

# BELLAMACK ROYSTONEA BIORETENTION SYSTEM

## Functional Design Report

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Prepared for the Northern Territory Department of Planning and Infrastructure  
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**April 2008**  
**07512593.01**

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Document Control Sheet	
Report title:	Functional Design of Roystonea Ave Bioretention Systems
Suggested Reference:	Ecological Engineering (2007), <i>Bellamack WSUD Strategy</i> .
Version:	Draft
Author(s):	David Knights
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Signed:	
Date:	April 2008
File Location:	Sydney Server
Distribution:	DPI, SKM

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## **EXECUTIVE SUMMARY**

### **Report Objective and Background**

The major objective of this report is to provide the basis for detailed design documentation of a stormwater treatment system at Bellamack Residential Sub-division within Palmerston City Council. Bellamack has been chosen as a showcase development for WSUD in the Darwin region.

The concept designs are based on the preliminary concepts described in Bellamack WSUD Strategy (Ecological Engineering, 2007a).

### **Bioretention System Overview**

The Roystonea Avenue bioretention systems will form an attractive landscape feature within the open space area north of Roystonea Avenue. The bioretention systems will have a footprint of approximately 7500m<sup>2</sup> and will treat runoff from a 38 hectare catchment in the Bellamack Residential Subdivision.

Treated stormwater will be delivered underneath Roystonea Avenue to a shallow bunded area to distribute flows into the an existing natural channel. The treated stormwater is ultimately discharged into Mitchell Creek, a subcatchment of Elizabeth River.

### **Catchments**

The catchments that will be treated by the bioretention systems are residential catchments and consist of predominantly single and low density dwellings and local and collector roads.

### **Bioretention Systems Performance**

The bioretention systems have been designed to remove 80% of total suspended solids and 45% of total nitrogen and 45% of total phosphorous. The bioretention system has few site constraints.

### **Water Quality Monitoring**

A water quality monitoring program has also been discussed in the report. Water quality monitoring is feasible at the site and monitoring is recommended at the site and would be particularly advantageous to have monitoring undertaken to 'proof up' the performance of bioretention systems in the wet dry tropics.

# 1 INTRODUCTION

Ecological Engineering was commissioned by Department of Planning and Infrastructure to develop detailed designs for stormwater treatment systems for Bellamack Residential Subdivision. Bioretention systems have been proposed as one treatment measure. Specifically the bioretention systems proposed for the treatment of stormwater runoff is located:

- (i) North of Roystonea Avenue

The detailed designs are a key step in the implementation of the integrated approach to managing stormwater within Bellamack. The integrated approach to management has been formalised in the Bellamack WSUD Strategy a program was undertaken to develop a plan for urban water management within the development. The strategy for Bellamack is based on a series of multi-disciplinary and multiple stakeholder planning workshops. The stormwater management strategy is shown in Figure 1.

The current detailed design is based on concepts broadly described in the Bellamack WSUD Strategy (Ecological Engineering, 2007a) and Stormwater Treatment Options for Darwin (Ecological Engineering, 2007c). The wider goal of the strategy is to provide integrated urban water management to best management practice standards and to meet the WSUD objectives for Darwin such as those outlined in WSUD Design Objectives (Ecological Engineering, 2007b).

The objective of this report is to document the detailed design for the treatment systems in sufficient detail to inform key stakeholders, including Department of Planning and Infrastructure and Palmerston Council and to provide a basis for detailed design drawings.



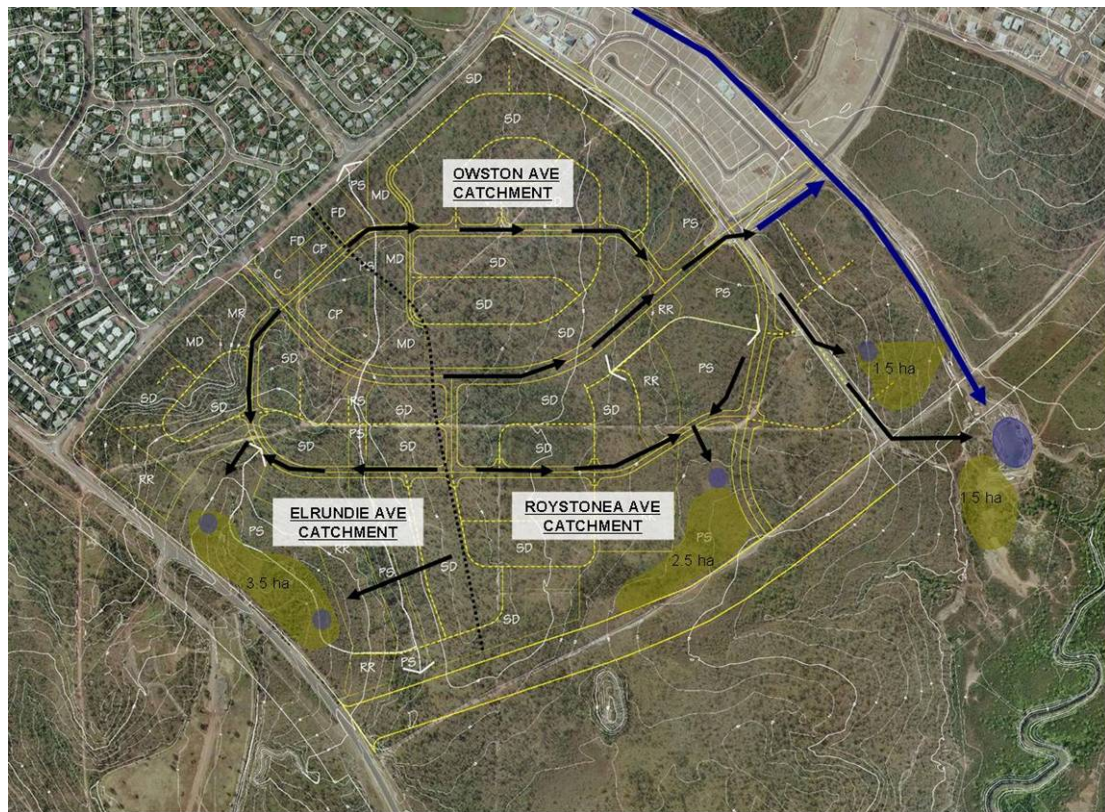


Figure 1 Bellamack WSUD Strategy

## 2 CATCHMENT AND DESIGN FLOWS

This section discusses the catchment areas that will be treated by the bioretention system, the volume of the flows that will be treated by the bioretention systems and the delivery of the stormwater to the bioretention system.

### 2.1 Catchment Areas

The design philosophy for the bioretention system is to treat stormwater runoff that drains from a residential catchment before it is discharged into the existing open channel along Owston Avenue.

The catchment area, of the Roystonea Avenue system is approximately 36 hectares (refer Figure 2), consisting of 23 hectares of single and multi dwelling residential and 5 hectares of road and footpath and 8 hectares of community and open space. The percentage imperviousness of the catchment is estimated to be approximately 40%.

The details of the catchment areas are summarised in Table 1.

**Table 1 Summary of Catchment Details**

Land Use	Road Catchment (ha)	Estimated % Impervious
Roads and footpath	5.1	100
Open Space	8.1	10
Rural Low Density	5.3	30
Single Dwelling	17.2	40
<b>TOTAL</b>	<b>35.8</b>	<b>40</b>



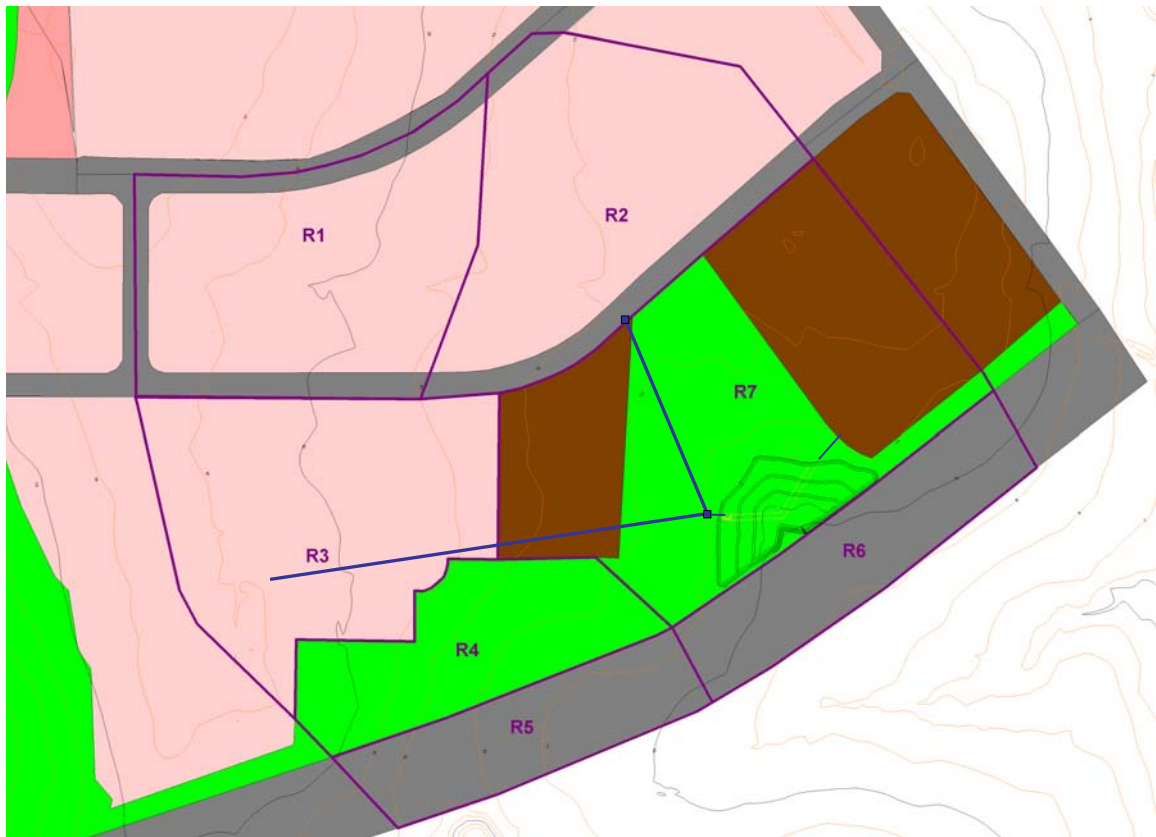


Figure 2 Catchment Contributing to Owston Avenue bioretention system

## 2.2 Delivery to Bioretention System

It is proposed to deliver the majority of the Roystonea Avenue catchment into a 1050mm pipe which will involve collecting the street drainage from the R1, R2, and R3 sub catchment upstream of the inlet to the bioretention system. To provide sufficient cover and a 1% slope it will be necessary to convey stormwater, at the upstream end of the catchments, in the surface street drainage as long as possible. Also within the open space it may be necessary to reduce the slope and cover on the pipe to ensure that all the catchment can be delivered to the bioretention system. These details should be finalised during the design of the drainage within the development.

Discharges from the catchment have been estimated, based on the Probabilistic Rational Method described in Australian Rainfall and Runoff (ARR) (1997). The details of this are shown below:

$$Q = CIA/360 \text{ (from ARR, Vol 1, 1997)}$$

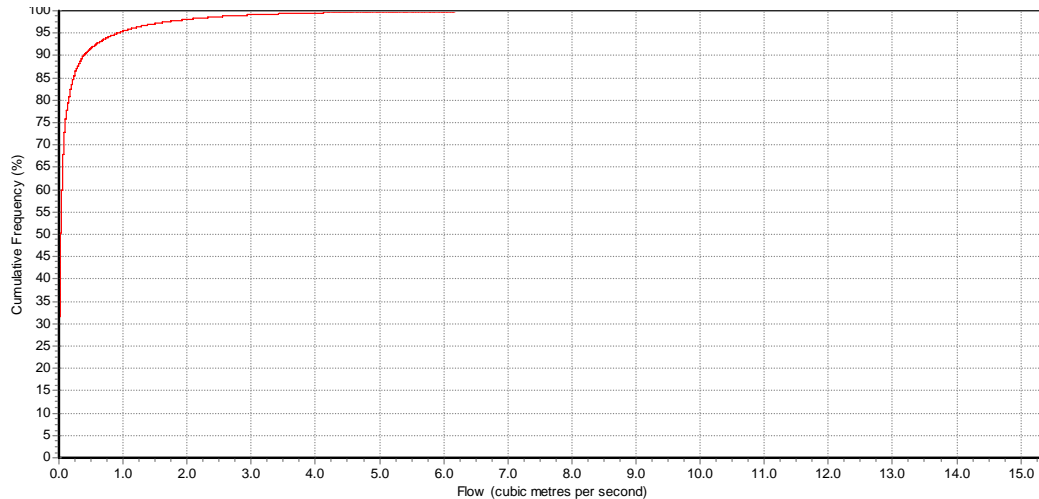
Area = 35.7 hectares

The catchment area is estimated to be 40% impervious.

Intensity = 70mm/h for the 1 year ARI event with a time of concentration of 32 minutes.

$Q_{1 \text{ year}}$  for the catchment using the Rational Method is  $4.4 \text{ m}^3/\text{s}$ .

This value was compared with a cumulative frequency distribution based on 6 minute intensity rainfall data modelled in MUSIC. This showed that a diversion value of  $3.0 \text{ m}^3/\text{s}$  diverted approximately more than 98% of flows from the catchment.



**Figure 3 Flow Cumulative Frequency Distribution**

Thus, up to  $3 \text{ m}^3/\text{s}$  through the system will divert the overwhelming majority of flows through the system. A diversion flow rate of  $3 \text{ m}^3/\text{s}$  was adopted in MUSIC and found to have minimal impacts on water quality performance of the system.

A small area of the rural residential land use in the catchment will not be able to drain to the main inlet. The rural residential zone in the south eastern part of the catchment will drain directly to the eastern end of the inlet channel. The 1 year design flow for this 3.2 Hectare catchment is approximately  $0.4 \text{ m}^3/\text{s}$ .

### 3 BIORETENTION SYSTEM OPERATION

#### 3.1 Introduction

This section documents the individual design elements of the bioretention system. It discusses the inlet surface area and depth of the bioretention system, how the stormwater will be delivered to the bioretention system, how stormwater will leave the bioretention system and how treated water will be conveyed to the existing stormwater systems. The design process has, in general, been based on the WSUD Engineering Procedures: Stormwater (Melbourne Water, 2006)

#### 3.2 Overview of Operations

The bioretention system will be located north of Roytanea Ave and to the west of Owston Ave. This area is currently vegetated with open forest in varying condition and is shown in Figure 4. The concept sketches, including plan views, cross sections, long sections and details, are shown in Appendix B and are described in detail below.



**Figure 4 Proposed location of bioretention treatment system**

Flows will enter the bioretention system via a rock lined distribution channel approximately 6m wide and 0.3 to 0.4m deep. The distribution channel ensures a more even distribution of water throughout the system.

The stormwater will then percolate through a prescribed soil filtration media and be collected with perforated pipes at the base and conveyed to the existing natural channel located to the south of Roystonea Ave via culverts underneath the Avenue. The bioretention media is planted with native vegetation ranging from grasses and sedges to shrubs and trees.

The bioretention system will be ringed by two bunds. The bunds primarily divide the bioretention system into three cells to provide a more even distribution of flows in the system. It should be noted the cells are not completely disconnected from one another. These bunds provide a number of secondary functions including:

- Provision of a landscape element which differentiates the surface of the basin
- Provision of a greater planting depth for vegetation such as trees and large shrubs which will benefit from greater soil depths.

When the soil infiltration capacity is exceeded, flows will temporarily pond up to 300 mm above the bioretention surface, and above the bunds and subsequently infiltrate through the prescribed filtration media. When levels exceed 300 mm ponding, water will discharge out through 4 overflow pits into a pipe to the sediment basin. Water will briefly pond up to a depth of 0.3m above the overflow pits (0.6m above the surface in total). An overflow weir is not required for the bioretention system to discharge larger flows and if water overtops the banks due to more than 50% blockage of pits water will flow overland and into the open channel.

Sandy loam has been selected as the filtration media and the filtration media specification is attached in Appendix A. Laid directly underneath the filter layer is a 100mm transition layer. A 150 mm gravel drainage layer is laid underneath the transition layer. A series of subsurface drainage pipes will be laid in the drainage layer which drains directly to the overflow pits. Collected water will exit the overflow pits via two separate 675 mm stormwater pipes.

### **3.3 Services Analysis**

A complete services analysis check will be required to be undertaken to determine if there are any conflicts with any services or future services including:

- water and sewer
- electricity cables
- gas mains

- telstra communication services
- optic fibre cables

### 3.4 Inlet Design

As described in Section 2.1 the bioretention inlet will comprise of a 1050 mm inlet pipe which delivers stormwater into the bioretention system. Before the inlet to the bioretention system a GP, a Humegard 40GA or similar, is placed which is designed to remove the coarse sediment and litter before the flows enter the bioretention system.

At the inlet to the bioretention system a scour pad has been designed. The scour pad is designed to protect the surface of the bioretention system for a maximum outlet velocity. In principle, the continuity equation is used to determine the outlet velocity with an outlet control. The downstream cross section of the distribution channel is used as the downstream cross sectional area.

In practice a standard culvert software program has been used to determine the maximum velocity discharging from the stormwater pipe. The maximum outlet velocity has been determined to be approximately 3.65 m/s.

A scour pad is required at the outlet due to the reasonably high outlet velocities. The scour pad will require carefully placed rocks with a  $d_{50}$  greater than 300mm and a length of 8m spanning from 2m wide at the inlet of the pipe to 6m wide at the outlet of the scour pad into the main distribution channel running south east which meets with a 'secondary channel' running .

The channel is not required to convey the full 3 m<sup>3</sup>/s, its main purpose is to distribute the majority of flows along the length of the bioretention system. Stormwater will be required to pond in the distribution channel before it can exit the channel into the bioretention system.

The distribution channels will be

- a trapezoidal in shape with a 4m base and 1 in 3 batter slopes
- 0.3m deep at the inlet of the scour pad and 0.45m deep at the centre
- 6m wide at the edge and 6.2m wide at the centre of the bioretention system.
- laid at a 0.25% slope from the edge (IL 9.8m) into the centre of the bioretention system (IL 9.65 m) and -0.25% slope from the centre to the opposite side of the bioretention system (IL 9.8 m).
- gravel lined ( $d_{50} > 20\text{mm}$ )
- vegetated

- underlain with filter media to ensure the channel drains

The main distribution channel will intersect at with a secondary distribution channel which runs from the south east to the north west of the bioretention system. This channel has the same cross section and slope as the main distribution channel.

Based on the characteristics above, Manning's equation predicts for a flow depth 0.3m, a minimum discharge of 1.2 m<sup>3</sup>/s at a velocity of 0.82 m/s.

The rural residential inlet will discharge directly into the eastern end of the distribution channel. The outlet velocity will be approximately 0.5m/s. The channel will be able to withstand velocities in this range without additional protection.

Boardwalks could be provided as a landscape element over the distribution channel to allow access into the centre of the bioretention system for observation.

### 3.5 Bioretention System Cross Section

The typical depth of the bioretention system is 850 mm and the typical cross section of the bioretention system is

- 600 mm of a specially selected filter media (RL 10.1 m) underlain by
- 100mm of a coarsely graded sand (RL 9.4 m) of 0.5 mm to 1.0 mm underlain by
- 150mm of a drainage layer consisting of coarsely graded gravel (2mm to 5mm) (RL 9.25 m) which is laid with a series of 150 mm drainage pipes

The total depth of the bioretention filter media is 1050 mm in the location of the bunds (RL 5.2) where the filter media is 800 mm deep.

### 3.6 Overflow Pits

To allow flows from the Owston Ave bioretention system to discharge back into the existing stormwater system when the bioretention system is full (i.e. extended detention is fully engaged) a series of overflow pits will be constructed with the crest at the same level as the top of extended detention (RL 10.4 m).

The overflow system must be able to pass the peak design flow entering the system (i.e. 3 m<sup>3</sup>/s). The outlet has been sized such that the maximum height of water over the riser crest is 300 mm. Two scenarios are checked:

- drowned conditions (orifice equation) and



- free overfall conditions (weir equation).

For drowned conditions at the riser pipe using the orifice equation:

$$A = Q / B.C.\sqrt{2gh} \quad \text{with}$$

$C = \text{orifice coefficient (0.6),}$   
 $B = \text{blockage factor (0.5),}$   
 $Q = 3 \text{ m}^3/\text{s}$   
 $H = \text{available head (0.3 m)}$

Assuming 50% blockage, a minimum area of 4.1 m<sup>2</sup> is required.

To check free overfall conditions, using the weir equation:

$$L = Q_{\text{des}} / B.C.H^{3/2} \quad \text{with}$$

$B = \text{blockage factor (0.5)}$   
 $C = \text{weir coefficient (1.7),}$   
 $H = \text{head over weir (0.3 m) and}$   
 $L = \text{outlet circumference}$

Assuming 50% blockage, a minimum length of 22.0 m is required.

A series of four 1.5 m square overflow pits are recommended. These pits provide:

- an area of 9 m<sup>2</sup> area
- an overflow weir length of 24m

Blockage of the overflow pit is one of risk factors in any overflow design. Blockage can occur from leaf litter or rubbish depositing on the grated inlet. The risk of blockage is managed by providing

- design of the overflow pit so that if the top of the overflow pit blocks the pit can still function as an overflow weir. A combined overflow weir pit and orifice is less prone to blockage
- a conservative blockage factor of 50%
- separate pits
- placement of the overflow pits at a significant distance from the inlet point

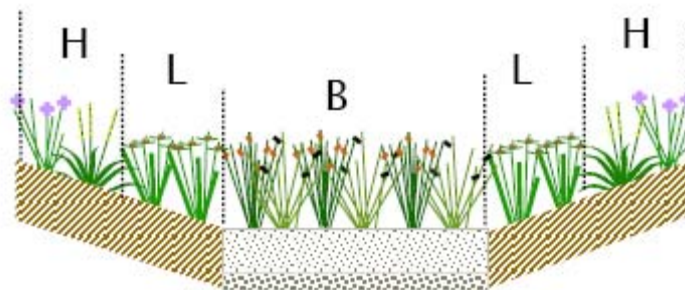
### 3.7 Vegetation

Vegetation enhances the function of the filter media by preventing erosion of the surface of the filter media, continuously breaking up the soil through

plant and root growth to prevent clogging of the system and providing biofilms on plant roots that pollutants can adsorb to. Generally the denser and higher the vegetation, the better the filtration process. Vegetation is critical to maintaining porosity of the filtration layer and retention of nutrients within the filter media.

The bioretention systems will have a total vegetated filter area of 7500 m<sup>2</sup>. The proposed area of planting is slightly greater than the area of the bioretention system filter area as it is proposed to plant the batter slopes with native vegetation as well.

Indicative species for the bioretention system are listed in Table 2. Figure 5 shows the zones of planting across the bioretention system.



**Figure 5 Cross section of vegetation showing high (H), low (L) and base (B) planting sections within the bioretention system.**

Note that this is not an exhaustive list of species that are suitable and other local native species will be substituted if those listed above are not available. In general the species from the L and H zone are the most flexible.

The planting densities are suggested minimums and can be increased with project budget which will assist in reducing weed invasion and reduce the need to replant if some plants have difficulty establishing.

Exact planting specifications can be confirmed during the production of construction drawings and in consultation with local nurseries and organisation such as Greening Australia to understand their ability to supply various species.

**Table 2 List of potential plant species**

Scientific Name	Common Name	Type of Plant	Maximum Height (m)	Planting Density
<b>Bioretention Media - Trees on sandy media</b>				
Eucalyptus miniata	Woollybutt	Tree	8-20	1 per 10 m <sup>2</sup>
Eucalyptus tetradonta	Stringybark	Tree	10-30	1 per 10 m <sup>2</sup>
<b>Bioretention Media - Shrubs on sandy media</b>				
Boronia gradisepala		Shrub	0.5	1 per 3 m <sup>2</sup>
Boronia lanuginosa		Shrub	0.5-1.5	1 per 3 m <sup>2</sup>
Bossaia bossaioides		Shrub	1-2	1 per 3 m <sup>2</sup>
Calytrix exstipulata	Turkey bush	Shrub	1-4	1 per 3 m <sup>2</sup>
Grevillea pungens		Shrub	1-1.5	1 per 3 m <sup>2</sup>
Grevillea angulata		Shrub	1-4	1 per 3 m <sup>2</sup>
Jacksonia dilatata		Shrub	2-4	1 per 3 m <sup>2</sup>
Templetonia hookeri		Shrub	1-3	1 per 3 m <sup>2</sup>
Verticordia cunninghamii		Shrub	1.5-5	1 per 3 m <sup>2</sup>
<b>Bioretention Media - understorey on sandy media</b>				
Grevillea formosa		Shrub	0.5	1 per 3 m <sup>2</sup>
Imperata cylindrica	Blady grass	Grass	1	8 per m <sup>2</sup>
Platyzoma microphyllum	fern	Fern	0.15-0.5	8 per m <sup>2</sup>
Sorghum plumosum		Grass		8 per m <sup>2</sup>
Sorghum stipodeum		Grass		8 per m <sup>2</sup>
<b>Extended Detention Area Trees on clay soils</b>				
Melaleuca dealbata	Paperbark	Amphibious tree	12	1 per 8 m <sup>2</sup>
Melaleuca viridiflora	Paperbark	Amphibious tree	12	1 per 8 m <sup>2</sup>
<b>Extended Detention Area - Understorey on clay soils</b>				
Cyperus scariosis	Sedge	Amphibious sedge	0.8	8 per m <sup>2</sup>
Fimbristylis dichotoma	Sedge	Amphibious sedge	1	8 per m <sup>2</sup>
Isoetes coromandelina	Quillwort	Amphibious fern	0.8	8 per m <sup>2</sup>
<b>Upper Batter (terrestrial vegetation)</b>				
Eucalyptus miniata	Woollybutt	Tree	8-20	1 per 10 m <sup>2</sup>
Eucalyptus tetradonta	Stringybark	Tree	10-30	1 per 10 m <sup>2</sup>
Sorghum plumosum		Shrub		8 per m <sup>2</sup>
Sorghum stipodeum		Shrub		8 per m <sup>2</sup>
Themeda australis	Kangaroo grass	Grass	0.75	8 per m <sup>2</sup>
<b>Bunds - trees</b>				
Melaleuca dealbata	Paperbark	Amphibious tree	12	1 per 8 m <sup>2</sup>
Melaleuca viridiflora	Paperbark	Amphibious tree	12	1 per 8 m <sup>2</sup>
Pandanus spiralis	Screw palm	Amphibious tree	10	1 per 8 m <sup>2</sup>
<b>Bunds - understorey</b>				
Cynodon dactylon	Couch	Grass	0.6	8 per m <sup>2</sup>
Isoetes coromandelina	Quillwort	Amphibious fern	0.8	8 per m <sup>2</sup>
Sorghum plumosum		Grass		8 per m <sup>2</sup>
Sorghum stipodeum		Grass		8 per m <sup>2</sup>

The scour velocity over the vegetation should be less than 0.5 m/s to ensure the integrity of the vegetation. The scour velocity is calculated by dividing the maximum flow by the flow area. The maximum flow that can be carried by the channel is 3 m<sup>3</sup>/s and the depth of the flow in the bioretention system will be approximately 0.3m. Based on this the flow area will need to be a minimum of 10 m to ensure that the flow velocity will be less than 0.5m/s. This width is significantly lower than the typical widths in the bioretention

system hence the flow velocity in the bioretention will be significantly less than this as the cross sectional area is significantly greater.

### 3.8 Irrigation

The vegetation will require irrigation during the dry season to ensure that it is sufficiently robust at the end of the dry season that the surface of the media is not compromised by the first few events at the beginning of the wet season. If the vegetation is not robust enough to maintain the surface of the system then it is possible that erosion and scour of the surface could occur as well as clogging of the surface due to deposition of sediment on the surface of the bioretention system and subsequent loss of permeability.

The local native species that are planted in the bioretention system do not require irrigation. However irrigation provides a number of benefits including

- stronger and more vigorous planting growth
- provide greater local landscape amenity due to a perceived more attractive planting palette

An automatic aboveground sprinkler irrigation system is proposed to irrigate the bioretention system during the dry season. The irrigation system will be designed to provide minimal irrigation but sufficient irrigation events to maintain vigorous plant growth. The irrigation system will supply

- 10mm per square meter
- at an irrigation frequency of one irrigation event every week
- during the dry season months (typically from the end of April to early October)
- during the early hours of the night, when evaporation rates are lowest

Based on this regime approximately 1950 kl/yr of water will be used or the equivalent of water consumption of four typical single dwellings in Darwin.

Native plants have a significantly lower crop factor and can also withstand significant periods of water stress. Crop factors for native plants have been adopted as 0.3 to 0.4 to determine the required irrigation volume during the dry season. However the irrigation volume can be modified post construction to optimise the irrigation regime

It is recommended that plants in the bioretention system be planted at the beginning of the wet season with the bioretention system off line to reduce irrigation establishment requirements.

### 3.9 Filter Media

The filter media will be a sandy loam with a hydraulic conductivity of approximately 50 to 200 mm/hr (assumed 100 mm/hr) and an effective particle diameter of 0.3 to 0.5 mm (See Appendix 1 for detailed specification).

The maximum infiltration rate through the filter media has been calculated using Darcy's Equation. The maximum head of water over the bioretention surface is equal to the extended detention depth (0.3m).

$$Q = k.A.(h+d)/d \quad \text{with,}$$

$k$  = hydraulic conductivity (100 mm/hr),

$h$  = maximum height of pondage (0.30 m),

$d$  = depth of filter media (0.6 m),

$A$  = surface area (7500 m<sup>2</sup>).

The maximum infiltration rate into the perforated pipes is

- 0.31 m<sup>3</sup>/s.

### 3.10 Collection Pipes

The water that infiltrates through the filter media will be collected in perforated pipes located within a gravel drainage layer that will run the length of the bioretention system. A series of 20 perforated pipes will be laid in a north to south direction spaced at 5m intervals. A total of 632.5m of subsoil drainage pipe are proposed. The pipes will drain to a central collection pipe in the centre of the bioretention system running west to east. The drainage pipes will be laid flat and will operate under head drain to the overflow pits RL 9.25 m.

The perforation capacity of a standard diameter 150 mm perforated pipe was determined using the orifice equation. A standard perforated pipe with a minimum of 1500 mm<sup>2</sup>/m of perforations was selected. It is conservatively assumed that 50% of the holes are blocked. The maximum head over the perforated pipes is the maximum head of water over the bioretention surface (0.3 m) plus the filter media depth (0.6 m), plus the section of the transition layer above the perforated pipe (0.1 m).

$$Q = CA\sqrt{2ghB} \quad \text{with,}$$

$Q$  = perforation capacity L/s;

$C = 0.61$  (sharp edged orifice);

$A$  = total orifice area ( $m^2$ ) =  $1500/10^{-6}$ ;

$g = 9.81 \text{ m}^3/\text{s}$ ;

$h$  = total head = 1 m

$B$  = blockage factor = 0.5

The perforation capacity of a standard 150 mm pipe is therefore 0.0019  $m^3/\text{s}$  per meter of pipe. The total capacity of the 900 m pipes is 1.71  $m^3/\text{s}$  which is in excess of the maximum infiltration rate (0.31  $m^3/\text{s}$ ).

The perforated pipes are to extend to the surface of the bioretention system in order to allow access for inspection and maintenance when required. This vertical section of the under-drain must be a solid pipe with a cap placed on the end of the pipe to avoid short circuiting of untreated water directly to the underdrain.

### 3.11 Liner

It is not proposed to line the bioretention system. The treated stormwater will have contribute to recharging the local groundwater during the early wet. The drainage within the bioretention system will be free draining ensuring that the majority of the treated stormwater will be collected in the drainage pipes.

Groundwater levels are not known in the vicinity of the bioretention system. Due to its proximity to the existing drainage path it is likely that groundwater levels are close to the current drainage invert of approximately 9m AHD. There is some chance that the bioretention system will intercept the local groundwater levels. However the consequences of this are considered low risk as the bioretention drainage levels is not significant different from the invert of the current free drainage path that currently exists.

### 3.12 Connection to Existing Drainage System

It is proposed to drain the bioretention system either to

- the culvert laid underneath Roystonea Avenue or
- as two 675mm pipes underneath Roystonea Avenue

It is preferable to drain the outflow from the bioretention through the batter and into the existing drainage depression upstream of the invert and . The invert of from the bioretention system is RL 9.25 m and the invert of the



outlet pipe will be approximately RL 9.0 m. The invert of the culvert is not known but the survey determined that the current surface level is 9.6m AHD and it is possible that the future culvert underneath Roystonea Ave will be higher than the outlet pipes.

Thus it may not be able possible to deliver the outflow from the basin to the future culvert. If this is the case it will be necessary to deliver the bioretention outflow underneath Roystonea Ave via two 675mm pipes (invert RL 8.1m) and surcharge the pipe at RL 8.7 m. The total distance of the two pipes is approximately 115m.

On the downstream, southern, side of Roystonea Ave, the culvert outlet (and pipe outlets if required) will be surrounded by a low 0.1m vegetated bund which has 1 in 4 batter and is formed from excess cut from the bioretention system. The bund will have an RL of 8.8 and a total length of 100 m. The bund should be tied into the existing contours to ensure that the bund is not outflanked and the total length of the bund is approximately 75m.

### **3.13 High Flow Bypass**

Flows greater than Q2 ARI event will be diverted around the bioretention system via an overland flow path as outlined in the Headworks Plan. The flow path will need to be designed to pass around the bioretention system. Preliminary calculations using Mannings have shown that a grass swale of approximately 20m in width and up to 0.45 m in height will convey a Q100 ARI event of 15 m<sup>3</sup>/s (based on the Rational Method).

It is likely that the major overland flows will drain from the road where it meets the open parkland. From this point the overland flow should head in a south-westerly direction to bypass the most westerly point of the bioretention system. To ensure the flows can adequately pass around the bioretention may require some minor modifications to the edge of the bioretention system. The final details of this high flow by pass will need to be determined by the stormwater drainage engineer for the development when determining the overland flow path for the development.

### **3.14 Amenity and Aesthetics**

Urban design is a key component of the bioretention system. Typically bioretention systems are landscaped to look similar to gardens. This is because of their vegetated surfaces. A bioretention system can either be “soft-landscaped” or “hard-landscaped”. Soft landscaping involves only the use of vegetation to define the boundaries of the bioretention system while hard landscaping uses “engineered” structures such as fences, retaining walls and seats to define the boundaries.

It is proposed to soft landscape the bioretention system .The batter slopes of the bioretention will be heavily vegetated with grasses and sedges, shrubs and trees. The appearance and aesthetics of the bioretention system will look similar to a native garden. The use of soft landscaping matches with the existing landscape in this area adjacent to the channel.

During workshops there was strong advocacy for native planting and this has been reflected in the choice of vegetation. Illegal dumping was observed during site visits. Hence it is proposed to have dense planting of vegetation to prevent any illegal dumping within the site and bollards off Roystonea Avenue.

Hard landscaping elements that could be incorporated into the bioretention system include.

- A boardwalk which runs through the middle of the bioretention system. The boardwalk could also be connected to a pathway that takes local residents down to Mitchell Creek or connects with a bridge across the channel and to the Roystonea Hub
- Interpretive signage, especially along the northern edge of the bioretention system where the open space has the maximum connection to the Bellamack development. The signage would provide educational opportunities to explain the role, and function of the bioretention system
- As the bioretention system is located in parkland which connects to the proposed future urban development, picnic, playground, shelter facilities etc could also be provided as part of the bioretention system landscaping.

These landscape elements need to be decided in consultation with the landscape designs for the future development and the direction of the open parkland, but are considered essential elements to the design of the bioretention system.

### **3.15 Aquifer Recharge**

Currently the dolomite aquifer fully recharges during the wet season despite the significant extraction undertaken by Palmerston City Council for irrigation. The aquifer has a sustainable yield of 4 to 6 ML/d during (Yin Foo, 1988).

The long term sustainability of aquifer extraction is not known due to the lack of metering of extraction for irrigation and the impacts of urbanisation on recharge of the aquifer.

For this reason it is proposed to adopt an adaptive management process to the aquifer. The aquifer water levels should be monitored. In particular the water level in the aquifer at the end of the wet season and at the end of the dry season are key water levels that need to be monitored annually as a minimum. If full recharge does not occur during the wet season due to changes in the catchment then aquifer recharge will be required.

The bioretention system has been designed to allow for aquifer recharge in the future. A pit has been included in the design to the south of the bioretention system which drains the bioretention system. The modification would involve including a weir plate and a diversion pipe to a pump sump.

The treated stormwater that flows through the media filter is approximately 205 ML/yr. This value flows at a constant rate up to 210 L/s. A pit has been designed in the bioretention system from whereby future diversions to an aquifer recharge pumping system could be located. This system captures all the flows that have passed through the media filter but avoids storing the partially treated overflows. This is to ensure that the highest quality of treated stormwater is stored in the aquifer to reduce the risk of causing a deterioration in the aquifer water quality while still providing a significant portion (more than 70%) of the flows into the system.

### **3.16 Monitoring**

For stormwater managers to effectively deliver stormwater quality management programs the performance of stormwater treatment devices is of key concern. Monitoring is the best way to assess the performance of these systems. A more detailed monitoring strategy will be developed in consultation with Councils and the NT Government. This section discusses how the designs have incorporated future monitoring requirements into the design.

Monitoring requires sampling points at the inlet and outlet of the system. Monitoring can be undertaken at the inlet into the bioretention system. A pit will be provided for access for monitoring for water quality sampling and flow monitoring. A good flow monitoring site requires steady flow conditions with minimal changes in pipe direction or pipe size. This area is easily accessible from the open parkland.

Monitoring will also need to be undertaken at the outlet of the bioretention system. The aquifer reuse pit can also be used as the monitoring sampling pit. This area is accessible from the open parkland and Roystonea Avenue.

### 3.17 Construction Cost Estimate

Preliminary cost estimates for the Roystonea Avenue bioretention system have been produced for constructing the treatment system. Cost estimates were developed from determining expected earthworks required for construction and by quantifying key element and structures of the systems. These are detailed in Table 3.

**Table 3 Preliminary Construction Cost Estimate**

Item	Quantity	Unit	Unit Cost	Cost
Clear Site of vegetation	9000	sqm	\$ 0.45	\$ 4,050
Humegard HG40A (or similar) GPT	1	Unit	\$ 85,500	\$ 85,500
Inlet to Bioretention and Scour Pad	1	Unit	\$ 25,000	\$ 25,000
Delivery Channel - 30mm coarse gravel 0.1mm thick layer	100	cum	\$ 56	\$ 5,600
Excavation and Earthworks	7936	cum	\$ 10	\$ 79,360
Filter Media	4725	cum	\$ 30	\$ 141,750
Transition Layer	750	cum	\$ 56	\$ 42,000
Gravel Layer	1125	cum	\$ 56	\$ 63,000
150mm flexible coil PE subsoil pipes	850	m	\$ 20	\$ 17,000
Vegetation	8700	sqm	\$ 15	\$ 130,500
1.5m by 1.5m overflow pits	4	unit	\$ 3,000	\$ 12,000
675mm outlet pipe	240	m	\$ 350	\$ 84,000
1500mm by 1500mm Monitoring Pit	1	Unit	\$ 2,000	\$ 2,000
Bunded outlet to existing drainage channel	1	Unit	\$ 20,000	\$ 20,000
Irrigation System	0.75	Has	\$ 12,000	\$ 9,000
<i>Subtotal</i>				<i>\$ 720,760</i>
Contingency			25%	\$ 180,190
<b>TOTAL</b>				<b>\$ 900,000</b>

## 4 REFERENCES

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## APPENDIX A: SOIL FILTRATION MEDIA SPECIFICATIONS



# GUIDELINE SPECIFICATIONS FOR SOIL MEDIA IN BIORETENTION SYSTEMS

The following guideline specifications for soil media in bioretention systems have been prepared on behalf of the Facility for Advancing Water Biofiltration (FAWB) to assist in the development of bioretention systems, including the planning, design, construction and operation of those systems.

The guideline specifications are in two parts:

- Soil Media Specifications for Bioretention Systems with a Range of Vegetation Types
- Soil Media Specifications for Tree Pod Bioretention Applications

## Disclaimer

The Guideline Specifications for Soil Media in Bioretention Systems are made available and distributed solely on an "as is" basis without express or implied warranty. The entire risk as to the quality, adaptability and performance is assumed by the user.

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## 1 SOIL MEDIA SPECIFICATIONS FOR BIORETENTION SYSTEMS WITH A RANGE OF VEGETATION TYPES

### 1.1 Bioretention Systems with Imported Media

The bioretention soil media specifications require three layers of media. Filter media (600mm deep or as specified in the engineering design), a transition layer (100mm deep) and a drainage layer (150mm deep).

#### 1.1.1 Filter Media – General Description

The material can be of siliceous or calcareous origin. Only, minimal light compaction to avoid subsidence and uneven drainage should be carried out. The bioretention system will operate so that water will infiltrate into the filter media and move vertically down through the profile. The prescribed hydraulic conductivity will generally be between 50–300mm/hr.

**Maintaining the prescribed hydraulic conductivity is crucial. Permeability testing using the Australian Standard (AS4419–2003 Appendix H) method will generally be suitable for determining the hydraulic conductivity of a particular soil. However, in some circumstances, additional hydraulic conductivity testing will be required (see below for further details).**

The media is required to support a range of vegetation types (from groundcovers to trees) that are adapted to freely draining soils with occasional flooding.

In general the media should be a sandy loam to loamy sand soil with an appropriately high permeability under compaction and should be free of rubbish and deleterious material. The soils should contain some organic matter for increased water holding capacity but be low in nutrient content. In general appropriate material is likely to be approximated by a mix of 80–90% sand, 10–20% loam soil and 3–10% composted organics or peat. A detailed specification for filter media is described below.

### 1.1.2 Filter Media – Testing Requirements

To determine whether a soil is suitable the following tests should be undertaken:

1. Particle size distribution (PSD)
2. AS4419–2003 – Soils for landscaping and garden use (specification for natural soil or soil blend unless stated above)
3. Water Holding Capacity – *required where PSD does not meet specifications but silt + clay is <12% or in regions likely to experience extended dry spells*
4. Saturated Hydraulic Conductivity – *required where PSD does not meet specifications*

#### Information from suppliers

In some cases, suppliers may have PSD and AS4419–2003 testing results available for various soils. If the testing was carried out on the batch of soil available for purchase these results should be adequate. (Additional hydraulic conductivity and water holding capacity testing may still be required).

#### Soils that do not meet PSD

Soils that do not lie within the specified PSD may be suitable if the silt plus clay content is less than 12% and it meets the specifications for the following tests:

1. AS4419–2003
2. Additional Hydraulic Conductivity Testing (e.g. McIntyre and Jakobsen (1998) method)
3. Water Holding Capacity

### 1.1.3 Filter Media – Detailed Specifications

Detailed specifications (compiled with assistance from Sydney Environmental and Soil Laboratory, March 2006) are listed below. Testing requirements to confirm the suitability of a soil will vary depending on the information provided by the supplier and the quantity of soil required (see ‘testing requirements below).

#### 1. Particle Size Distribution

Soils with infiltration rates in the appropriate range typically vary from sandy loams to loamy sands. Soils with the following composition (percentage range w/w) are likely to have an infiltration rate in the appropriate range and have suitable structural integrity (adapted from United States Golf Association: Method of Putting Green Construction, 1993)–

Clay	2–4%	(<0.002 mm)
Silt	4–8%	(0.002–0.05 mm)
Very Fine Sand	5–10%	(0.05–0.15 mm)
Fine Sand	10–25%	(0.15–0.25 mm)
Medium to Coarse Sand	60–70%	(0.25–1.0 mm)
Coarse Sand	7–10%	(1.0–2.0 mm)
Fine Gravel	<3%	(2.0–3.4 mm)

Variation in large particle sizes is flexible (i.e. an approved material does not have to be screened). However, the particle size distribution of the smaller particles (clay and silt) is a crucial element of the filter media specification. Where soils are prone to structural collapse the hydraulic conductivity may change dramatically depending on the state of collapse of the soil. However, ensuring the total clay and silt mix is less than 12% reduces the likelihood of structural collapse of such soils.

2. *AS4419– 2003 (Soils for Landscaping and Garden Use)*

- i. Bulk density – as specified for ‘natural soils and soil blends’ >0.7 kg/L
- ii. Organic Matter Content – **between 3 and 10% w/w** (For soils low in organic matter content the top layer (~300mm) of the filter media should be amended to meet the specified organic matter content (3 –10% w/w))
- iii. Wettability – as specified for ‘natural soils and soil blends’ >5 mm/hr
- 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’ <1.2dS/m
- vi. Phosphorus – <20mg/kg
- vii. Nitrogen Drawdown (NDI) – as specified for ‘natural soils and soil blends’ >0.5 NDI<sub>150</sub> (NDI assesses the ability of a soil to drawdown or immobilize soluble nitrogen).
- viii. Toxicity – as specified for ‘natural soils and soil blends’
- ix. Dispersibility – as specified for ‘natural soils and soil blends’ Category 1 or 2
- x. Permeability – **hydraulic conductivity as specified in engineering design**. The prescribed hydraulic conductivity will generally be between 50–300mm/hr. A suitable soil will demonstrate a saturated hydraulic conductivity within  $\pm 20\%$  of the hydraulic conductivity prescribed in the engineering designs.
- xi. Texture – sandy loam to loamy sand
- xii. Large particles – as specified for ‘natural soils and soil blends’

3. *Additional Hydraulic Conductivity Testing – required where PSD does not meet specifications but silt + clay is <12%*

Saturated hydraulic conductivity – as specified in engineering design. (Suitable methods include: McIntyre and Jakobsen (1998) method, AS/NZS 1547 permeability testing method).

4. *Water Holding Capacity – required where PSD does not meet specifications but silt + clay is <12% or in regions likely to experience extended dry spells*

Water Holding Capacity– at least 15–20% by volume at 300mm of suction using the McIntyre and Jakobsen (1998) method.

Any component or soil found to contain high levels of salt, high levels of clay or silt particles (exceeding the particle size limits set above), extremely low levels of organic carbon or any other extremes which may be considered retardant to plant growth and denitrification should be rejected.

Testing requirements to determine suitable soils are described in Filter Media – Testing Requirements. It may be possible to ‘construct’ a suitable filter media by amending the local soils. A procedure for constructing a suitable filter media is outlined below.

#### 1.1.4 Transition Layer – Detailed Specifications

Transition layer material shall be sand/ coarse sand material. An indicative particle size distribution is provided below:

% passing	1.4 mm 100 %
	1.0 mm 80 %
	0.7 mm 44 %
	0.5 mm 8.4 %

This grading is based on a Unimin 16/30 FG sand grading.

Geotextile fabrics are not recommended for use in bioretention systems due to the risk of clogging. An open knitted shade cloth can be placed between the transition layer and the drainage layer to help reduce the downward migration of smaller particles.

#### 1.1.5 Drainage Layer – Detailed Specifications

The drainage layer is to be fine gravel, such as a 2–5 mm screenings.

## 1.2 Constructing Filter Media from In-situ Soils

1. Identify if local top soil is capable of supporting vegetation growth and if there is enough top soil (some top soils are very shallow) be used as a base for the filter media (may require active collection of top soil during the construction process). Any topsoil found to contain high levels of salt, extremely low levels of organic carbon ( $<<5\%$ ), or any other extremes which may be considered retardant to plant growth should be rejected. If the top soil is not suitable, a sandy loam soil can be purchased from a supplier for use as a base soil.
2. Conduct laboratory tests to establish hydraulic conductivity, water holding capacity, particle size distribution, and AS4419–2003 parameters.
3. If the soil needs to be amended to achieve the desired design saturated hydraulic conductivity and particle size distribution either mix in a loose non-angular sand (to increase saturated hydraulic conductivity) or a loose soft clay (to reduce saturated hydraulic conductivity).
4. The required content of sand or clay (by weight) to be mixed to the base soil will need to be established in the laboratory by incrementally increasing the content of sand or clay until the desired saturated hydraulic conductivity is achieved (within reasonable bounds). The sand or clay content (by weight) that achieves the desired hydraulic conductivity should then be adopted on-site.
5. The base soil should have sufficient organic content to establish vegetation on the surface of the bio-retention system. If the proportion of base soil in the final mix is less than 50% then it may be necessary to add in additional organic material. This will be limited to 10% organic content (measured in accordance with AS1289 4.1.1).
6. The pH of the soil mixture for the filtration layer is to be amended to between 5.5 and 7.5, before delivery to the site.
7. Ensure soil meets the specifications for:
  - a. hydraulic conductivity,
  - b. water holding capacity,
  - c. particle size distribution, and
  - d. AS4419–2003 parameters.

as set out in the Section 1.1.3 – Filter Media Detailed Specifications.

## 1.3 Targeting Specific Pollutants

The media specification described above is designed for applications where the types and concentrations of pollutants are expected to be similar to 'normal' urban pollutant loads. In some cases, receiving waters may be more sensitive or target pollutants may differ (excessive heavy metals or increased nutrient concentrations for example). For sensitive sites or where the runoff is expected to have a composition that differs from general urban pollutant loads, media can be further amended to increase treatment efficiency.

For example, activated carbon (or another material with a high adsorption capacity) can be added where high concentrations of heavy metals are expected; the organic matter content of the media can be increased for sites where nitrogen is the target pollutant (and therefore denitrification is the target process); commercial products with high adsorption capacity that target specific pollutants such as phosphorus can also be added to the media where required.

## 2 SOIL MEDIA SPECIFICATIONS FOR TREE POD BIORETENTION APPLICATIONS

### 2.1 Bioretention Systems for trees

For trees, the hydraulic conductivity will generally be prescribed to be within the range of 30 – 100 mm/hr. Maintaining the prescribed hydraulic conductivity is crucial.

Where soils are prepared for trees the pH of the soil mixture is to be corrected to between 5.5 and 7.5, using dolomite, before delivery to the site.

The filter media of 'Tree Bioretention Pods' consists of two layers, the base layer and the surface layer. The difference between the layers is the organic content, as discussed below. The total depth of the filter media profiles for trees must be deep enough to provide tree stability

As in other bioretention applications, a transition layer and a drainage layer are also required.

#### 2.1.1 Base Layer

The tree media base layer should meet the same specifications as described for bioretention filter media with exception to the Organic Matter Content which should be low. PSD and AS4419–2003 testing should be carried out and a suitable media will demonstrate the following characteristics:

##### 1. Particle Size Distribution

Soils with infiltration rates in the appropriate range typically vary from sandy loams to loamy sands. Soils with the following composition are likely to have an infiltration rate in the appropriate range and have suitable structural integrity –

Clay	2–4%	(<0.002 mm)
Silt	4–8%	(0.002–0.05 mm)
Very Fine Sand	5–10%	(0.05–0.15 mm)
Fine Sand	10–25%	(0.15–0.25 mm)
Medium Sand	60–70%	(0.25–0.5 mm)
Coarse Sand	7–10%	(1.0–2.0 mm)
Fine Gravel	<3%	(2.0–3.4 mm)

Variation in large particle sizes is flexible (i.e. an approved material does not have to be screened). However, the particle size distribution of the smaller particles (clay and silt) is a crucial element of the filter media specification. Where soils are prone to structural collapse the hydraulic conductivity may change dramatically depending on the state of collapse of the soil. However, ensuring the total clay and silt mix is less than 12% reduces the likelihood of structural collapse of such soils.

##### 2. AS4419– 2003 (Soils for Landscaping and Garden Use)

Bulk density – as specified for 'natural soils and soil blends' >0.7 kg/L

Organic Matter Content – **less than 3–5% w/w**

Wettability – as specified for 'natural soils and soil blends' >5 mm/hr

pH – as specified for 'natural soils and soil blends' 5.5 – 7.5 (pH 1:5 in water)



Electrical Conductivity (EC) – as specified for ‘natural soils and soil blends’ <1.2dS/m

Phosphorus – <20mg/kg

Nitrogen Drawdown (NDI) – as specified for ‘natural soils and soil blends’ >0.5 NDI<sub>150</sub>

Toxicity – as specified for ‘natural soils and soil blends’

Dispersibility – as specified for ‘natural soils and soil blends’ Category 1 or 2

Permeability – **hydraulic conductivity as specified in engineering design**

Texture – sandy loam to loamy sand

Large particles – as specified for ‘natural soils and soil blends’

### 2.1.2 Surface Layer

The tree media surface layer is the top 150mm of soil (placed onto the base layer). The tree media surface layer should be the same as the base layer however further amended to include:

**Organic matter at 10% by volume.**

Suitable organic matter will be coco peat or fine compost. Any compost used should conform to the description of “composted soil conditioner” in Australian Standard AS 4454–1999.

### 2.1.3 Transition Layer

Transition layer material shall be sand/coarse sand material. An indicative particle size distribution is provided below:

<b>% passing</b>	1.4 mm 100 %
	1.0 mm 80 %
	0.7 mm 44 %
	0.5 mm 8.4 %

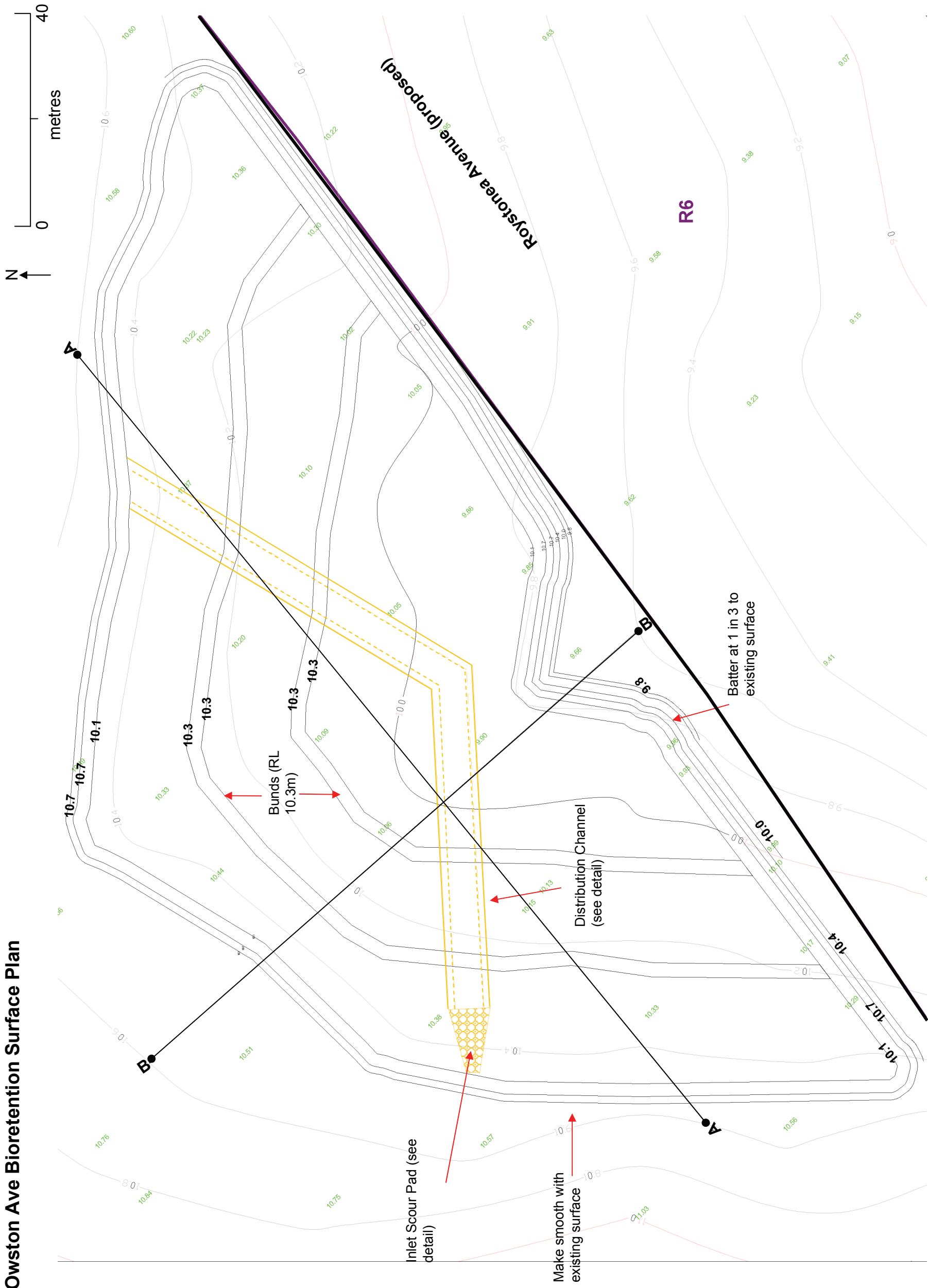
This grading is based on a Unimin 16/30 FG sand grading.

### 2.1.4 Drainage Layer

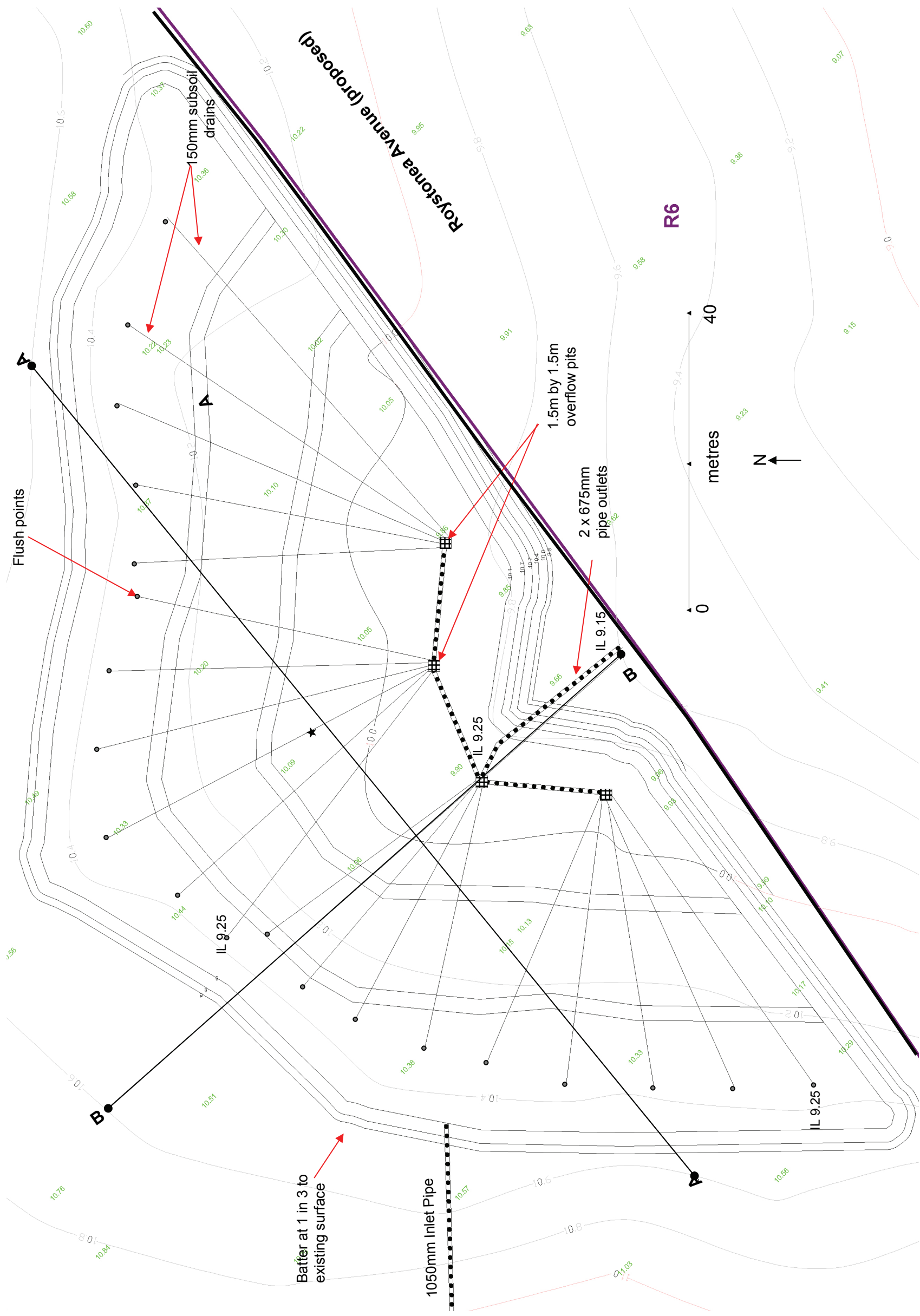
The drainage layer is to be fine gravel, such as a 2–5 mm screenings.

## APPENDIX B: CONCEPT DESIGN SKETCHES

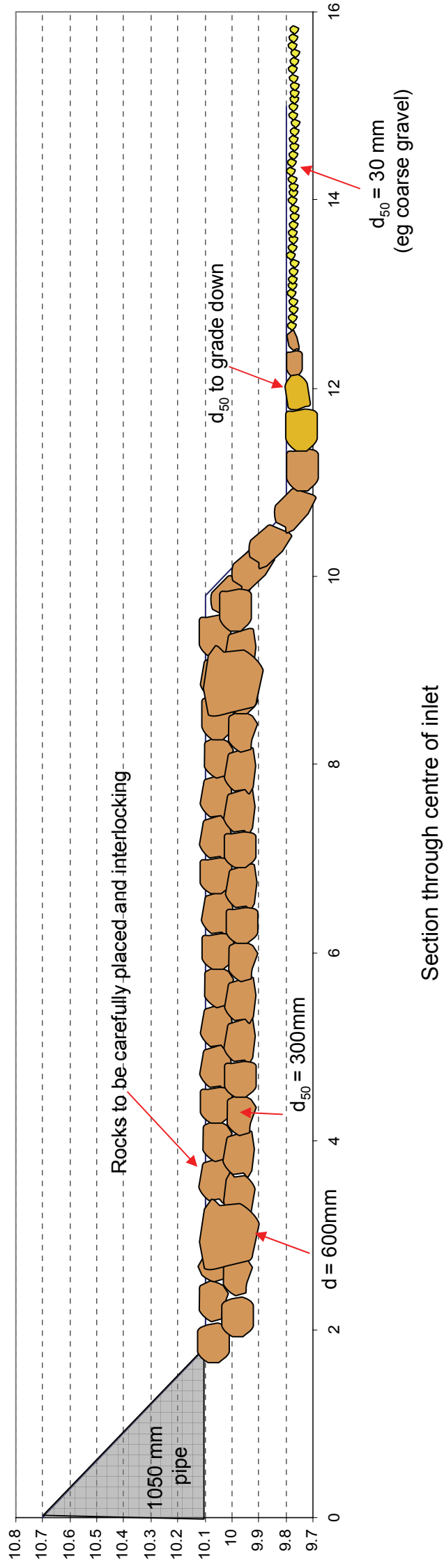
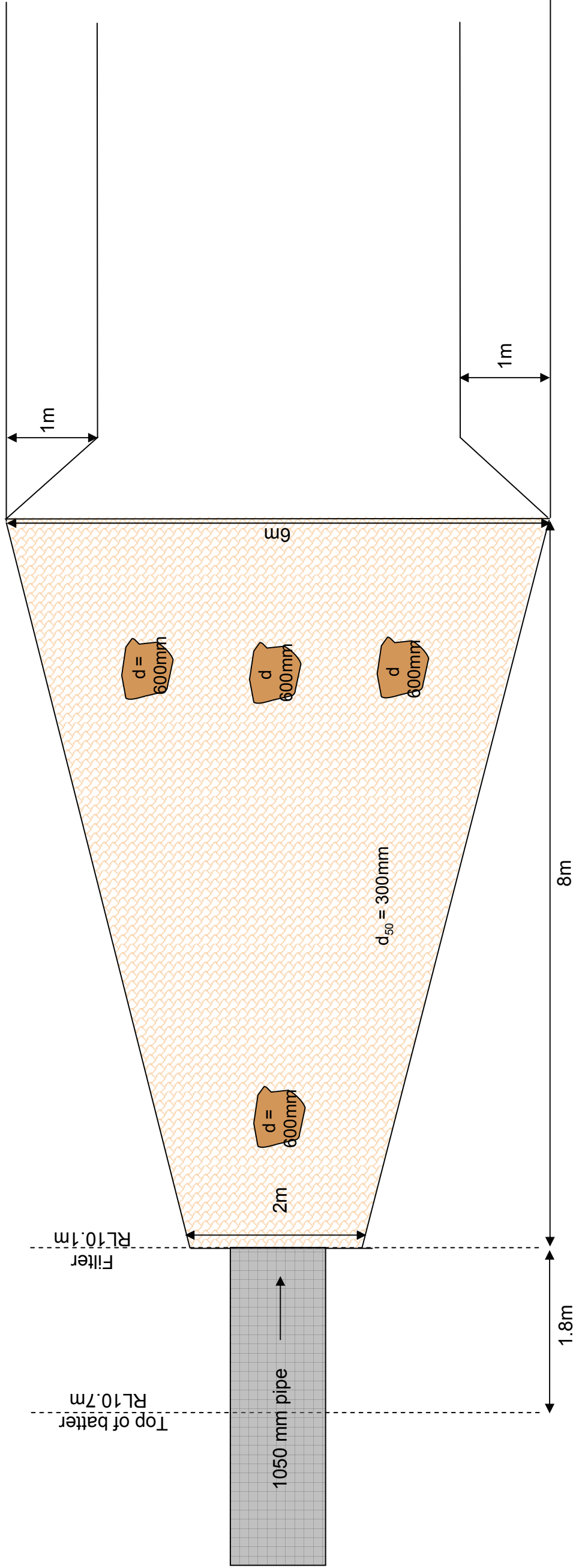
# Owston Ave Bioretention Surface Plan



# Owston Ave Bioretention Drainage Plan

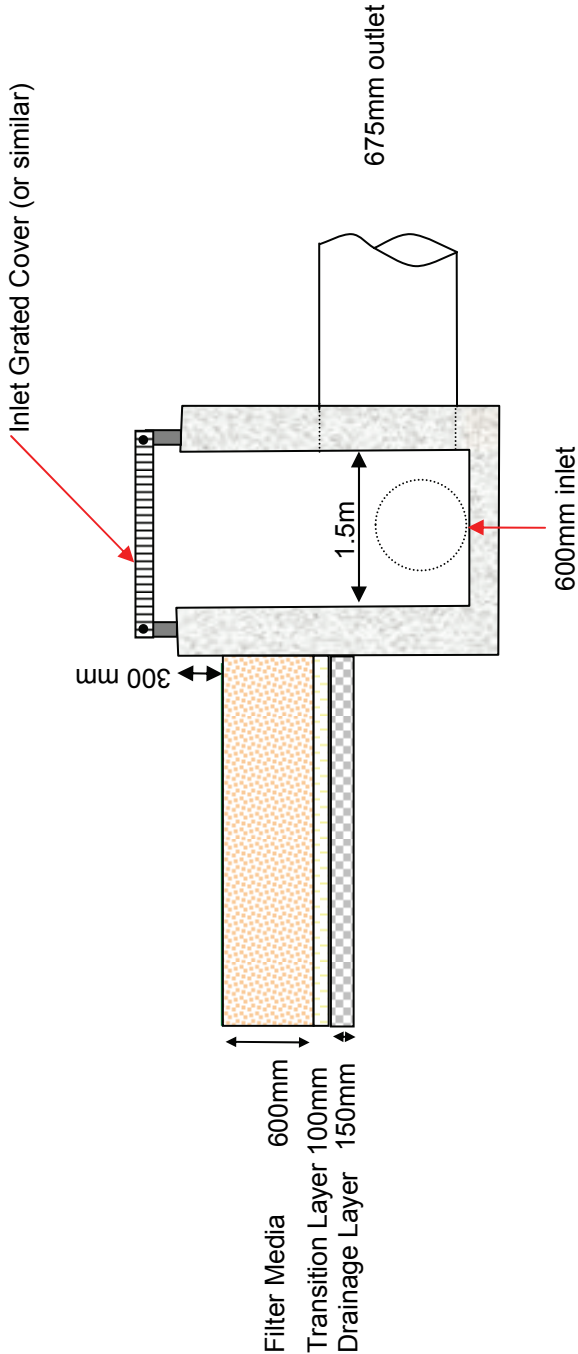


Owston Ave Bioretention Inlet

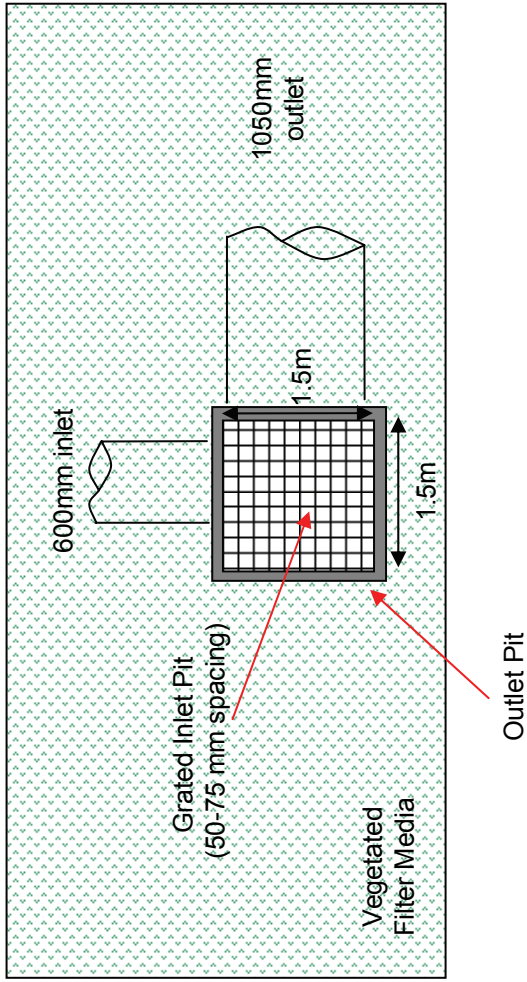


Owston Ave Bioretention Overflow Pit

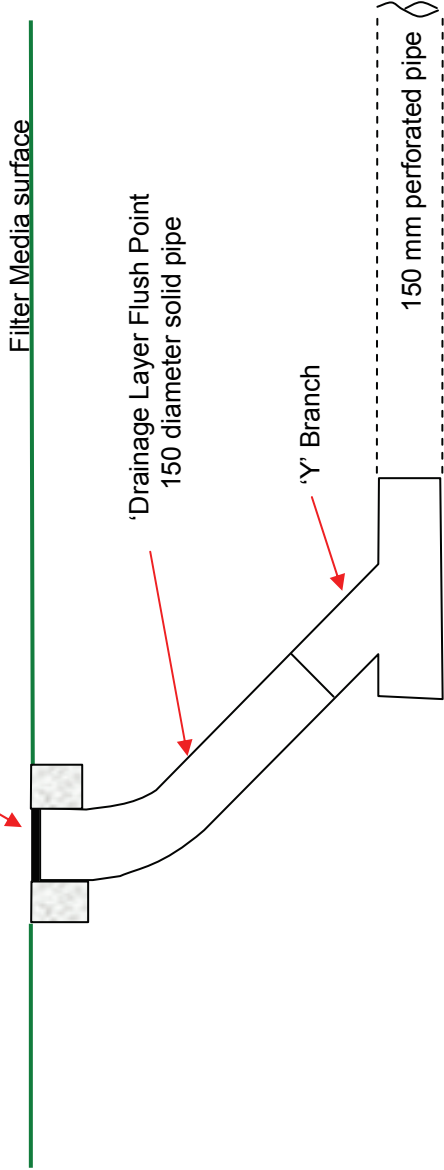
Overflow Pit Cross Section Detail



Overflow Pit Plan View Detail

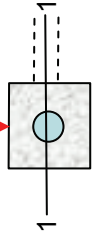


Screw cap and 350 x 350 x 150 concrete surrounding cap.



Flush Point Section 1-1 Detail

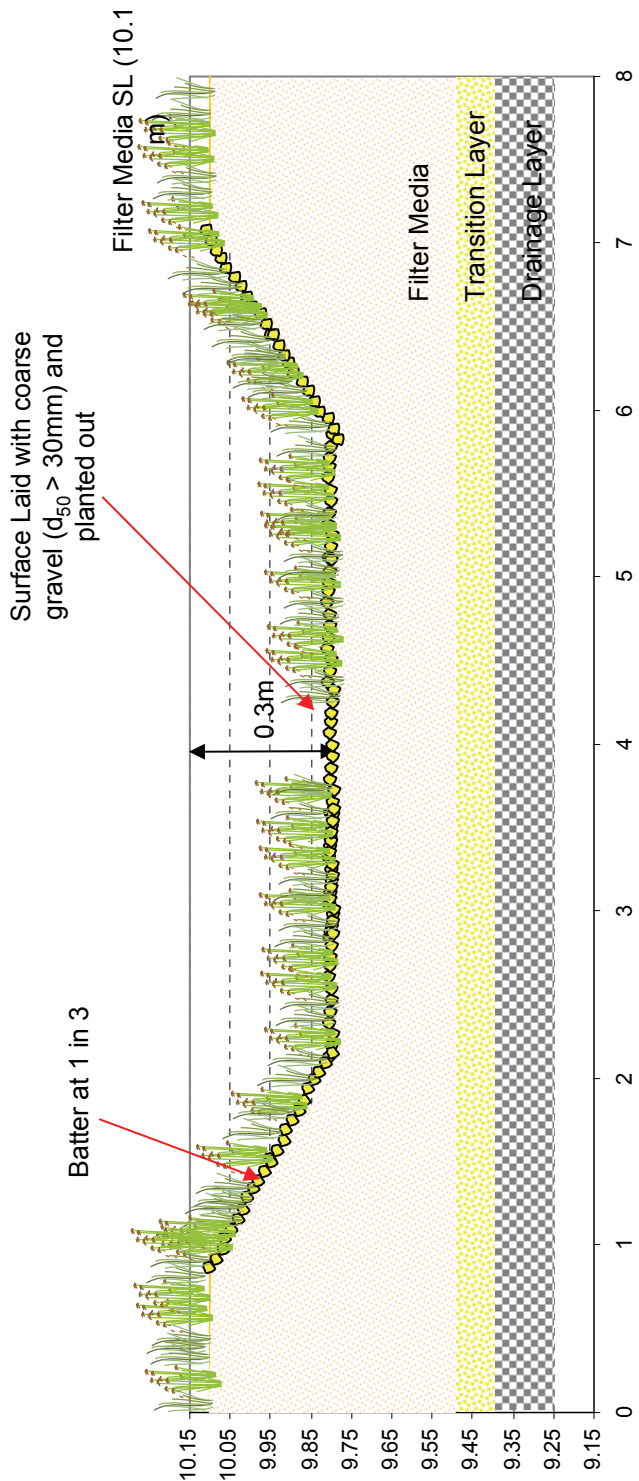
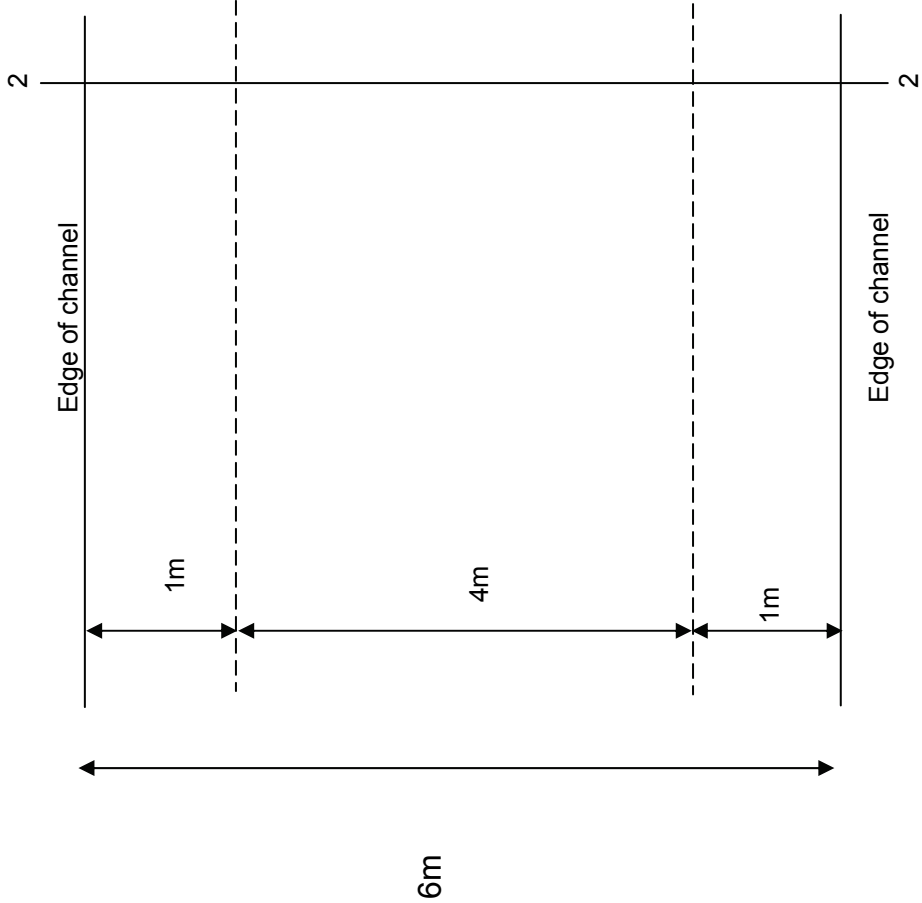
Screw Cap and 350 x 350 x 150 concrete surrounding cap.



Flush Point Plan View

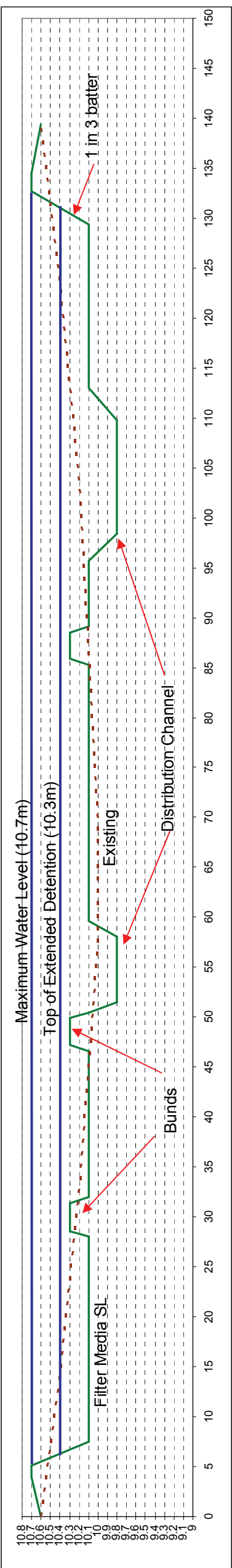
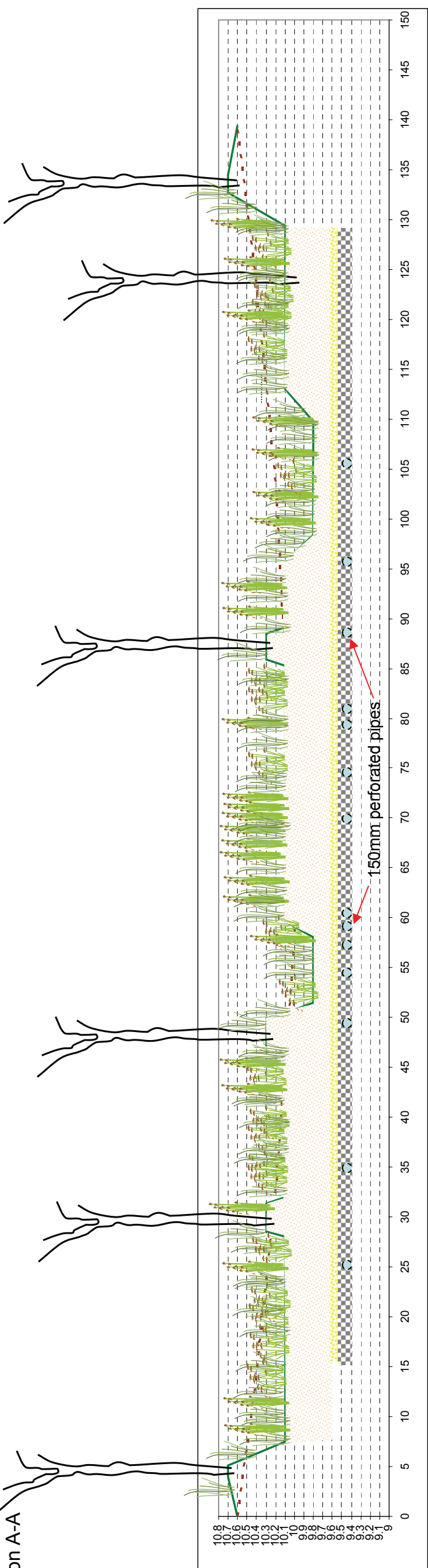


Owston Ave Bioretention Distribution Channel Details



Owston Ave Bioretention Cross Sections

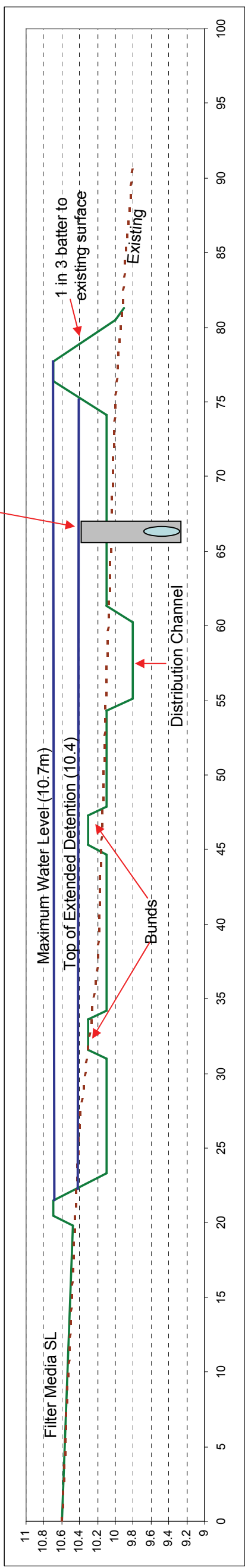
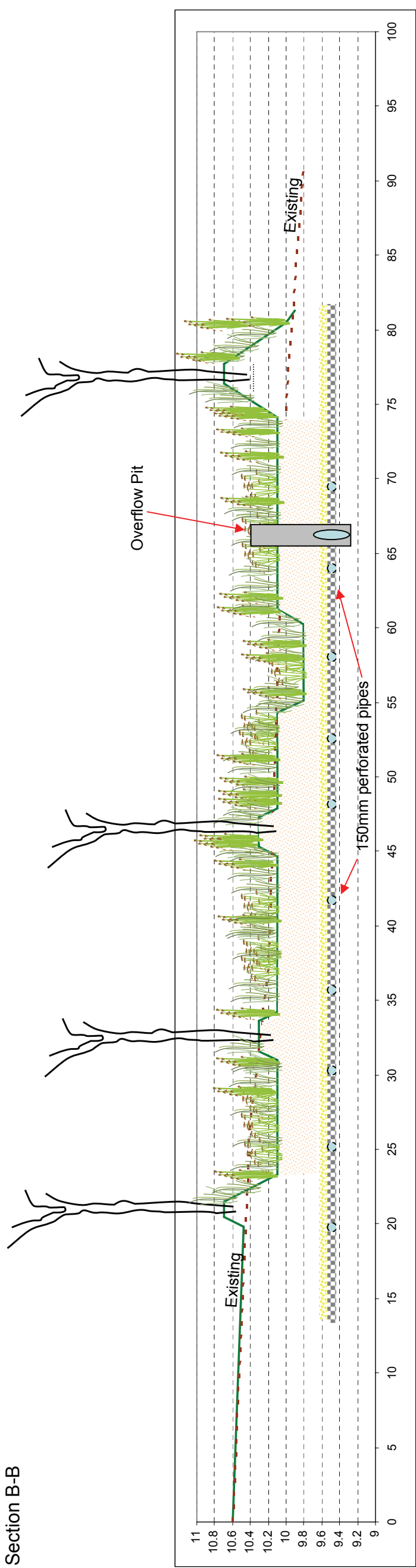
Section A-A

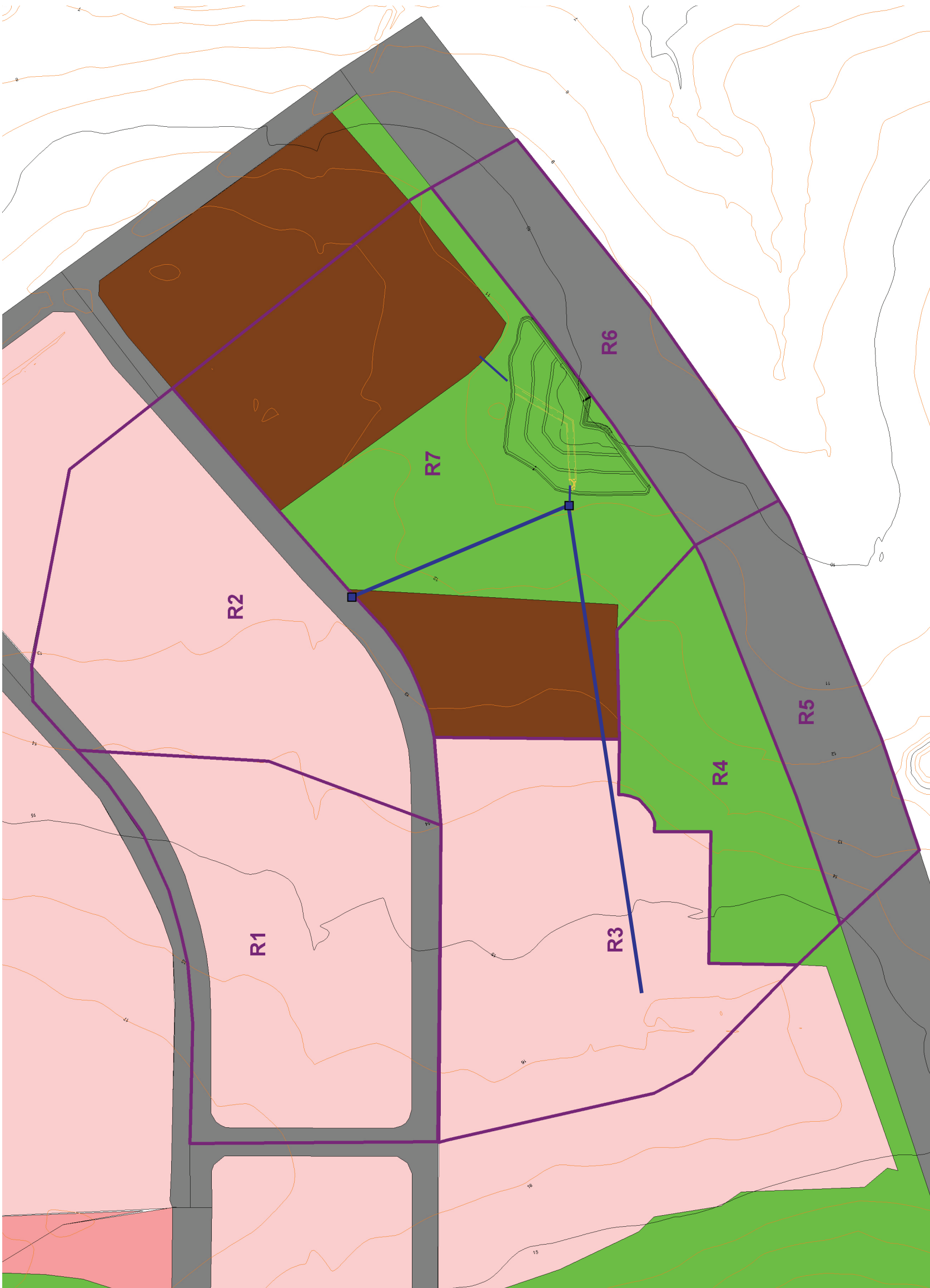




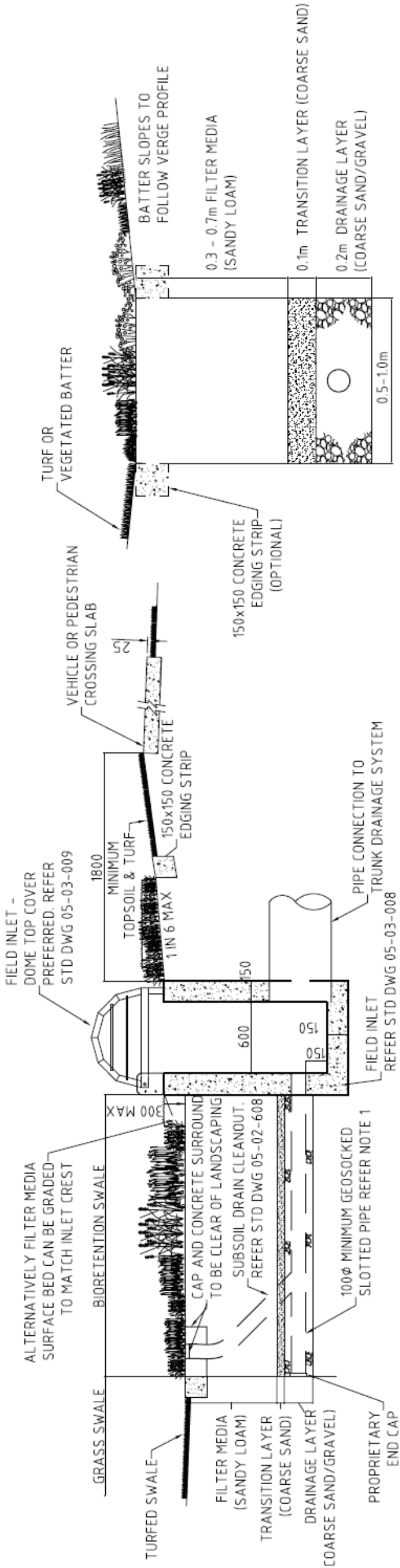
Owston Ave Bioretention Cross Sections

Section B-B





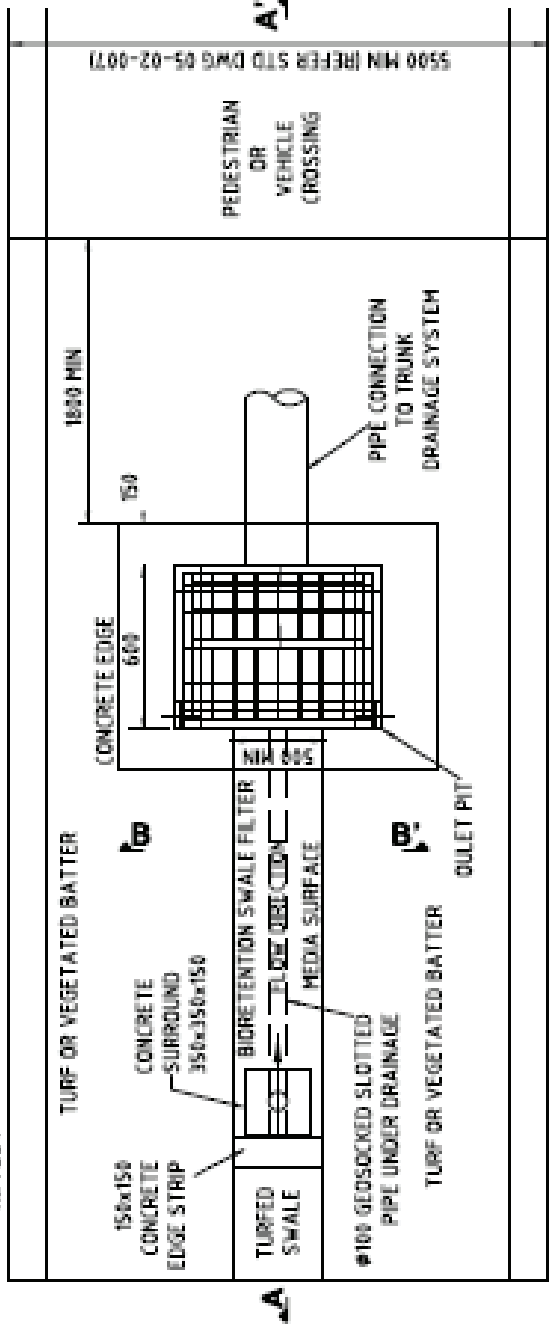
Owston Bioretention Overflow Pit



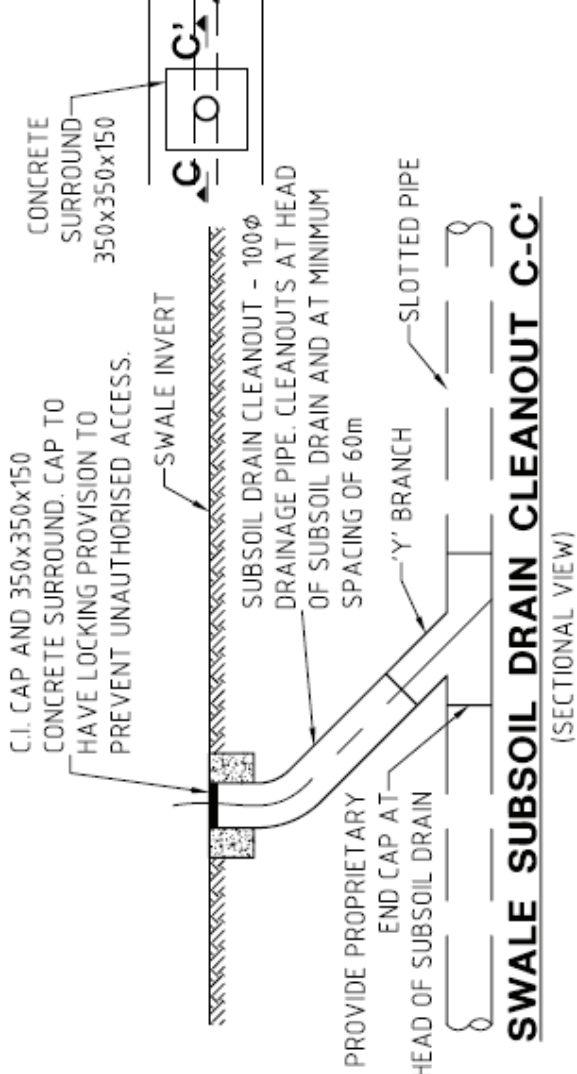
BIORETENTION CELL LAYOUT A-A'

(SECTIONAL VIEW)

TYPICAL SECTION B-B'



ROAD VERGE BIORETENTION PLAN VIEW



SWALE SUBSOIL DRAIN CLEANOUT C-C'

(SECTIONAL VIEW)

# Bellamack bioretention: cross section

