area (ha):	Wetland Area (ha):		

Treatment	**Y**	**N**
MUSIC modelling performed?		
Inlet Zone	**Y**	**N**
Discharge pipe/structure to inlet zone sufficient for maximum design flow?		
Scour protection provided at inlet for inflow velocities?		
Configuration of inlet zone (aspect, depth and flows) allows settling of particles >125µm?		
Bypass weir incorporated into inlet zone?		
Bypass weir length sufficient to convey 'above design flow'?		
Bypass weir crest at macrophyte zone top of extended detention depth?		
Bypass channel has sufficient capacity to convey 'above design flow'?		
Bypass channel has sufficient scour protection for design velocities?		
Inlet zone connection to macrophyte zone overflow pit and connection pipe sized to convey the design operation flow?		
Inlet zone connection to macrophyte zone allows energy dissipation?		
Structure from inlet zone to macrophyte zone enables isolation of the macrophyte zone for maintenance?		
Inlet zone normal water level above macrophyte normal water level?		
Maintenance access allowed for into base of inlet zone?		
Public safety design considerations included in inlet zone design?		
Where required, gross pollutant protection measures provided on inlet structures (both inflows and to macrophyte zone)		
Macrophyte Zone	**Y**	**N**
Extended detention depth >0.25m and <0.75m?		
Vegetation bands perpendicular to flow path?		
Appropriate depth and configuration of macrophyte zone to maximize water retention?		
Will deep pools retain water year-round to support mosquito predators?		
Vegetation appropriate to inundation regime in each section of the wetland?		
Aspect ratio provides hydraulic efficiency =>0.5?		
Velocities from inlet zone <0.05 m/s or scouring protection provided?		
Public safety design considerations included in macrophyte zone?		
Maintenance access provided into areas of the macrophyte zone (especially open water zones)?		
Provision for overland flows?		
Safety assessment of publicly accessible areas undertaken?		
Freeboard provided above extended detention depth to define embankments?		
Outlet Structures	**Y**	**N**
Riser outlet provided in macrophyte zone?		
Notional detention time of 48-72 hours?		
Orifice configuration allows for a linear storage-discharge relationship for full range of the extended detention depth?		
Maintenance drain provided?		
Discharge pipe has sufficient capacity to convey maximum of either the maintenance drain flows or riser pipe flows with scour protection?		
Protection against clogging of orifice provided on outlet structure?		
Comments		

9 Maintenance and Inspection Activities

A range of inspection and maintenance activities for bioretention systems are outlined in Table 10.

Table 10: Bioretention System inspection and Maintenance Activities (after Melbourne Water 2013).

Item	Action	Maintenance Timelines
Filter Media	• Remove leaf litter and gross pollutants • Check for biofilms (algal biofilms may develop on the surface of the filter media leading to clogging issues) • Monitor ponding of water following rainfall events • Check for permanently boggy/pooled areas	3 monthly or after major rain events
	• Remove sediment (or scarify filter media surface if required)	Annually
	• Replace filter media	25 years
Erosion	• Check for erosion/scouring • Check for evidence of preferential flow paths • Replace filter media in eroded areas • Add rock protection around inlets (if required)	3 monthly or after major rain events
Mulch	• Check depth and even distribution of mulch • Check mulch is not touching plant stems • Check for sediment/silt accumulation in mulch layer • Replace mulch (if required) • Retain mulch using jute mats or nets (if required)	3 monthly or after major rain events
Vegetation	• Inspect plant health and cover • Replace dead or diseased plants (maintain a consistent vegetation density of 6–10 plants per square metre across the raingarden filter media) • Remove weeds (avoid use of herbicides) • Prune plants (where applicable) • Water plants (if required during establishment phase)	6 weeks initially then dependent on system
Civil Components	• Check infrastructure for damage and repair as required • Ensure inlet (including diversion, if applicable) and outlet points are clear of sediment, litter and debris, and are flowing freely	3 monthly or after major rain events
	• Inspection opening for underdrain (slotted drainage pipe): o Check that inspection opening caps are in place o Check water level o Check for sediment accumulation within underdrainage o Flush the underdrain system (if required)	Annually

References

Bureau of Meteorology (2014) Climate Data Online; Available at http://www.bom.gov.au/climate/data/

City of Sydney (2013) Urban Ecology Strategic Action Plan [draft]; Available at: http://archive.sydneyyoursay.com.au/document/show/293

Chapman, G.A. and Murphy, C.L. (1989) *Soil Landscapes of the Sydney 1:100 000 sheet*. Soil Conservation Service of N.S.W., Sydney.

Fletcher, T., Duncan, H., Poelsma, P., Lloyd, S (2004) “Stormwater Flow and Quality, and the Effectiveness of Non-Proprietary Stormwater Treatment Measures — A Review and Gap Analysis”, Technical Report 04/8, December 2004, Cooperative Research Centre for Catchment Hydrology

Melbourne Water (2013). WSUD maintenance guidelines: Inspection and maintenance activities, Melbourne Water 2013.

NSW Office of Water (2012) Aquifer Interference Policy: NSW Government Policy for the licensing and assessment of aquifer interference activities;

Full web addresses are provided for the weblinks throughout this document:

Sydney CMA Typical WSUD Drawings
http://www.wsud.org/resources-examples/tools-resources/typical-drawings/

Sydney CMA Draft NSW MUSIC Modelling Guideline
http://www.wsud.org/resources-examples/tools-resources/tools/draft-music-modelling-guidelines-31-08-201011/

eWater – MUSIC software
http://www.ewater.com.au/products/ewater-toolkit/urban-tools/music/

South East Queensland’s (SEQ) ‘Water by Design’ Program’s WSUD Technical Design Guidelines for South East Queensland. http://waterbydesign.com.au/TechGuide/

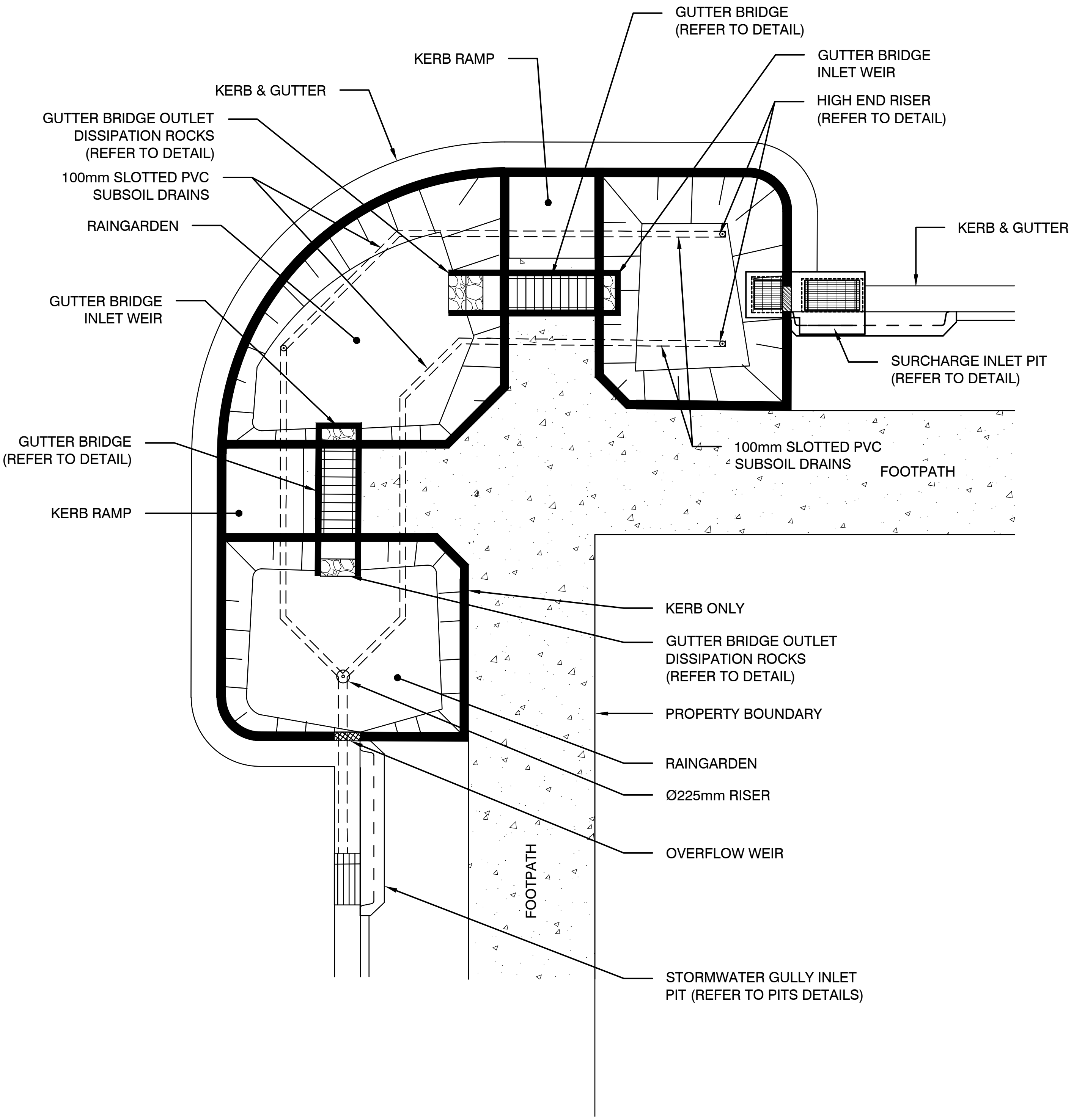
South East Queensland’s (SEQ) ‘Water by Design’ Program’s Concept Design Guidelines for WSUD.
http://waterbydesign.com.au/conceptguide/

Sydney Metropolitan CMA Concept Design Interim Reference Guideline. http://www.wsud.org/resources-examples/tools-resources/reference-guidelines/wsud-reference-guidelines/

South East Queensland ‘Water by Design’ Program Construction and Establishment Guidelines,
http://waterbydesign.com.au/CEguide/

Sydney Metropolitan CMA Construction and Establishment Interim Reference Guideline.
http://www.wsud.org/resources-examples/tools-resources/wsud-reference-guidelines/wsud-reference-guideline-construction-establishment-guidelines_final1/

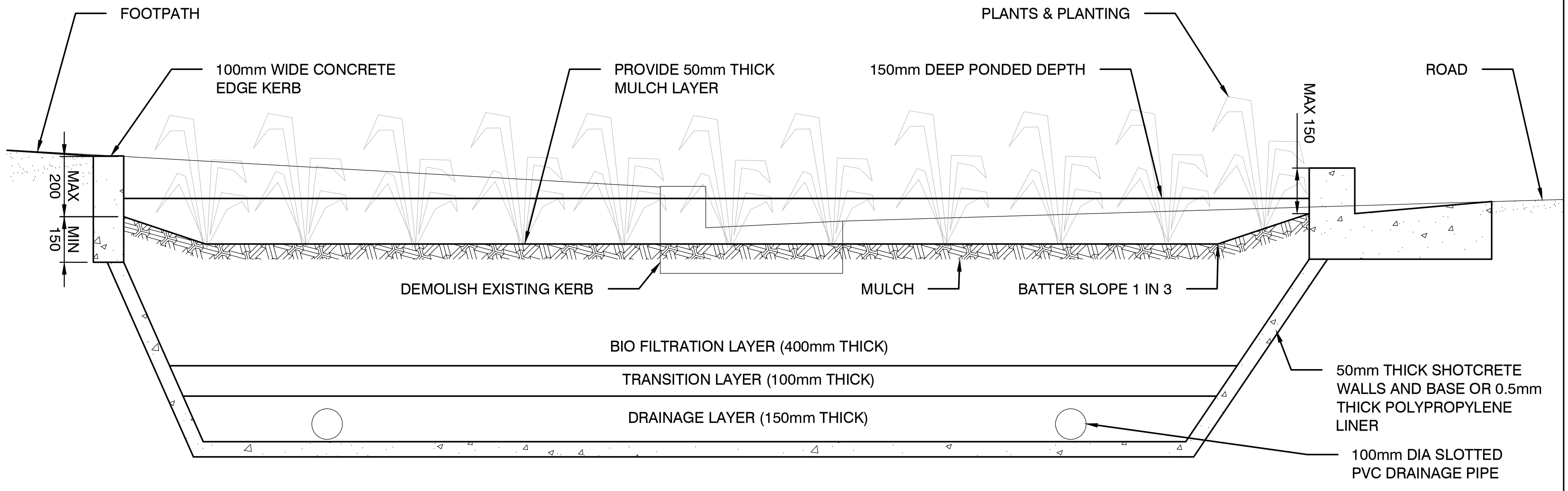
Appendix A – Street Tree Standard Drawings



PLAN 1:100

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030	RAINGARDENS TYPICAL SCENARIO	**Rev** B **Date** 22.03.13 **Approved** P S	DRAINAGE Dwg No. 7.2.1



SECTION 1:20

RAINGARDEN MEDIA SPECIFICATION

MULCH
- WASHED AGGREGATE 10-20mm

BIO FILTRATION SPECIFICATION
SANDY LOAM MIX (IN ACCORDANCE WITH FAWB GUIDELINES)

- SATURATED HYDRAULIC CONDUCTIVITY
100mm /Hr - 250mm \Hr

PARTICLE DISTRIBUTION

DESCRIPTION	PROPORTION	GRADING
Clay & Silt	<3%	<0.05mm
Very Fine Sand	5-30%	0.05-0.15mm
Fine Sand	10-30%	0.15-0.25mm
Medium to Coarse Sand	40-60%	0.25-1.0mm
Coarse Sand	7-10%	1.0-2.0mm
Fine Gravel	<3%	2.0-3.4mm

- TOTAL CLAY AND SILT CONTENT ≤3%
- ORGANIC CONTENT <5%
- PH (1:5 IN WATER) 5.5 - 7.5
- ELECTRICAL CONDUCTIVITY (EC) <1.2dS/m
- TOTAL NITROGEN <1000mg/kg
- ORTHOPHOSPHATE (PO_4^3) <80mg/kg

TRANSITION LAYER SPECIFICATIONS
COARSE WASHED RIVER SAND OR RECYCLED CRUSHED GLASS EQUIVALENT
- 90% PARTICLES RETAINED ABOVE 0.25mm
- SATURATED HYDRAULIC CONDUCTIVITY >250mm/Hr

DRAINAGE LAYER SPECIFICATION
NO FINES DRAINAGE GRAVEL

ACCEPTABLE PARTICLE DISTRIBUTION

PARTICLE SIZE	% RETAINED
>7mm	0
4-7mm	>70%
2-4mm	<20%
<2mm	0

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030

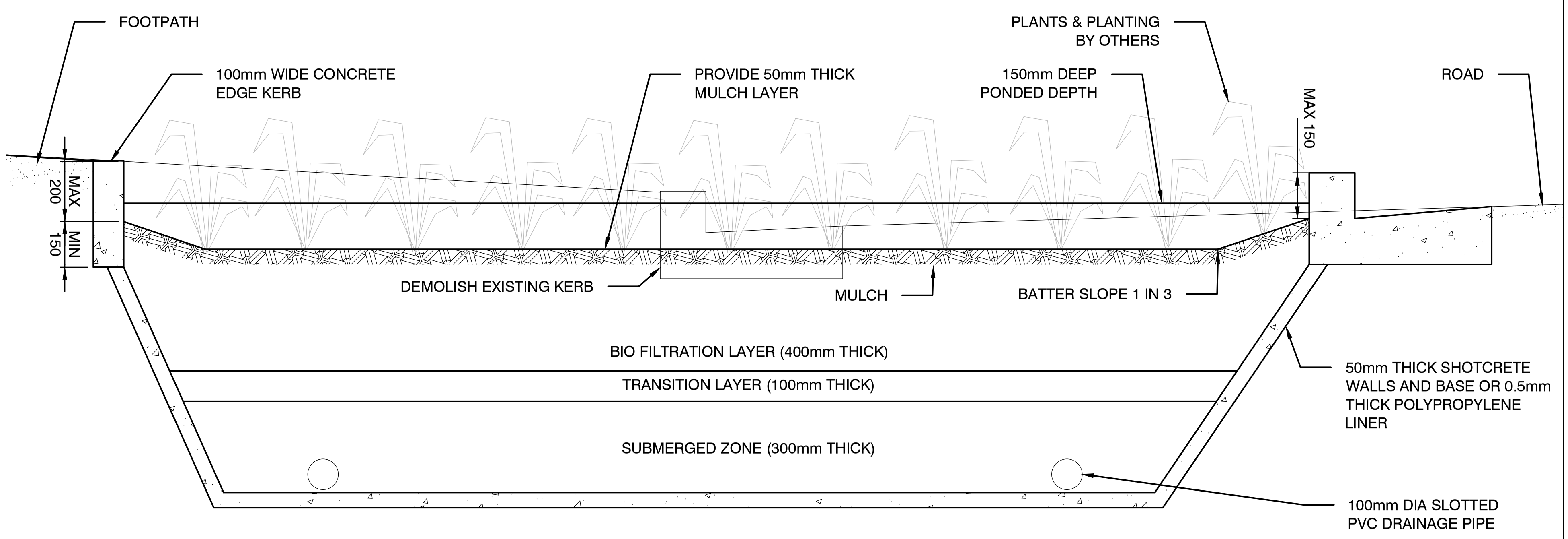
RAINGARDENS

LINED

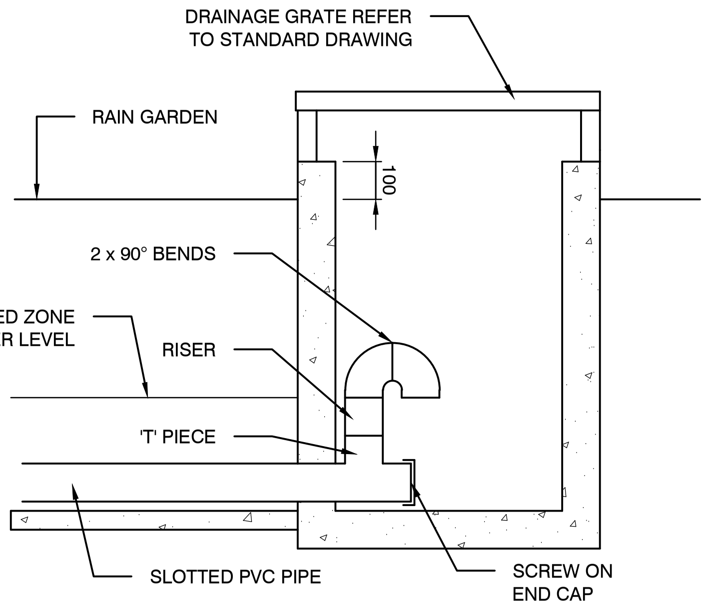
DRAINAGE

Rev D
Date 17.12.13
Approved P S

Dwg No. 7.2.2



PLAN 1:20



NON-STANDARD DRAINAGE PIT CONNECTION (SUBMERGED ZONE)

RAINGARDEN MEDIA SPECIFICATION

MULCH
- WASHED AGGREGATE 10-20mm

BIO FILTRATION MEDIA SPECIFICATION
SANDY LOAM MIX (IN ACCORDANCE WITH FAWB GUIDELINES)

- SATURATED HYDRAULIC CONDUCTIVITY 100mm /Hr - 250mm \Hr

PARTICLE DISTRIBUTION

DESCRIPTION	PROPORTION	GRADING
Clay & Silt	<3%	<0.05mm
Very Fine Sand	5-30%	0.05-0.15mm
Fine Sand	10-30%	0.15-0.25mm
Medium to Coarse Sand	40-60%	0.25-1.0mm
Coarse Sand	7-10%	1.0-2.0mm
Fine Gravel	<3%	2.0-3.4mm

- TOTAL CLAY AND SILT CONTENT ≤3%
- ORGANIC CONTENT <5%
- PH (1:5 IN WATER) 5.5 - 7.5
- ELECTRICAL CONDUCTIVITY (EC) <1.2dS/m
- TOTAL NITROGEN <1000mg/kg
- ORTHOPHOSPHATE (PO_4^3) <80mg/kg

TRANSITION LAYER SPECIFICATIONS
COARSE WASHED RIVER SAND OR RECYCLED CRUSHED GLASS EQUIVALENT
- 90% PARTICLES RETAINED ABOVE 0.25mm
- SATURATED HYDRAULIC CONDUCTIVITY >250mm/Hr

SUBMERGED ZONE SPECIFICATIONS
MIX OF
- NO FINES DRAINAGE GRAVEL
- 5% ORGANIC MULCH (SUGAR CANE MULCH)
- 5% HARDWOOD CHIPS (NOT TREATED)

ACCEPTABLE PARTICLE DISTRIBUTION

PARTICLE SIZE	% RETAINED
>7mm	0
4-7mm	>70%
2-4mm	<20%
<2mm	0

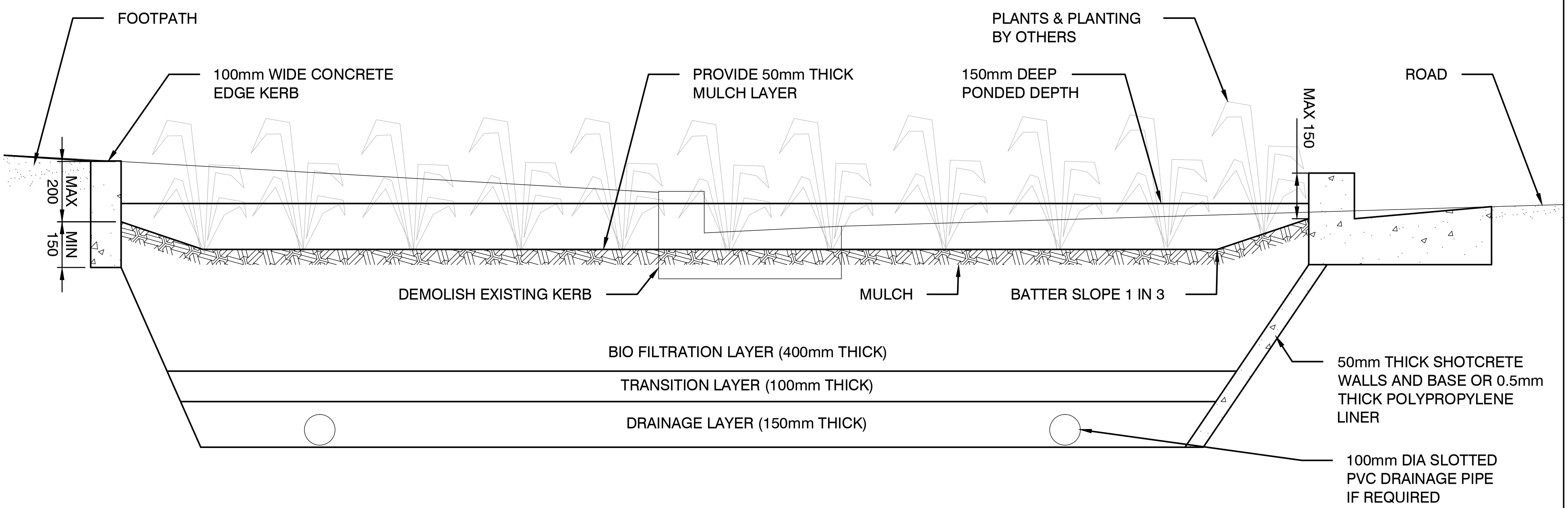
NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030

RAINGARDENS
LINED - SUBMERGED ZONE

Rev D
Date 17.12.13
Approved P S

DRAINAGE
Dwg No.
7.2.3



SECTION 1:20

RAINGARDEN MEDIA SPECIFICATION

MULCH
- WASHED AGGREGATE 10-20mm

BIO FILTRATION SPECIFICATION
SANDY LOAM MIX (IN ACCORDANCE WITH FAWB GUIDELINES)

- SATURATED HYDRAULIC CONDUCTIVITY 100mm /Hr - 250mm \Hr

PARTICLE DISTRIBUTION

DESCRIPTION	PROPORTION	GRADING
Clay & Silt	<3%	<0.05mm
Very Fine Sand	5-30%	0.05-0.15mm
Fine Sand	10-30%	0.15-0.25mm
Medium to Coarse Sand	40-60%	0.25-1.0mm
Coarse Sand	7-10%	1.0-2.0mm
Fine Gravel	<3%	2.0-3.4mm

- TOTAL CLAY AND SILT CONTENT ≤3%
- ORGANIC CONTENT <5%
- PH (1:5 IN WATER) 5.5 - 7.5
- ELECTRICAL CONDUCTIVITY (EC) <1.2dS/m
- TOTAL NITROGEN <1000mg/kg
- ORTHOPHOSPHATE (PO_4^3) <80mg/kg

TRANSITION LAYER SPECIFICATIONS
COARSE WASHED RIVER SAND OR RECYCLED CRUSHED GLASS EQUIVALENT
- 90% PARTICLES RETAINED ABOVE 0.25mm
- SATURATED HYDRAULIC CONDUCTIVITY >250mm/Hr

DRAINAGE LAYER SPECIFICATION
NO FINES DRAINAGE GRAVEL

ACCEPTABLE PARTICLE DISTRIBUTION

PARTICLE SIZE	% RETAINED
>7mm	0
4-7mm	>70%
2-4mm	<20%
<2mm	0

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

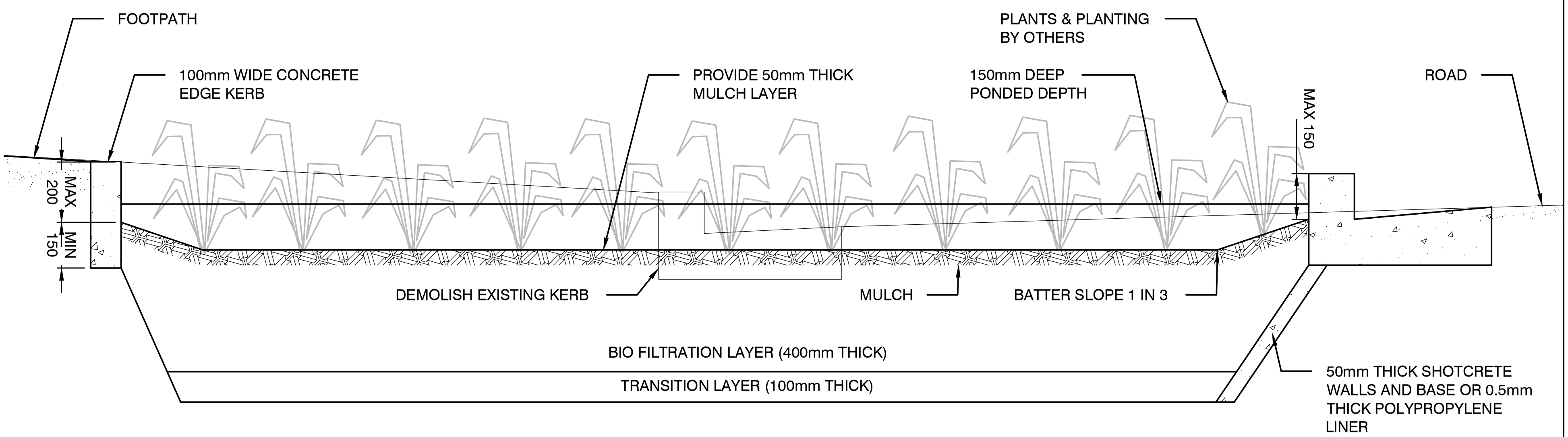
CITY OF SYDNEY 2030

RAINGARDENS
UNLINED

Rev D
Date 17.12.13
Approved P S

DRAINAGE
Dwg No.
7.2.4

SECTION 1:20



RAINGARDEN MEDIA SPECIFICATION

MULCH
- WASHED AGGREGATE 10-20mm

BIO FILTRATION SPECIFICATION
SANDY LOAM MIX (IN ACCORDANCE WITH FAWB GUIDELINES)

- SATURATED HYDRAULIC CONDUCTIVITY 100mm /Hr - 250mm \Hr

PARTICLE DISTRIBUTION

DESCRIPTION	PROPORTION	GRADING
Clay & Silt	<3%	<0.05mm
Very Fine Sand	5-30%	0.05-0.15mm
Fine Sand	10-30%	0.15-0.25mm
Medium to Coarse Sand	40-60%	0.25-1.0mm
Coarse Sand	7-10%	1.0-2.0mm
Fine Gravel	<3%	2.0-3.4mm

- TOTAL CLAY AND SILT CONTENT ≤3%
- ORGANIC CONTENT <5%
- PH (1:5 IN WATER) 5.5 - 7.5
- ELECTRICAL CONDUCTIVITY (EC) <1.2dS/m
- TOTAL NITROGEN <1000mg/kg
- ORTHOPHOSPHATE (PO_4^3) <80mg/kg

TRANSITION LAYER SPECIFICATIONS
COARSE WASHED RIVER SAND OR RECYCLED CRUSHED GLASS EQUIVALENT
- 90% PARTICLES RETAINED ABOVE 0.25mm
- SATURATED HYDRAULIC CONDUCTIVITY >250mm/Hr

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030

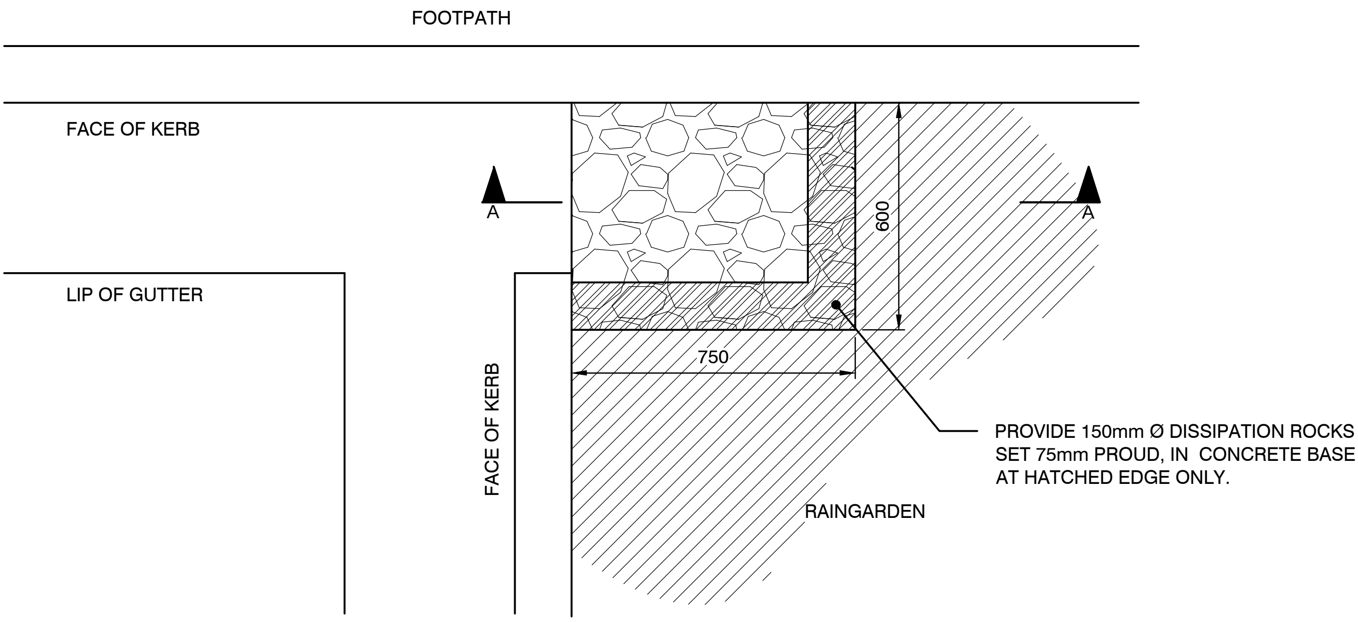
RAINGARDENS
UNLINED - UNDRAINED

DRAINAGE

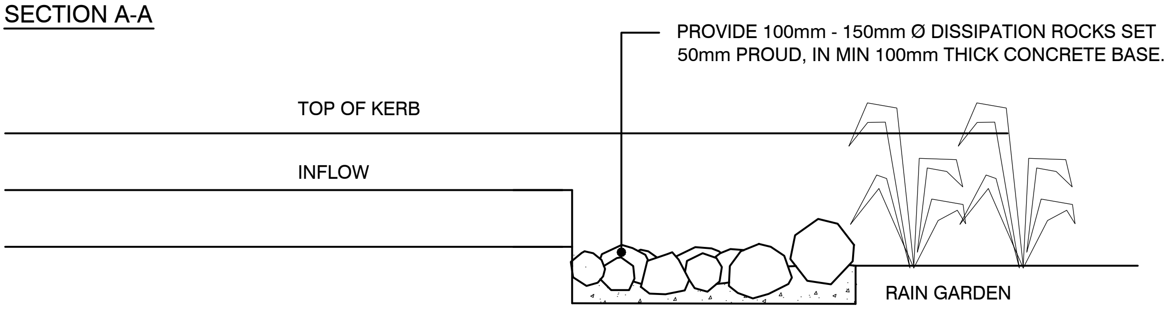
Rev C
Date 17.12.13
Approved P S

Dwg No. 7.2.5

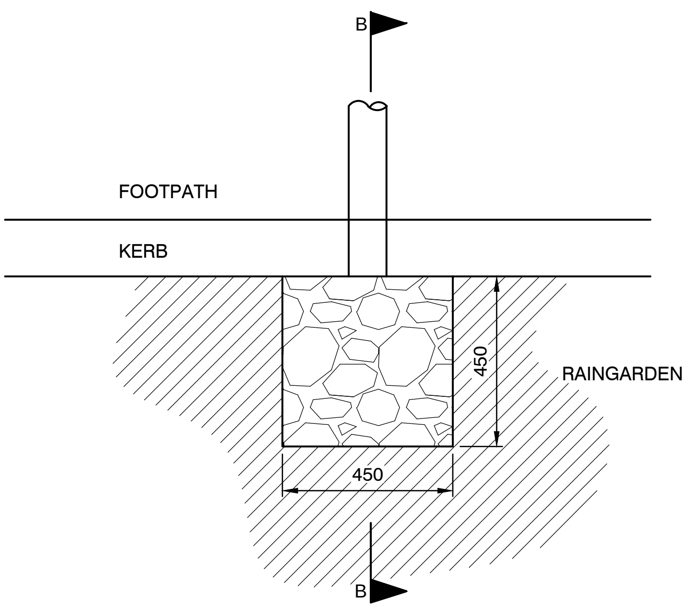
LARGE DISSIPATION ROCKS



SECTION A-A



SMALL DISSIPATION ROCKS



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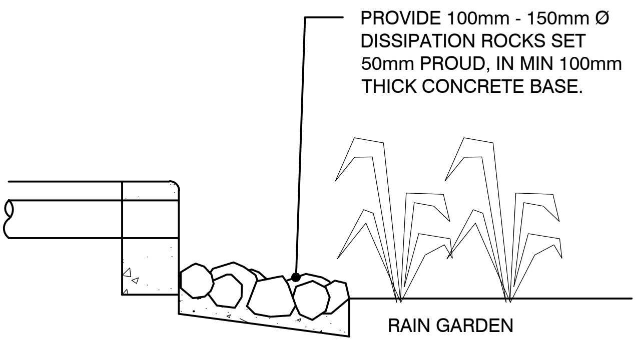


SCALE 1:20

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030

RAINGARDENS

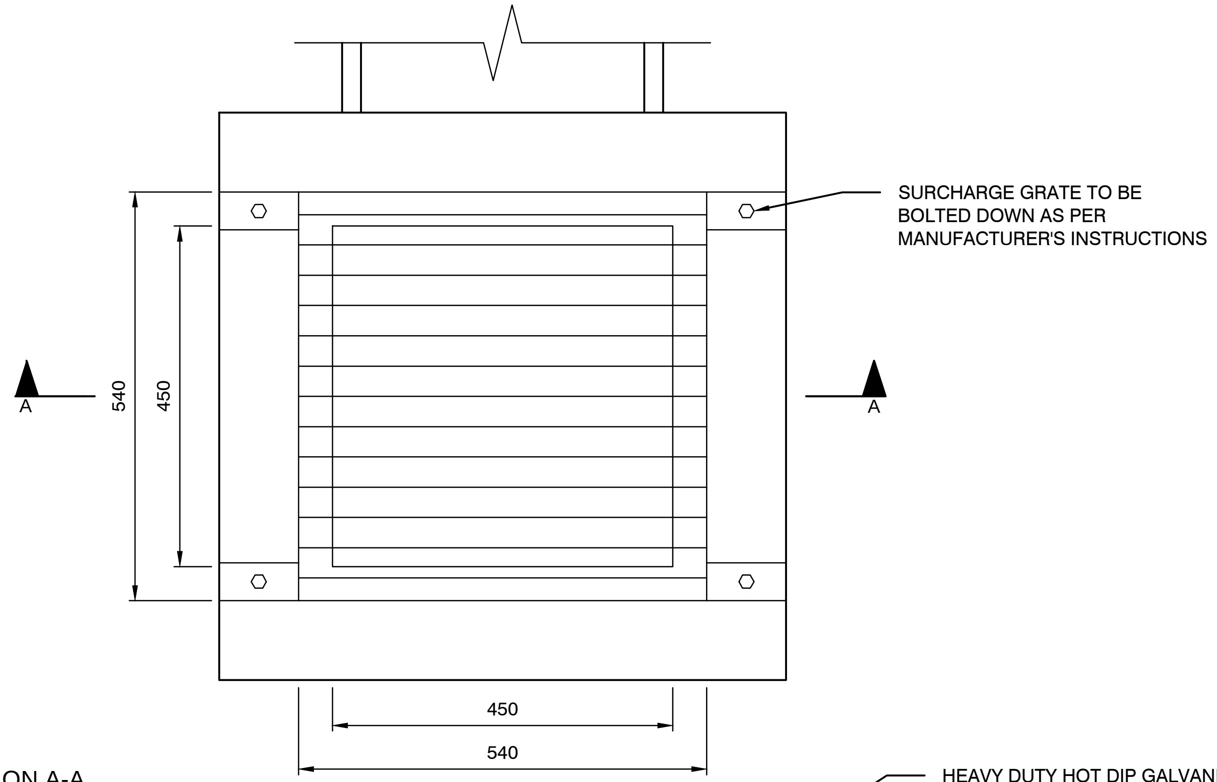
DISSIPATION ROCKS

DRAINAGE

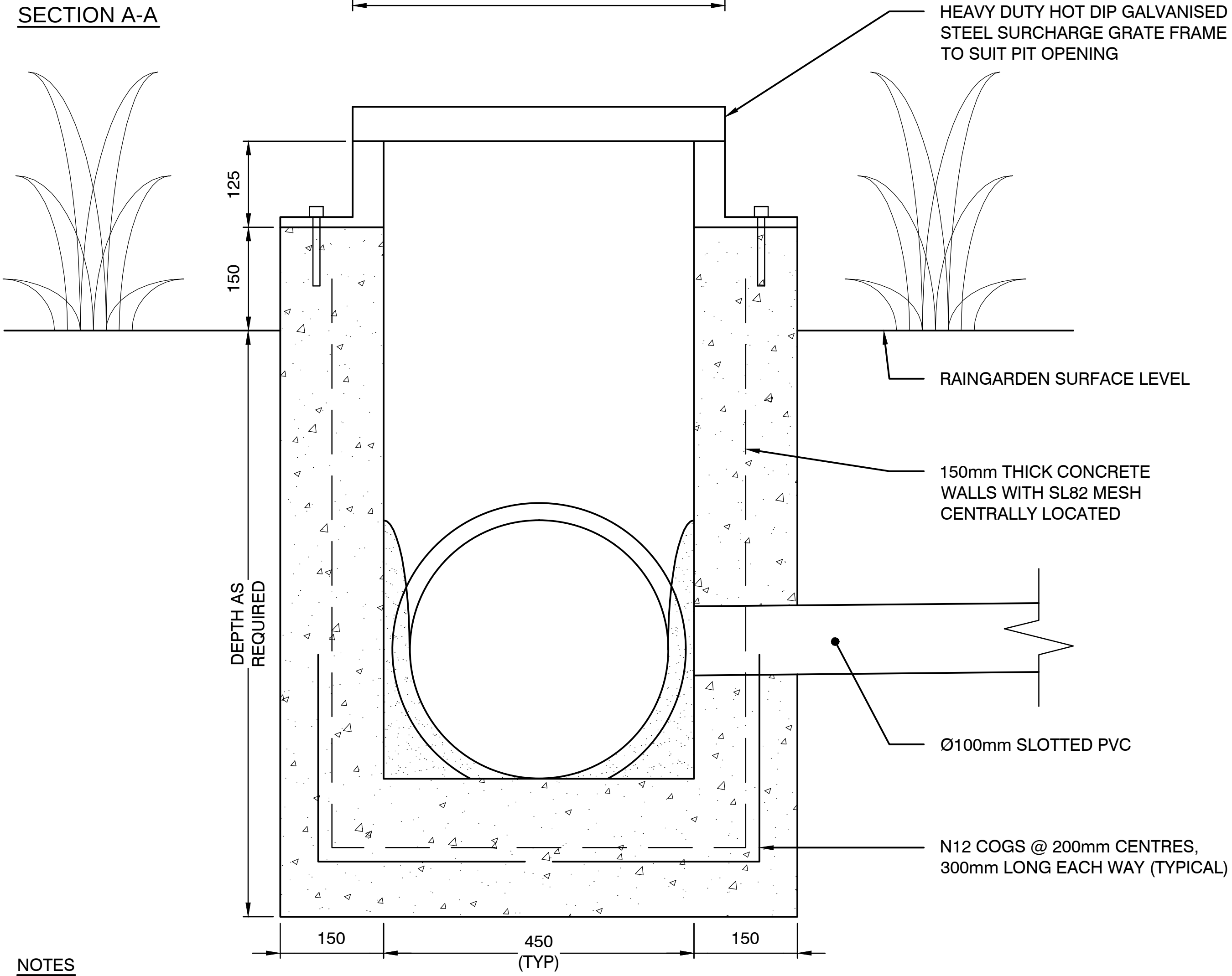
Rev B
Date 22.03.13
Approved P S

Dwg No. 7.2.6

PLAN



SECTION A-A



NOTES

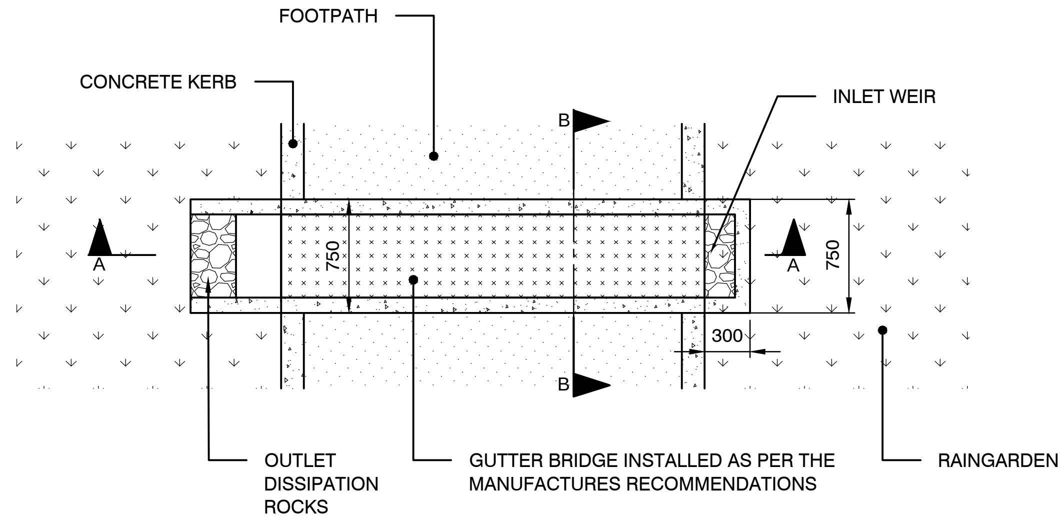
1. ALL CONCRETE IS TO HAVE A MINIMUM STRENGTH OF 32 MPa.
2. PIT STRUCTURE TO BE 150mm THICK UNLESS NOTED OTHERWISE.
3. DRAINAGE PIPE TO BE MINIMUM 375Ø CLASS 4 REINFORCED CONCRETE PIPE

SCALE 1:10

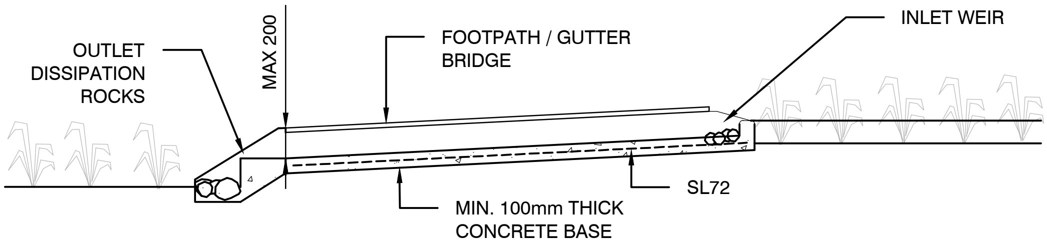
NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030	RAINGARDENS STANDARD SURCHARGE PIT	**Rev** C **Date** 21.11.13 **Approved** P S	DRAINAGE Dwg No. 7.2.7

PLAN



SECTION A-A



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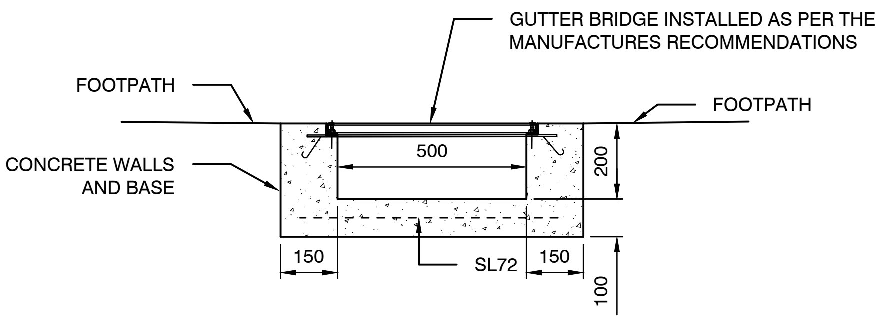
SECTION B-B



SCALE 1:20

GUTTER BRIDGE SELECTION		
ADJACENT FOOTPATH	TYPE	MATERIAL
GRANITE CONCRETE UNIT PAVING	TYPE 1	ACO KLASSIKDRAIN (OR APPROVED EQUIVALENT)
BRICK ASPHALT CONCRETE	TYPE 2	TERRA FERMA FIBERGLASS (OR APPROVED EQUIVALENT)
OTHER		AS APPROVED

NOTE:

1. TYPE 1 TO COMPLY WITH THE FOLLOWING REQUIREMENTS;
   1.1. LOADING CLASS C
   1.2. GRADE 304 STAINLESS STEEL
   1.3. HEALSAFE - MIN 6mm WIDE GAPS
   1.4. MEET SLIP RESISTANCE OF MINIMUM W AS PER HB197
   1.5. MUST BE LOCKABLE
2. TYPE 2 TO COMPLY WITH THE FOLLOWING REQUIREMENTS;
   2.4. LOADING CLASS C
   2.5. MEET SLIP RESISTANCE OF MINIMUM W AS PER HB197
   2.6. COLOURED TO MATCH ADJACENT FOOTPATH
   2.7. MUST BE LOCKABLE

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY

RAINGARDENS

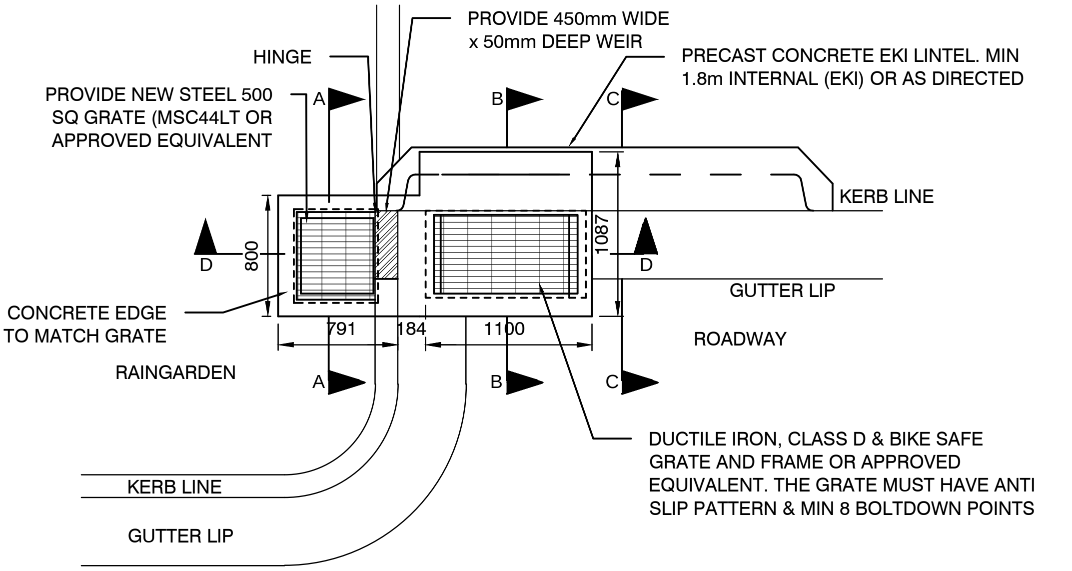
GUTTER BRIDGE

DRAINAGE

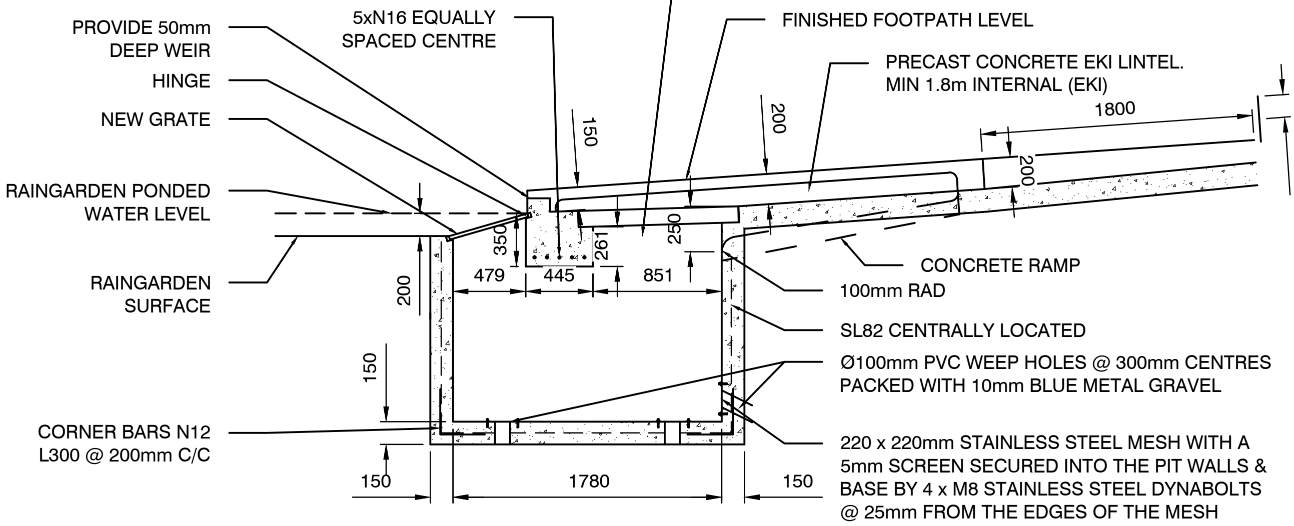
Rev B
Date 21.11.13
Approved P S

Dwg No. 7.2.8

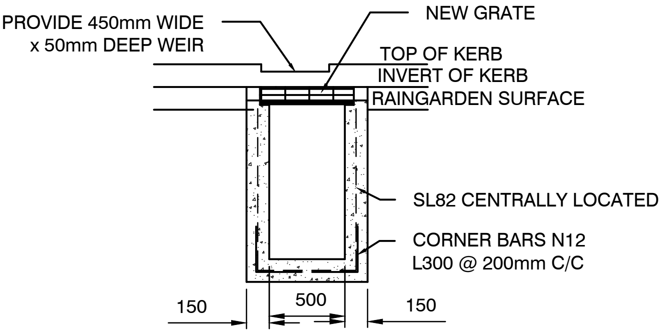
PLAN



SECTION D-D



SECTION A-A



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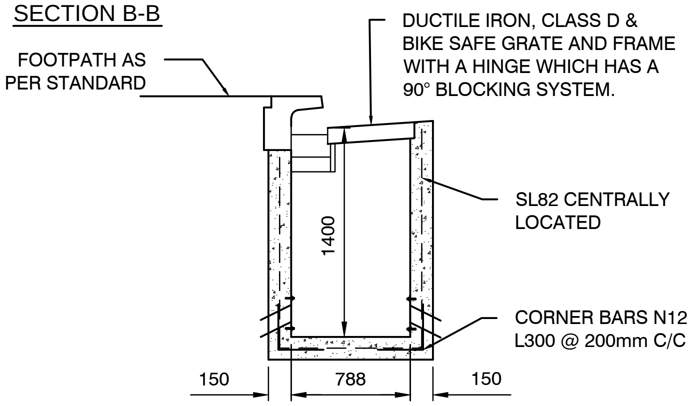
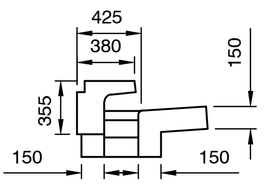


SECTION C-C



SCALE 1:50

NOTES:

1. COMPRESSIVE STRENGTH OF CONCRETE AT 28 DAYS TO BE 32MPa.
2. 75mm MINIMUM BENCHING TO HALF PIPE HEIGHT TOTAL BENCHING TO OBVERT OF PIPE.
3. Ø100mm SUBSOIL DRAINAGE PIPE 3.0m LONG WRAPPED IN FABRIC SOCK TO BE PROVIDED IN PIPE TRENCHES ADJACENT TO INLET PIPES.
4. PROVIDE STEP IRONS WHERE PIT IS DEEPER THAN 1.0m AT 300mm CENTRES.
5. PITS OVER 1.5m IN DEPTH TO BE REINFORCED WITH SL82 MESH RETURNED 300mm INTO BASE WITH WALLS 200mm THICK.
6. PITS OVER 2.4m IN DEPTH TO BE DESIGNED BY STRUCTURAL ENGINEER.
7. GRATES SHALL BE BICYCLE SAFE AND HAVE MAXIMUM INLET CAPACITY. ALL GRATES MUST BE APPROVED BY THE CITY'S REPRESENTATIVE.
8. ALL CONCRETE IS TO HAVE A MINIMUM STRENGTH OF 32MPa.

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030

RAINGARDENS

SURCHARGE INLET PIT

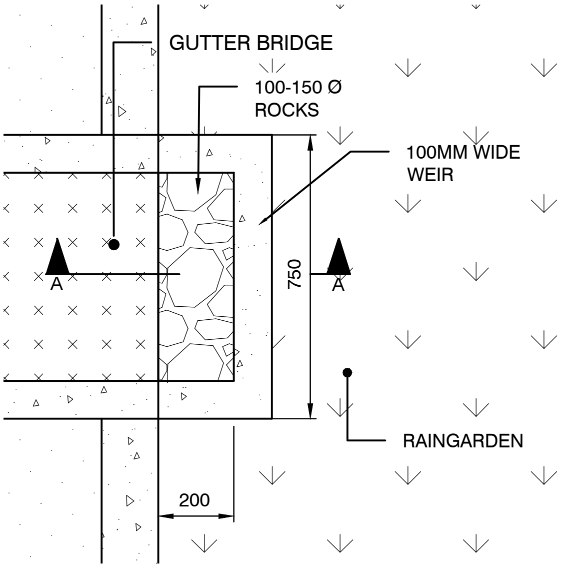
DRAINAGE

Rev	C
Date	21.11.13
Approved	P S

Dwg No. 7.2.9

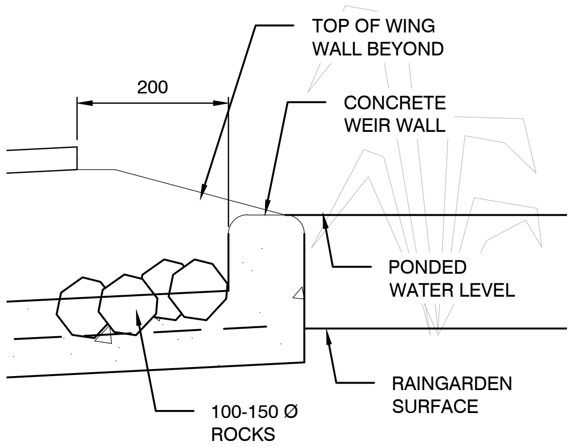
INLET WEIR

PLAN



SCALE 1:20

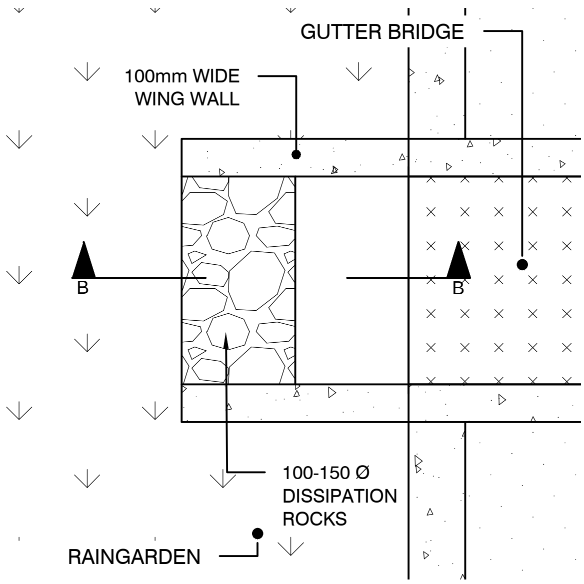
SECTION A-A



SCALE 1:10

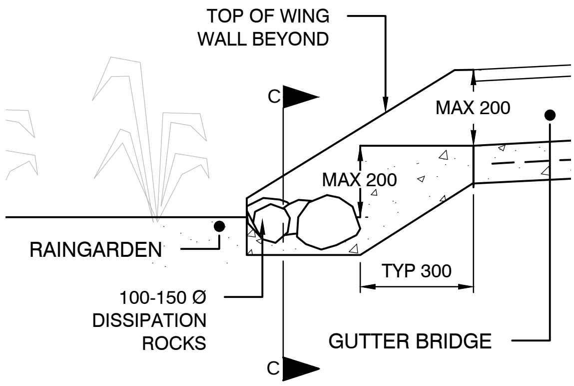
OUTLET DISSPATION ROCKS

PLAN



SCALE 1:20

SECTION B-B



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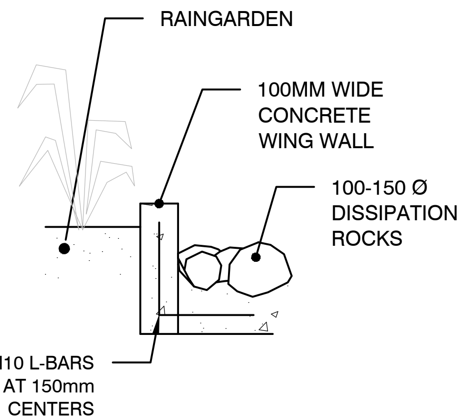
SECTION C-C



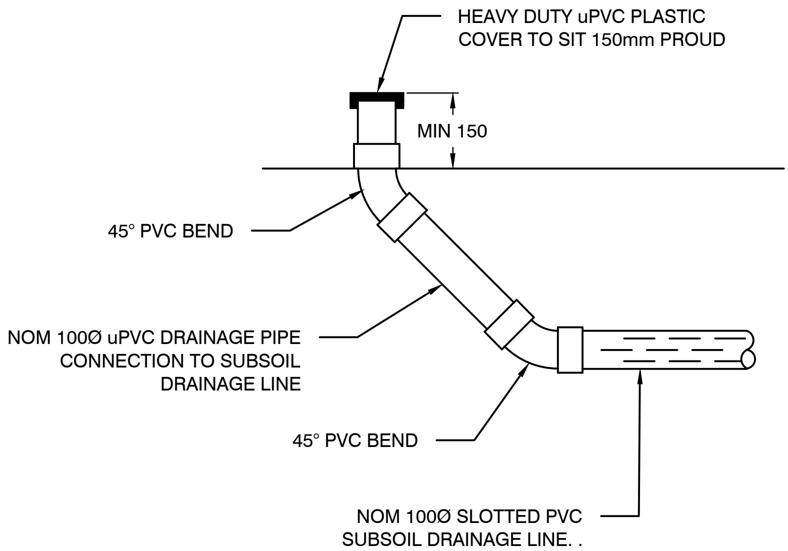
SCALE 1:20

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

CITY OF SYDNEY 2030	RAINGARDENS GUTTER BRIDGE INLET WEIR AND OUTLET DISSIPATION ROCKS	DRAINAGE **Rev** A **Date** 23.11.12 **Approved** P S Dwg No. 7.2.10

100Ø HIGH END RISER

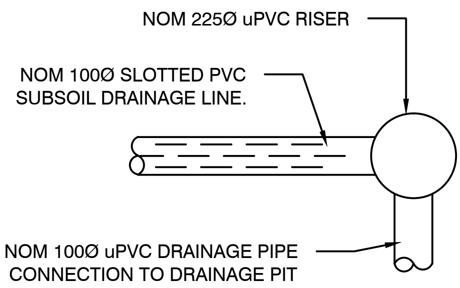
SECTION



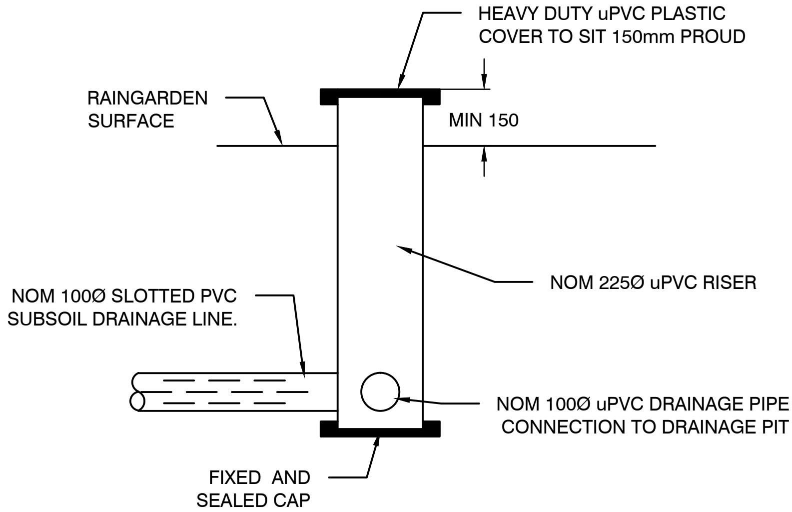
SCALE 1:20

225Ø HIGH END RISER JUNCTION

PLAN



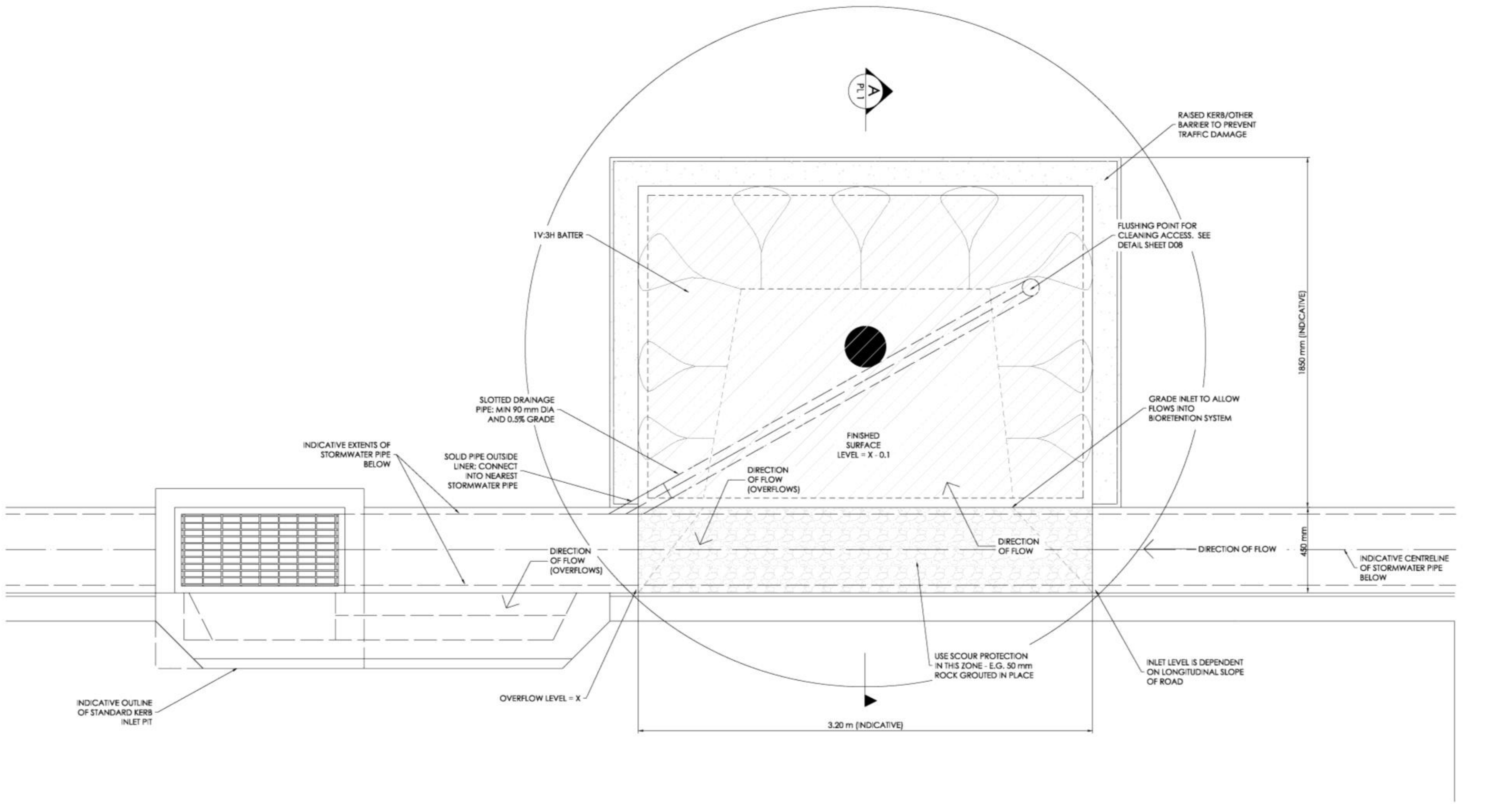
SECTION



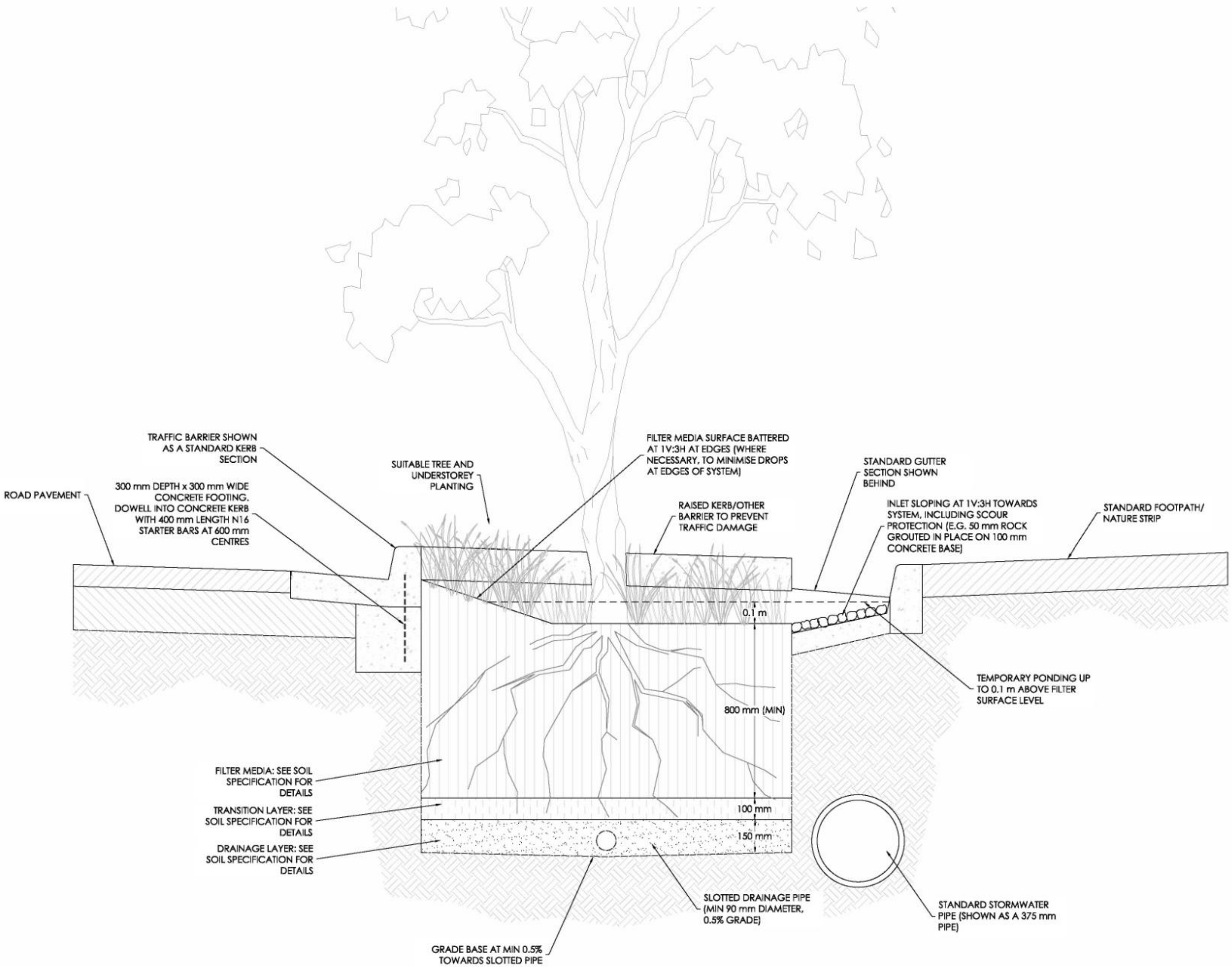
SCALE 1:20

NOTE: ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

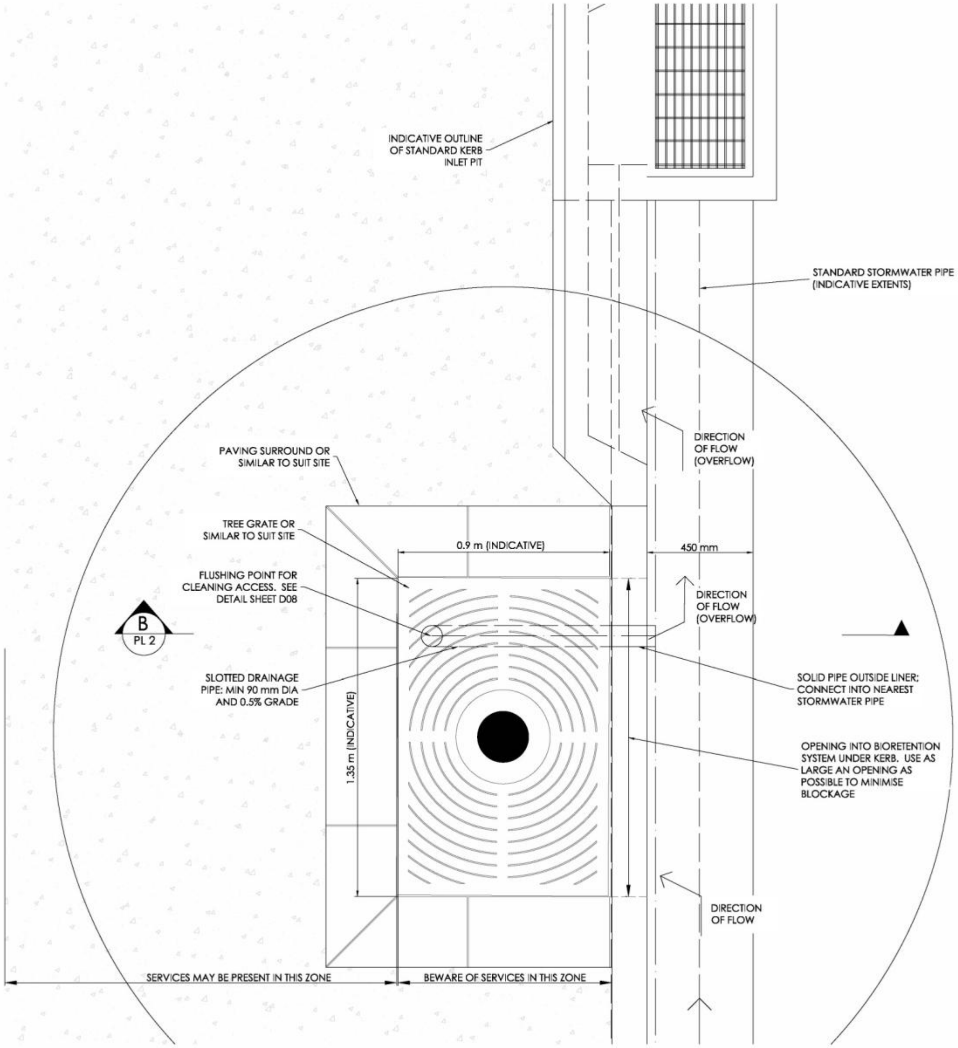
CITY OF SYDNEY 2030	RAINGARDENS HIGH END RISER	DRAINAGE **Rev** A **Date** 23.11.12 **Approved** P S Dwg No. 7.2.11



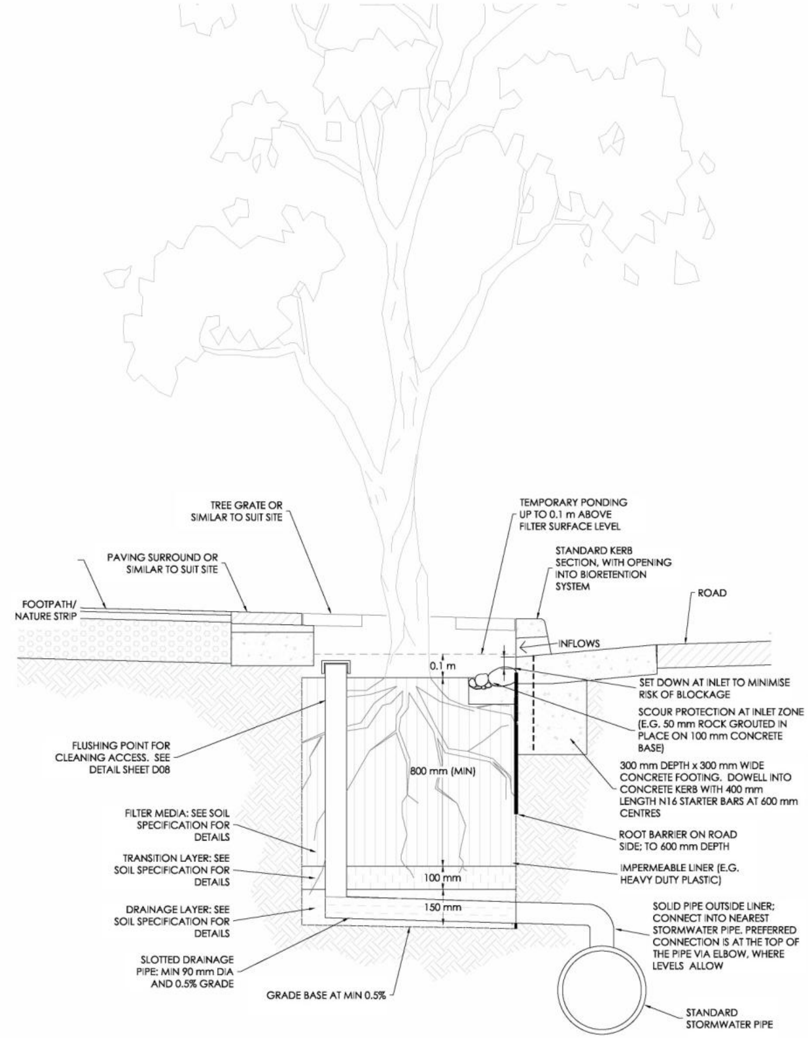
PLAN 1
TYPICAL PLAN OF BIORETENTION STREET TREE IN ROAD



SECTION A PL 1



PLAN 2
TYPICAL PLAN OF BIORETENTION STREET TREE IN FOOTPATH



SECTION B PL 2