

CONCEPT STORMWATER AND WATER QUALITY MANAGEMENT REPORT

Proposed Development of

**46-66 O'CONNELL STREET
CADDENS NSW**

MAY 2021

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EXECUTIVE SUMMARY

GDS has been commissioned to prepare the engineering road and drainage design for the proposed residential subdivision at 46-66 O'Connell St, Caddens (Lot 3 on DP1103503). It is proposed to subdivide the subject site into 236 title lots, and 1 residue lot. This report investigates stormwater management in both quality and quantity aspects after site development based on Penrith City Council guidelines.

The site is located within The Penrith City Council (Council) Local Government Area (LGA). The proposed layout will generally be in accordance with the Indicative Layout Plan. The site will be designed in accordance with Penrith City Council's Development Control Plan, referred to as the Design Specification hereafter.

The site is currently used as a general agricultural use. The site is located on top of a crest and the slope varies from 6% to 12%. The site is located within the Werrington Creek catchment. The site is not flood affected.

To meet Penrith City Council's requirements in terms of stormwater quality and quantity, two temporary and three permanent onsite detention basins and WSUD measures will be supplied. To achieve the water quality targets, rainwater tanks and a bioretention basin have been designed for this site.

ABBREVIATIONS

AEP	Annual Exceedance Probability
AMC	Antecedent Moisture Content
ARI	Average Recurrence Interval
BMP	Best Management Practice
CC	Construction Certificate
CP	Contributions Plan
DA	Development Application
DCP	Development Control Plan
DD	Design Development
DP	Deposited Plan
GPT	Gross Pollutant Trap
IFD	Intensity-Duration-Frequency
ILP	Indicative Layout Plan
LGA	Local Government Area
MUSIC	Model for Urban Stormwater Improvement Conceptualization
OSD	On-Site Stormwater Detention
PMF	Probable Maximum Flood
QUDM	Queensland Urban Drainage Manual
RMS	Roads and Maritime Services
SQID's	Stormwater Quality Improvement Devices
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WSC	Water Servicing Coordinator
WCMS	Water Cycle Management Strategy Report
WQO	Water Quality Objective
WSUD	Water Sensitive Urban Design

REFERENCED STANDARDS & DOCUMENTATION

The following documents have been used as part of this review:

1. Penrith City Council (2013a). Water Sensitive Urban Design Policy.
2. Penrith City Council (2015). Water Sensitive Urban Design Technical Guidelines.
3. Penrith City Council (2013c), Design Guidelines for Engineering Works for Subdivisions and Developments, in force from 20 May 1997, amended 20 November 2013
4. Penrith City Council (2015), Penrith Development Control Plan 2015.
5. Penrith Local Environmental Plan (Caddens) 2009, Land zoning map
6. MUSIC Model for Urban Stormwater Improvement Conceptualisation, User Guide Version 6.3.

1. INTRODUCTION

1.1. Background

Group Development Services Pty Ltd (GDS) has prepared the engineering earthworks, road, and drainage design for the proposed residential subdivision of the land known as 46-66 O’Connell Street, Caddens, referred to as “the site” from hereafter. The site is located within Penrith City Council (Council) Local Government Area (LGA). Figure 1 shows the location of the development site.



Figure 1-Site Location

At the time of preparing this report, it is understood that none of the adjoining properties are under a development process and the southern adjoining property has been developed recently. This report has been prepared to support the proposed modification of Development Application to Council.

It should be noted that this stormwater strategy has been based on the road longitudinal grading that was designed. The road grading was assumed to be “frozen” for design purposes. Should the road grading be changed, it may be necessary to re-visit the stormwater management strategy to ensure that it is still relevant.

1.2. Study Scope

The scope of this study is to produce a stormwater management strategy for redevelopment, which addresses how the development proposes to manage stormwater run-off and analyses both water quantity and water quality of stormwater flows leaving the site.

The following tasks have been undertaken to complete this study:

- Preparation of concept drainage engineering plans.
- Stormwater conveyance for the minor 5 year ARI.
- Major flow management of the 100 year ARI.
- Stormwater detention so that the 2 and 100 year ARI flows are the equivalent of the pre-developed land.
- Produce a concept stormwater strategy design as per the IWCM guidelines.
- Review of standards, codes, policies and relevant Council reports, consultant reports and relevant planning instruments.

2. SITE CHARACTERISTICS

2.1. Location

The site is located within the suburb of Caddens, within The Penrith City Council (Council) Local Government Area (LGA). The region is semi-rural with approximately 12.15 ha in size.

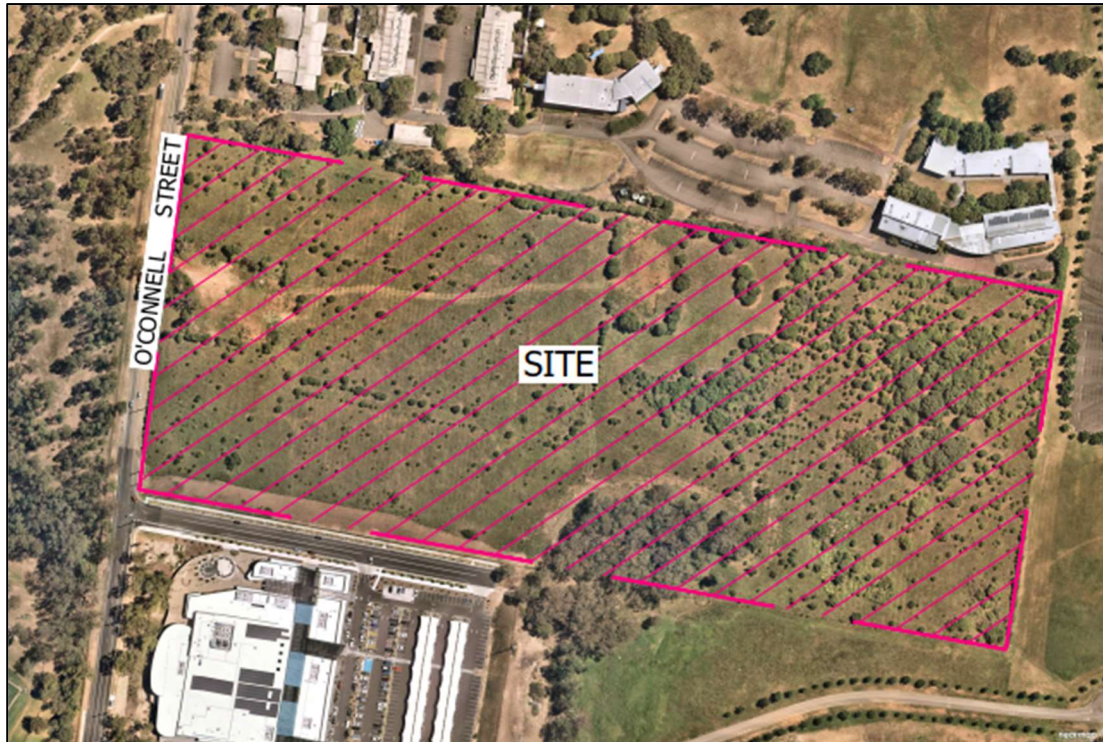


Figure 2- Developed Area

2.2. Topography

For the purpose of the analysis the site has been divided into seven different pre-development sub catchment areas. Considering the overland flow for each of them there is a discharge point along the north-west corner of the site, another one on the north-east, one on the south-east and a major one along the south-west corner. The existing site levels range from 66.5m AHD to 46.0m AHD. Refer to Figure 3 for an illustration of the site catchment areas in the pre-development conditions.

2.3. Water Courses

There is no specified watercourse through the site.

2.4. External Catchments

Based on the site topography, there is no upper catchment for the site Refer to **Appendix C** for the definition of the catchments plan.

2.5. Flooding

The development site is clear of the PMF flood level.

3. STORMWATER DRAINAGE

3.1. Existing Stormwater Drainage

There is currently no major formalised drainage infrastructure within the site. The site overflow hardstand areas are assumed to be drained via overland flow that discharges into the existing street or water course. The site is located on the top of a hill with an elevation of 66.50 m AHD and grades to the north to 50.0 m AHD at an average grade of 7% and to the south down to 46.0 m AHD with an average grade of 6%. The site divided into seven sub-catchments. Figure 3 illustrates the site catchment areas in the pre-development conditions.



Figure 3- Site catchment areas in pre-development condition

3.2. Site Catchment

As in pre-development condition, the site run-off discharges un-concentrated, however, in post-developed condition, the site run-off will be directed into the same discharging points with less and/or same flow rate. For the purpose of this study the discharge in post-developed condition has been split in two major point of discharge: West including OSD 1, 2, 3, 4 and bypass areas; and East which includes OSD 5. Refer to Figure 4 for an illustration of the site catchment areas in the post-development conditions. Six different developed sub catchments and three undeveloped areas are defined based on discharging points:

- 1) The north-western catchment which will discharge north into O'Connell street in Post-development condition (OSD 1 and Bypass North-West).
- 2) The south-western catchment which will discharge south into O'Connell street in Post-development condition (OSD 2, OSD 3, Bypass South-West and Bypass South 2).
- 3) The south catchment which will discharge within the site through an outlet and a Rip-Rap to release the run-off to the adjoining property in safe condition (OSD 4 and Bypass South 1).

- 4) The north-eastern catchment which will discharge within the site through an outlet and a Rip-Rap to release the run-off to the adjoining property in safe condition (OSD 5).

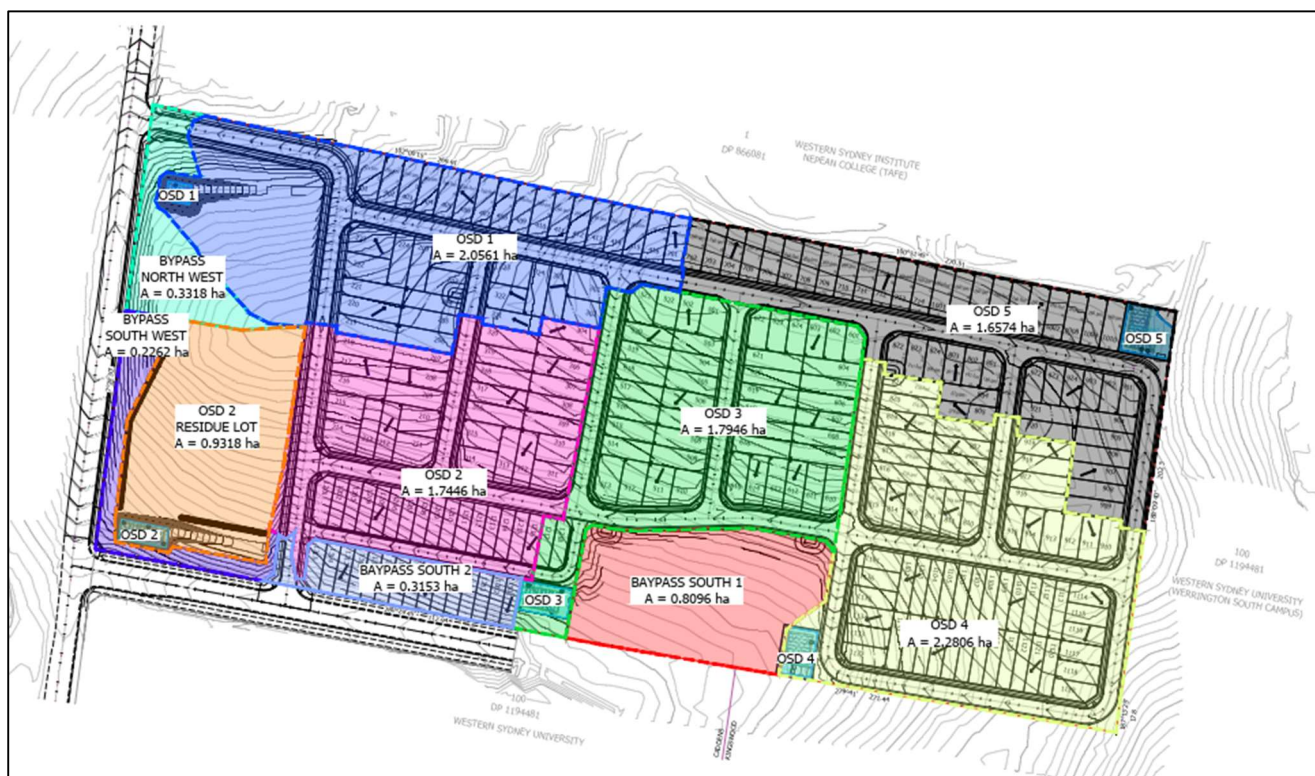


Figure 4- Site catchment areas in post-development condition

Hydrological modelling has been undertaken using the computer software package *DRAINS* for the design of the drainage network. *DRAINS* perform design and analysis calculations for urban stormwater drainage systems and models the flooding behaviour of rural and urban catchments.

The Rainfall Runoff Parameters used in the Drains model were the ILSAX comply with Council’s design guidelines.

The site has been modelled as individual nodes. Pre-development input parameters and design flows from the 50% to 1% AEP storm event are summarised in Table 1. A hydraulic assessment of the external catchment conveyance through the site will be conducted during the detailed design. The post-development discharge location is proposed to be the same as the existing catchment.

Table 1- Pre-development and Post-development model parameters and design flows (without OSD)

	Site Catchment (ha)	External Catchment (ha)	Fraction impervious (%)	AEP design flow (m ³ /s)					
				50%	20%	10%	5%	2%	1%
Pre-development model	12.149	0.0	5	0.450	1.476	2.239	3.027	3.995	4.723
Post-development model	12.149	0.0	85	2.046	3.065	3.830	4.627	5.701	6.517

Notes:

- Catchment losses and antecedent moisture conditions (AMC) are in accordance with Council’s Engineering Guidelines.
- Rainfall intensity-frequency-duration (IFD) and temporal pattern data is in accordance with Australian Rainfall and Runoff (AR&R) (Appendix A).

- Storm durations considered between 5 minutes and 6 hours.
- Pre-development catchment time of concentration based on sheet flow for the first 50m and minor concentrated flows for the remaining length.
- Post-development catchment time of concentration based on 5-minute property travel time to the road gutter and 1.5 m/s concentrated flow for the remaining length (based on Section 4.6.3 (b) of the *Queensland Urban Drainage Manual (2013)* (QUDM)).

3.3. Proposed Drainage Strategy

The stormwater drainage design will be carried out in accordance with Council’s Engineering Design Guidelines. The piped drainage will be designed to convey the 5-year ARI minor storm event with the road carriageway used to convey excess flows generated in the 100-year ARI major storm event.

The development will introduce an increase in impervious areas consisting of roofs, roads, driveways and footpaths reducing the potential for infiltration. Additionally, water intercepted by these impervious surfaces will be directed into the stormwater system and rapidly conveyed to the catchment outlet increasing the peak flows from the site. To mitigate these potential impacts, on-site detention will be required within the site to attenuate the flows back to the equivalent rural level. It is proposed that detention will be provided through bio-retention basins.

3.4. On-Site Stormwater Detention

To meet Council’s requirement in terms of stormwater quality and quantity, onsite detention basins are required. Preliminary sizing of the basins has been based on the following criteria:

- Council requires post-development peak flows limited to pre-development peak flows for all storms up to and including the 100-year ARI event.
- Basins are not to encroach into the proposed and future road reserve areas.

A preliminary design has been carried out using the *DRAINS* software. For DA purposes, all storms up to and including the 100-year ARI event have been assessed. Final basin areas and volumes are likely to change pending confirmation of design criteria. It is not proposed to attenuate the existing external catchment. A pass-through system is proposed to let this catchment discharge under the site and continue downstream. This system is to be independent of the site’s stormwater drainage.

Lots will be required to provide stormwater detention for runoff from the roofs over and above the reuse requirements and will be effective for the 5 and 20-year ARI events. Bio-detention basins will be provided with total storage volume of approximately 3,133 m³. It is proposed that these on site detention basins will be located in the site low points.

Preliminary configuration for bio-retention basins is summarized in Tables 2. The analysis shows post-development peak flows have been reduced up to pre-development peak flows whilst achieving the assumed design criteria. Moreover, bio-retention filter media has been provided for water treatment in each OSD. The results are summarised in tables 3 and 4.

Table 2- Designed Basin Details

Item	Name	Catchment Area (m ²)	Bottom Area (m ²)	Volume (m ³)
1	OSD1	2.056	125.0	996.0
2	OSD2	2.676	250.0	490.0
3	OSD3	1.795	379.0	570.0
4	OSD4	2.281	401.0	600.0
5	OSD5	1.657	557.0	477.0

Table 3- Site Catchment Outlets Analysis

	Site Area(ha)	Fraction impervious (%)	ARI design flow (m3/s)						
			50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	
EAST	Pre-development model	1.471	5	0.054	0.185	0.285	0.381	0.491	0.578
	Post-development model	1.657	85	0.048	0.106	0.173	0.322	0.412	0.551
WEST	Pre-development model	10.678	5	0.396	1.291	1.954	2.646	3.504	4.145
	Post-development model	10.492	85	0.389	0.756	1.168	1.778	2.296	2.853
Total	Pre-development model	12.149	5	0.501	1.554	2.316	3.149	4.008	4.766
	Post-development model	12.149	85	0.397	0.953	1.559	2.288	3.131	4.055

Table 4- Maximum volume and water level of on-site detention Basins

BASIN 1 (OSD1)	
	50% AEP
MAX WATER LEVEL (m)	50.34
	20% AEP
MAX WATER LEVEL (m)	51.16
	10% AEP
MAX WATER LEVEL (m)	51.69
	5% AEP
MAX WATER LEVEL (m)	52.03
	2% AEP
MAX WATER LEVEL (m)	52.30
	1% AEP
MAX WATER LEVEL (m)	52.35
MAX VOLUME (m3)	359.3
	569.8
	728.9
	841.1
	934.9
	955.3
BASIN 2 (OSD2)	
	50% AEP
MAX WATER LEVEL (m)	46.01
	20% AEP
MAX WATER LEVEL (m)	46.41
	10% AEP
MAX WATER LEVEL (m)	46.6
	5% AEP
MAX WATER LEVEL (m)	46.69
	2% AEP
MAX WATER LEVEL (m)	46.75
	1% AEP
MAX WATER LEVEL (m)	46.79
MAX VOLUME (m3)	231.0
	360.5
	428.5
	459.9
	481.9
	498.3
BASIN 3 (OSD3)	
	50% AEP
MAX WATER LEVEL (m)	52.72
	20% AEP
MAX WATER LEVEL (m)	53.08
	10% AEP
MAX WATER LEVEL (m)	53.25
	5% AEP
MAX WATER LEVEL (m)	53.41
	2% AEP
MAX WATER LEVEL (m)	53.62
	1% AEP
MAX WATER LEVEL (m)	53.77
MAX VOLUME (m3)	168.4
	305.0
	367.7
	430.0
	510.1
	565.8
BASIN 4 (OSD4)	
	50% AEP
MAX WATER LEVEL (m)	55.5
	20% AEP
MAX WATER LEVEL (m)	55.88
	10% AEP
MAX WATER LEVEL (m)	55.99
	5% AEP
MAX WATER LEVEL (m)	56.08
	2% AEP
MAX WATER LEVEL (m)	56.21
	1% AEP
MAX WATER LEVEL (m)	56.37
MAX VOLUME (m3)	244.0
	394.8
	438.8
	472.9
	526.6
	589.1
BASIN 5 (OSD5)	
	50% AEP
MAX WATER LEVEL (m)	62.54
	20% AEP
MAX WATER LEVEL (m)	62.75
	10% AEP
MAX WATER LEVEL (m)	62.86
	5% AEP
MAX WATER LEVEL (m)	62.91
	2% AEP
MAX WATER LEVEL (m)	62.95
	1% AEP
MAX WATER LEVEL (m)	62.98
MAX VOLUME (m3)	228.0
	339.3
	400.3
	429.0
	449.3
	470.6

Based on this assessment, the proposed development will be able to mitigate the peak flow from the site such that it will be less than or equivalent of the pre-developed site and not adversely impact on the downstream lands.

4. STORMWATER QUALITY

4.1. Pollutants of Concern

During the operational (post-construction) phase of a subdivision development, key pollutants which may be of concern in the site's stormwater runoff include:

- Litter
- Sediments
- Nutrients
- Surfactants
- Hydrocarbons

During the construction phase of the development, the typical pollutants that can be expected during this phase are outlined below. Measures should be put in place during the construction phase to mitigate these pollutants.

- Litter
- Sediments
- Hydrocarbons
- Toxic Materials
- pH Altering Substances

4.2. Receiving Waters

The receiving water for the site stormwater drainage is the Killarney Chain of Ponds.

4.3. Environmental Values and Water Quality Objectives (WQO's)

The Water Quality Guidelines for the development have been obtained from Council's DCP which is summarised below in.

- 85% reduction for Total Suspended Solids (TSS);
- 60% reduction for Total Phosphorous (TP);
- 45% reduction for Total Nitrogen (TN); and
- 90% reduction for Gross Pollutants.

4.4. Modelling/Assessment Approach

A quantitative assessment of stormwater runoff quality was considered only for the operational phase of the development.

The pollutants of concern during the construction phase are not readily modelled due to the varying and site-specific nature of construction practices. The pollutant sources are largely dependent on the site practices and the ability of the site to manage them. A Best Management Practice (BMP) approach was adopted in the selection of the construction phase management options.

In order to assess the post-development stormwater discharge concentration of key pollutants from the site, modelling of runoff for the site has been undertaken using the *Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6.3* software package. The site has been assessed using one model for the entire development.

4.5. Water Quality Treatment

Given the site characteristics, the Stormwater Quality Improvement Devices (SQID's) chosen to treat the stormwater discharge in accordance with the WQO's include rainwater tanks with reuse, and bio-retention basins. Refer to Figure 5 for the proposed stormwater quality treatment train used within MUSIC.

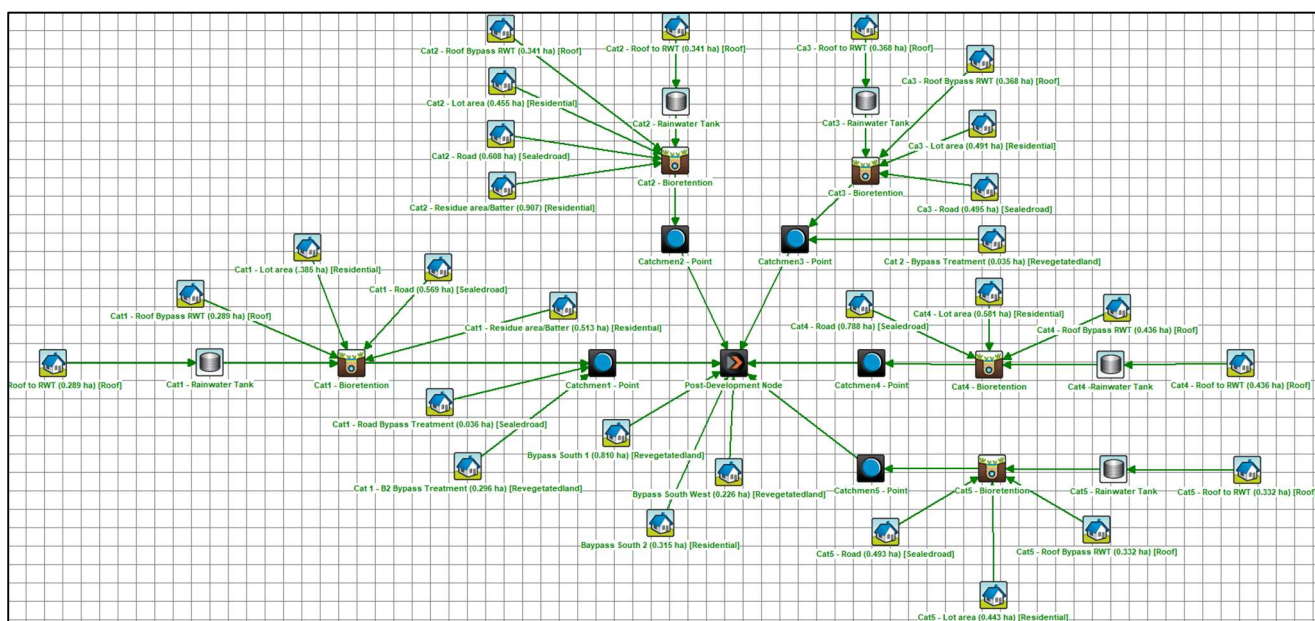


Figure 5- MUSIC Treatment Train.

4.5.1. Rainfall Data

The MUSIC software is capable of utilising rainfall data from a variety of sources based on a range of time steps, such as 6-minute to daily data steps. In accordance with the *Draft MUSIC Modelling Guidelines for New South Wales (2010)* a 6-minute time step has been adopted as this most accurately models such SQID's as rainwater tanks, GPTs, grassed swales and bio-retention basins.

The model runs were based on assessing the Monthly average areal potential evapotranspiration data and rainfall data from the Peats Ridge Bureau of Meteorology (BoM) data (Station No. 67113). This site was selected as it represented the closed BoM station to the Caddens site. The period represented the period where the data was most complete based on the data codes.

4.5.2. Catchment Parameters

The section outlines the MUSIC catchment parameters used to model the site's source nodes and meet the requirement with Penrith council MUSIC link.

For the purposes of the water quality modelling, the following catchment parameters were adopted:

- Impervious fraction of 100% for the roofed and 95% for paved roads reserve.
- Impervious fraction of 50% for open space in lot areas.
- Urban pollutant loads stochastically generated using parameters detailed in Table 3.10 of the *Draft MUSIC Modelling Guidelines for New South Wales (BMT WBM, 2010)*.
- Soil storage and field capacity are the default MUSIC rainfall-runoff parameters as summarised in Table 4-3.

Table 5- MUSIC Rainfall Runoff Parameters (Soil Characteristics)

Parameter	Urban
Rainfall Threshold (mm)	1.4
Soil Storage Capacity (mm)	105
Initial Storage (%)	30
Field Capacity (mm)	70
Infiltration Capacity coefficient - a	150
Infiltration Capacity exponent – b	3.5
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Baseflow Rate (%)	10
Daily Deep Seepage Rate (%)	0.0

Table 6- MUSIC Base and Storm Flow Concentration Parameters for Source Nodes

Land Use Category	Parameter	TSS (Log10 mg/L)		TP (Log10 mg/L)		TN (Log10 mg/L)	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban – Roofs	Mean	1.10	1.3	-0.82	-0.89	0.32	0.3
	Std. Dev	0.17	0.32	0.19	0.25	0.12	0.19
Urban– Remaining Ground Area	Mean	1.20	2.15	-0.85	-0.6	0.11	0.3
	Std. Dev	0.17	0.32	0.19	0.25	0.12	0.19
Urban – Roads incl. Verge	Mean	1.2	2.43	-0.85	-0.3	0.11	0.34
	Std. Dev	0.17	0.32	0.19	0.25	0.12	0.19

The above data has been sourced from Tables 3-09 and 3-10 of the *Draft MUSIC Modelling Guidelines for New South Wales (2010)*.

Table 7- MUSIC Catchment Parameters

Catchment Areas	Area (ha)	Lot Number	Lot area(ha)	Road area (ha)	Batter/Residue area (ha)	Bypass Road (ha)	Roof to RWT (ha)	Roof Bypass RWT (ha)	Lot Exclude Roof (ha)
Cat1	2.056	36	0.962	0.569	0.513	0.036	0.289	0.289	0.385
Cat2	2.677	45	1.137	0.608	0.907	0.000	0.341	0.341	0.455
Cat3	1.795	48	1.227	0.495	0.035	0.000	0.368	0.368	0.491
Cat4	2.281	62	1.453	0.788	0.000	0.000	0.436	0.436	0.581
Cat5	1.657	45	1.108	0.493	0.000	0.000	0.332	0.332	0.443
Bypass North-West	0.296								
Bypass South-West	0.226								
Bypass South 1	0.810								
Bypass South 2	0.315								

In lieu of documented guidance, the fraction impervious for the ground level area has been adopted and consistent with the *Water by Design MUSIC Modelling Guidelines (2012)*.

4.5.3. Rainwater Tanks

Rainwater tanks have been provided in accordance with the DCP. Rainwater tanks with 3KL per lot have been modelled.

Table 8- MUSIC Rainwater Tank Parameters

Parameter	Item
Rainwater Tank below pipe (kL)	3
Associated Lots	236
Total Rainwater Tank Volume (kL)	708
Internal Reuse Rate (kL/day)	0.08
External Reuse Rate (kL/year)	25

4.5.4. Bio-Retention Basin

The final stage of the MUSIC treatment process is the bio-retention filtration which will consist of a vegetated area that is backfilled with sand around the Subsoil drainage pipes. The final process has been designed to provide sediment and nutrient removal prior to stormwater being transferred into the stormwater system. Table 10 outlines the MUSIC input parameters used for the proposed development.

Table 9- MUSIC Bio-Retention Basin Parameters

Parameter		Bio-Ret. Basin1	Bio-Ret. Basin2	Bio-Ret. Basin3	Bio-Ret. Basin4	Bio-Ret. Basin5
Storage	Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3
	Total Area (m ²)	125	250	379	401	557
Infiltration	Total Filter Area (m ²)	110	200	200	200	250
	Saturated Hydraulic Conductivity (mm/hr)	125	125	125	125	125
	Filter Depth (m)	0.5	0.5	0.5	0.5	0.5
	TN Content of Filter Media (mg/kg)	800	800	800	800	800
	Orthophosphate Content of Filter Media (mg/kg)	40	40	40	40	40

4.5.5. MUSIC Modelling Results

Based on the proposed stormwater treatment train described within the previous sections of this report Table 10 details the stormwater pollutant reductions achieved.

Table 10- MUSIC Modelling Results

	Sources	Residual Load	% Reduction
Flow (ML/yr)	50	47.8	4.4
Total Suspended Solids (kg/yr)	8500	1270	85.1
Total Phosphorus (kg/yr)	16.6	5.27	68.3
Total Nitrogen (kg/yr)	112	52.4	53.3
Gross Pollutants (kg/yr)	1400	45.8	96.7

5. STORMWATER QUALITY MANAGEMENT PLAN – CONSTRUCTION PHASE

5.1. Objectives

The objective of the Construction Phase Management Plan is to ensure compliance with the DCP. The purpose of the management plan is to prevent the discharge of polluted stormwater off the site and to ensure that the environmental values of receiving waters are maintained or enhanced.

Pollutants typically generated during the Construction Phase are outlined in Table 12.

Table 11- Typical Construction Phase Pollutants

Pollutant	Sources
Litter	Paper, construction packaging, food packaging, cement bags, off-cuts.
Sediment	Unprotected exposed soils and stockpiles during earthworks and building.
Hydrocarbons	Fuel and oil spills, leaks from construction equipment.
Toxic materials	Cement slurry, asphalt prime, solvents, cleaning agents, wash waters (e.g. from tile works).
pH altering substances	Acid sulfate soils, cement slurry and wash waters.

As a guide refer to the *Water by Design Construction and Establishment Guidelines Version 1.1, April 2010* for the construction and establishment of the proposed stormwater treatment devices.

5.2. Management of Sedimentation & Erosion

A siltation and erosion fence are to be erected. It is expected that the siltation fence along the perimeter of the site will eliminate almost all risk of sediment being washed off the site. Accidental spills of soil or any other material shall be removed immediately if rainfall is likely to occur or at least upon completion of the days' work depending upon the material.

Entry and exit from the site will be restricted to a single stabilised location to minimise the risk of tracking sediment over the site. It is expected that a layer of crushed rock will provide the necessary stabilisation for the access route. A specific area on the site shall be designated for washing down the construction plant. The wash-down area will be contained by earth bunds. There will be no wastewater discharged from the site during construction. The details of the erosion and sediment control devices are to be confirmed during the Construction Certificate phase.

Sediment and erosion control measures, including the design of sediment basins during construction will be in accordance with *Managing Urban Stormwater Soils and Construction, (Landcom 2004) (The Blue Book)*.

5.3. Management of Contaminated Soils

The site is not listed as having Acid Sulphate Soils or Contaminated Land. However, in the event that Acid Sulphate Soils or Contaminated Land is found on site, a management plan is to be implemented and maintained by a suitably qualified professional.

5.4. Management of Imported Materials

Any material imported onto the site (including construction materials) will be stockpiled in a location where it cannot contaminate stormwater runoff.

5.5. Monitoring & Maintenance

Silt traps, sediment fences and structural measures should be checked daily during construction, by the Construction Manager. Inspections will ensure the integrity of control structures and other structural measures. Additional inspections will be required immediately following periods of heavy rain. Sediment build-up is to be removed from behind the silt fences and other barriers immediately after each major rainfall event. All noted stormwater treatment devices within this report are to be inspected, maintained, rectified and reported on in accordance with Council's requirements. Refer to the *Water by Design Maintaining Vegetated Stormwater Assets Version 1 (February 2012)* manual for a guide.

5.6. Responsibility & Reporting

Performance monitoring of all drainage control measures along with erosion and sediment control devices will remain the responsibility of the contractor. Site inspection forms/checklists shall be reported to the Construction Manager following inspection of water quality devices/measures.

The contractor should erect signage at the entrance to the site with contact information (including after-hours contact information). The contractor shall be responsible for the appropriate handling of all complaints.

The contractor is to report on all stormwater quality treatment devices in accordance with Council's requirements. Refer to the *Water By Design Maintaining Vegetated Stormwater Assets Version 1, February (2012)* manual for a guide.

6. STORMWATER QUALITY MANAGEMENT PLAN – OPERATIONAL PHASE

6.1. Objectives

Water quality objectives for stormwater leaving the developed site under the operational phase are based on reductions in mean annual pollutant loads detailed in Section 13 of this report. Pollutant reduction values are outlined in Table 12.

Table 12- Operational (Permanent) Water Quality Objectives

Pollutant Indicator	Pollutant Reduction
Total Suspended Solids	85%
Total Phosphorous	60%
Total Nitrogen	45%
Gross Pollutants	90%

6.2. Performance Requirements

Performance requirements for the Management Plan are in accordance with Council and New South Wales Department of Environment Marine Water Quality Objectives, and notably the following:

- The reduction of dust and particulate matter being washed into the stormwater drainage system; and
- The prevention of hydrocarbons, nutrients, chemicals and heavy metals washed from the stormwater drainage system to the external catchment.

6.3. Management Measures

The majority of the site will either be sealed or landscaped following development. The amount of sediment likely to be generated by a mulched and watered landscape area is considered to be minimal.

Gross pollutants such as paper and plastic waste will be prevented from entering the stormwater drainage system by the installation of grates to all stormwater inlets.

All stormwater pipes will be fully sealed, and no contaminants will be able to enter the stormwater system from the roof catchment area or through infiltration into the stormwater pipes constructed below the ground.

Dust and particulate matter washed into the stormwater system will be reduced by regular sweeping and removal from car parking and vehicle service areas.

Dangerous goods will be stored in properly designed and constructed storage areas as required by the relevant statutory requirements.

All stormwater treatment devices noted within this report are to be inspected, maintained, rectified and reported on in accordance with Council Requirements Refer to the *Water By Design Maintaining Vegetated Stormwater Assets Version 1 (February 2012)* manual for a guide.

6.4. Monitoring & Maintenance

Table 13 and Appendix E outlines the required inspections and maintenance frequency for each stormwater treatment device. The site is believed to be within a “Temperate” area. Inspections and maintenance are to be carried out in accordance with Penrith City Council.

Table 13- Typical Maintenance Regime (Source: Water By Design Maintaining Vegetated Stormwater Assets Version 1, 2012)

ASSET TYPE	SUB-TROPICAL		TROPICAL		TEMPERATE
	Wet season	Dry season	Wet season	Dry season	
Swales	4 months*	4 months*	4 months*	4 months*	4 months*
Bioretention systems	2 months	4 months	2 months*	4 months	3 months
Constructed wetlands	2 months	3 months	1 month**	3 months	3 months
Sediment basins	2 months	3 months	1 month**	3 months	3 months

*Turf swales will require more frequent mowing

** For tropical climates, monthly inspections are required during the wet season due to the risk of noxious/declared weeds (e.g. Salvia and Para grass)

Refer to **Appendix E – Water Quality Inspection and Maintenance Schedule** for a sample maintenance and inspection procedure checklist for the proposed stormwater quality treatment devices detailed within this report.

6.5. Bio-Retention Monitoring & Maintenance

The proposed bio-retention basins detailed within the report are to be inspected, maintained, reported on and rectified in accordance with Council. Refer to the *Water by Design Maintaining Vegetated Stormwater Assets Version 1 (February 2012)* – Section 3.2, Bio-Retention Technical Design Guidelines Version 1, October 2012 and the Facility for Advanced Water Biofiltration Bio-Retention Maintenance Plan for guidance. The filter media located within each bio-retention basin is to be tested in accordance with the FAWB Practice Note 1: In Situ Monitoring of Hydraulic Conductivity (**See Appendix E**). The resulting filter media hydraulic conductivity is to be assessed against the FAWB recommended filter media hydraulic conductivity chart, shown in Figure 6.

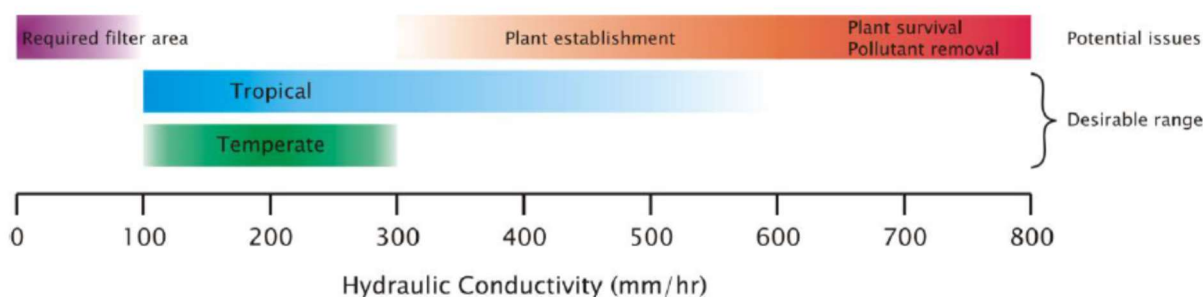


Figure 6- FAWB Recommended Filter Media Hydraulic Conductivity

In the event that the hydraulic conductivity for the filter media is not within the recommended range, the bio-retention system is to be rectified in accordance Council requirements.

6.5.1. *Maintenance of Raingarden*

In order for a raingarden to work properly, regular inspection and maintenance of its components must be undertaken. In general, a raingarden needs to be checked after a heavy rainfall for blockage or damage and at a minimum of every 3 months. A full inspection should also be carried out one year after construction and then annually.

The maintenance activities proposed in this plan are applicable after the establishment phase of the raingarden. The end of the raingarden's establishment phase can be defined as the time when the raingarden vegetation is suitably established. This would typically be expected 1 to 2 years following planting. Planting should be undertaken when the upstream catchment is fully developed and completely connected to the raingarden.

6.5.2. *Inspection & Maintenance Tasks*

Inspection and maintenance are to be conducted on a regular basis to ensure the raingarden functions as designed. Such checks should be carried out at least on a quarterly basis during the first few years of operating the raingarden. The inspection and maintenance tasks that need to be regularly undertaken to maintain the good condition and to ensure the operation of the raingarden can be grouped into the following categories:

- Filter Media;
- Horticultural; and
- Drainage.

The Inspection and Maintenance Schedule in Section 5 lists what needs to be done and how often they should be undertaken.

6.5.3. *Filter Media Monitoring & Field Testing*

In addition to the required inspection and maintenance tasks, the Facility for Advancing Water Biofiltration (FAWB) recommends field testing of the raingarden's filter media to be carried out at least twice. The first testing is to be conducted after one month following commencement of operation of the raingarden. The second is to be carried out during the second year of operation to assess the impact of vegetation on hydraulic conductivity.

After the second year, hydraulic testing should be undertaken every two years or when there has been a significant change in the catchment characteristics. In-situ hydraulic conductivity testing should be conducted in at least three evenly spaced locations for raingardens that have filter media area of less than 50m². Larger raingardens require additional testing locations for every 100m² of filter media. The in-situ hydraulic conductivity testing procedure is discussed in Practice Note 1: In-situ Measurement of Hydraulic Conductivity (FAWB 2008) included in **Appendix E**.

6.5.4. *Inspection & Maintenance Schedule*

The Inspection and Maintenance Schedule given in Table 15 a checklist in **Appendix F** has been provided to assist to inspection and maintenance of the raingarden. Inspection and maintenance of the raingarden will be the responsibility of developer/owners. All inspection and maintenance tasks should be undertaken by suitably qualified personnel.

6.5.5. *Workplace Health and Safety*

All raingarden maintenance activities shall be undertaken in a manner that minimises the workplace health and safety risk to maintenance personnel and the general health and safety of the public.

It is important that the maintenance staff:

- Comply with Council's Workplace Health and Safety (WH&S) policy and risk management processes;
- Have a thorough knowledge of the workplace, health and safety risks (i.e. able to identify and reduce any workplace hazards and risks) associated with maintenance activities (e.g. working in close proximity to traffic);
- Are equipped with adequate personal safety protection equipment; and
- Are aware of public health and safety risks associated with maintenance activities (e.g. undertaking maintenance activity during a significant rain event).

6.5.6. *The Developer's Responsibilities*

The developer will be responsible for all soil and water management until at least 12 months³ after more than 90 percent of a catchment is stabilised. Thereafter, any subdivision-scale water quality structure would be transferred to owners/ building management. A method of transfer is given in *Water by Design (2012a)*. A copy of this document is freely available from www.waterbydesign.com.au.

Although they may be built during the subdivision construction, the bioretention swales should not be activated until at least 90 percent of their catchment is stabilised (i.e. more than 90 percent is covered with hard surfaces or is vegetated). This is to prevent them from becoming clogged by excessive sediment.

6.5.7. *The Council's Responsibilities*

Council would ultimately become responsible for the trunk drainage of Railway Road. The bioretention swales would require ongoing maintenance under developer/owner responsibility. to the requirements of *Water by Design (2012b)*. A copy of this document is freely available from www.waterbydesign.com.au.

6.5.8. *The owners' Responsibilities*

The rainwater tank collection system (gutters, pipes, rainwater tanks, pumps and valves)/bio-retention basin and sediment basin would be maintained by owners committee/building management. They would require periodic inspection and maintenance, but the requirements are not great. Periodically all inlets, outlets and pumps for stability and operational performance should be inspected.

The tanks would be fitted with a back-flow prevention valve such that mains water can be used when the tank level falls below 5 percent. The valve must be checked annually by a registered plumber to the requirements of AS/NZS 2845.1:2010.

7. CONCLUSION

The proposed Stormwater Management Plan for 46-66 O'Connell Street Caddens consists of a conventional pit and pipe system to convey surface flows through the development to the bio-detention basins, water quality treatment and filtration devices. Detention is provided via five open bio-detention basins with a total volume of 3,133 m³ (2.5% of developed area).

Due to pollutant loads created by the development, water quality treatment is required to comply with council guidelines. A water quality treatment train has been provided to treat pollutant runoff before discharging into the downstream catchment. It is recommended that bio retention basins with total filter media area of 960 m² and a rainwater tank per lot to be installed to minimise the development potential impacts on water quality on the surrounding environment and to detain surface runoff back to pre-developed flows.

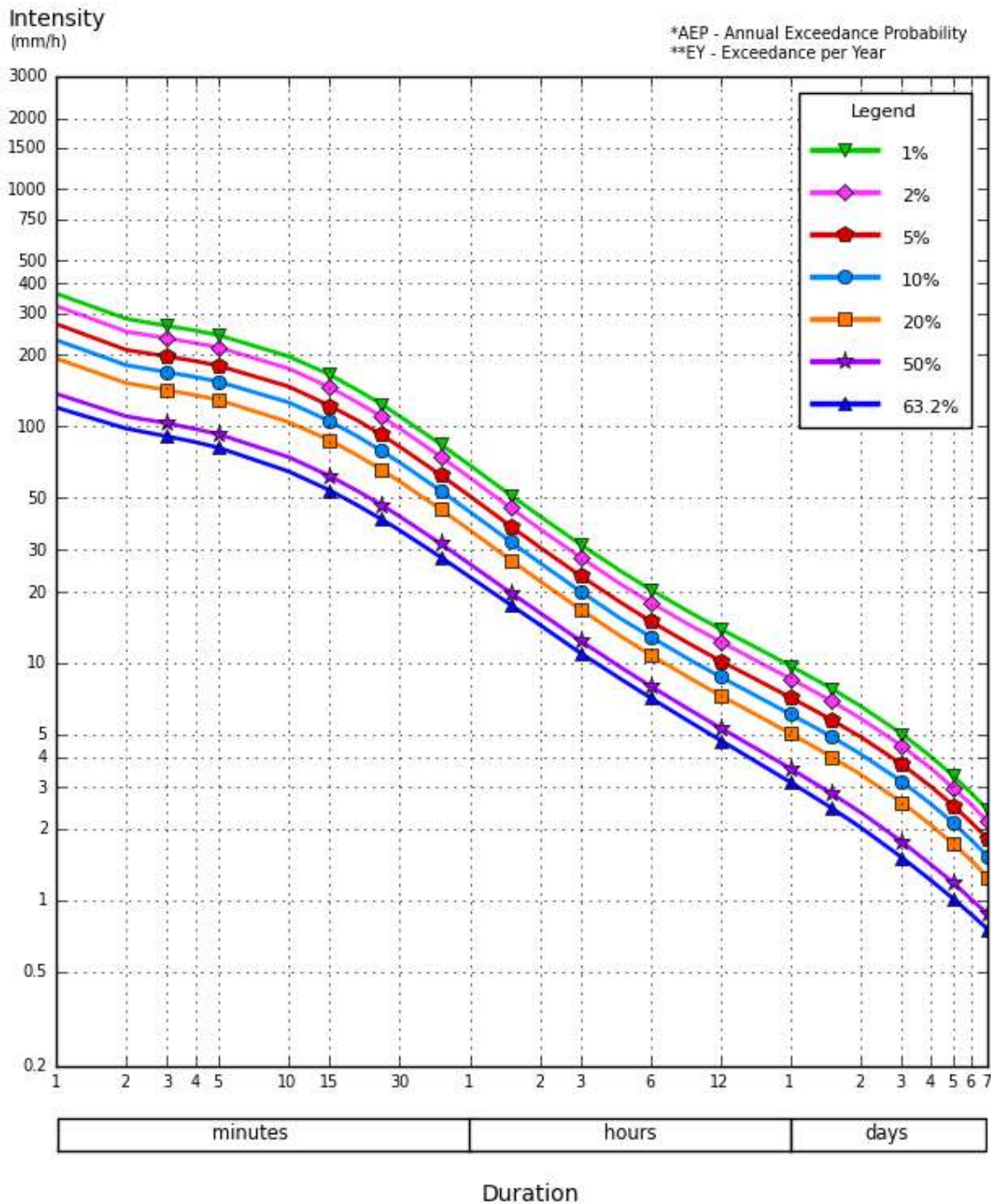
APPENDIX A IFD TABLE AND CHART

IFD Design Rainfall Intensity

Latitude: -33.25 33.2375 (S)
Longitude: 151.444 151.4375(E)]

Issued: 13 August 2020

Rainfall intensity (mm/h) for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).



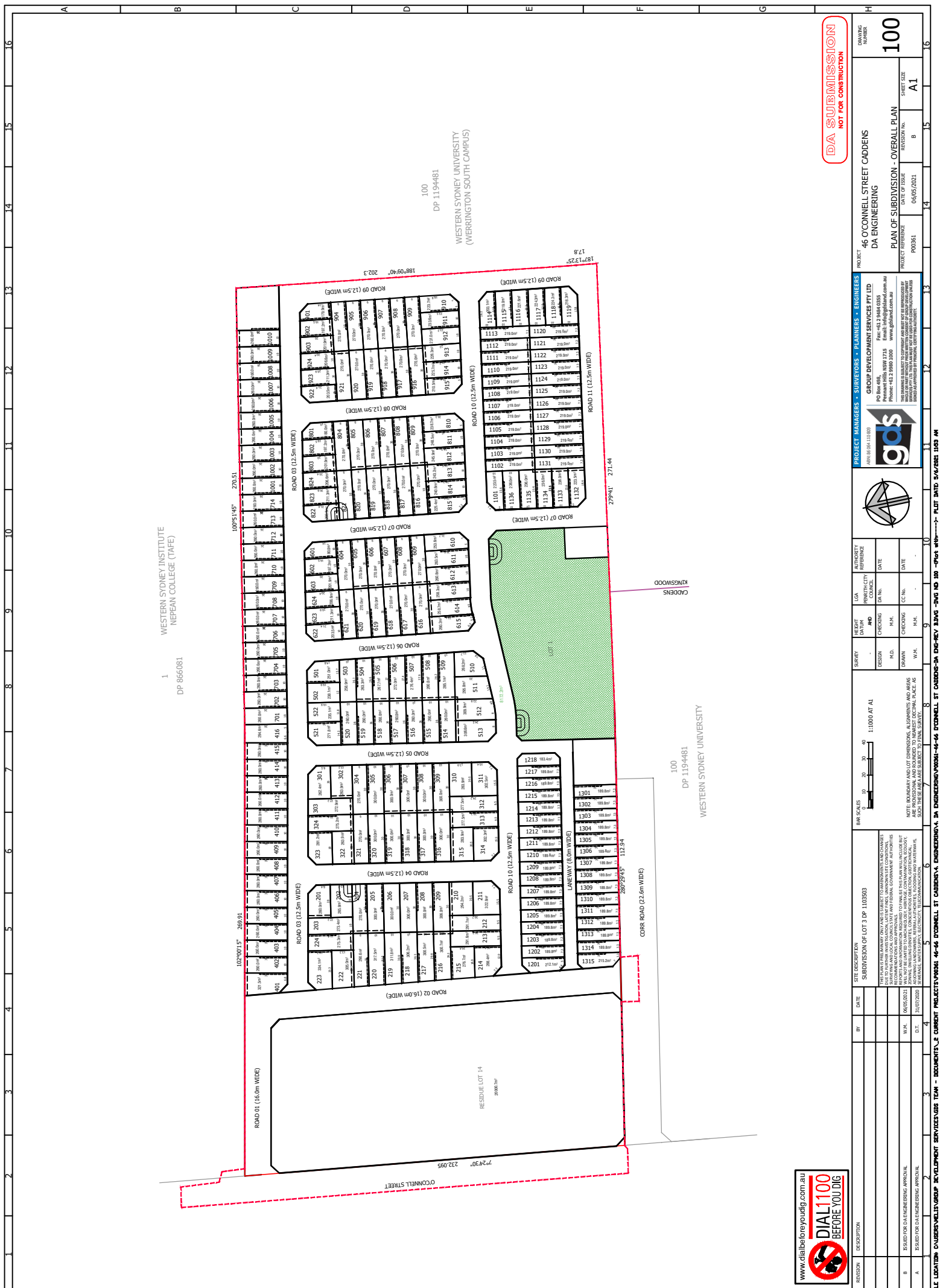
©Copyright Commonwealth of Australia 2016, Bureau of Meteorology (ABN 92 637 533 532)

Intensity-Frequency-Duration Table

Rainfall intensity in mm/hr for various duration and Average Recurrence Interval

Duration	Annual Exceedance Probability (AEP)						
	63.2%	50%#	20%*	10%	5%	2%	1%
1 min	120	137	193	231	270	322	363
2 min	97.7	110	152	181	210	251	284
3 min	90.6	103	142	169	197	235	265
4 min	85.5	97.1	135	161	188	224	253
5 min	81.1	92.4	129	154	180	215	242
10 min	64.4	74.0	104	126	147	175	197
15 min	53.6	61.6	87.2	105	122	146	165
20 min	46.0	52.9	74.7	89.9	105	125	141
25 min	40.5	46.5	65.5	78.8	92.0	110	124
30 min	36.3	41.6	58.4	70.2	81.9	97.8	110
45 min	28.0	31.9	44.5	53.4	62.2	74.3	83.8
1 hour	23.1	26.2	36.4	43.5	50.7	60.6	68.4
1.5 hour	17.6	19.8	27.2	32.5	37.8	45.2	51.1
2 hour	14.5	16.3	22.2	26.5	30.8	36.8	41.7
3 hour	11.0	12.4	16.8	20.0	23.3	27.9	31.6
4.5 hour	8.51	9.53	12.9	15.3	17.9	21.4	24.3
6 hour	7.12	7.98	10.8	12.9	15.0	18.0	20.4
9 hour	5.58	6.27	8.54	10.2	11.9	14.3	16.2
12 hour	4.71	5.31	7.29	8.73	10.2	12.3	13.9
18 hour	3.71	4.22	5.87	7.06	8.28	9.94	11.3
24 hour	3.13	3.58	5.03	6.07	7.14	8.58	9.70
30 hour	2.73	3.13	4.45	5.39	6.35	7.62	8.61
36 hour	2.44	2.81	4.01	4.88	5.75	6.90	7.79
48 hour	2.02	2.34	3.38	4.12	4.87	5.83	6.57
72 hour	1.51	1.76	2.58	3.16	3.74	4.47	5.02
96 hour	1.21	1.41	2.07	2.54	3.01	3.59	4.03
120 hour	1.01	1.18	1.72	2.11	2.50	2.97	3.33
144 hour	0.864	1.00	1.46	1.78	2.11	2.51	2.81
168 hour	0.754	0.873	1.25	1.53	1.82	2.15	2.41

APPENDIX B PLAN OF SUBDIVISION



WESTERN SYDNEY UNIVERSITY
(WERRINGTON SOUTH CAMPUS)

100
DP 1194481

WESTERN SYDNEY INSTITUTE
NEPEAN COLLEGE (TAPE)

1
DP 866081



DA SUBMISSION
NOT FOR CONSTRUCTION

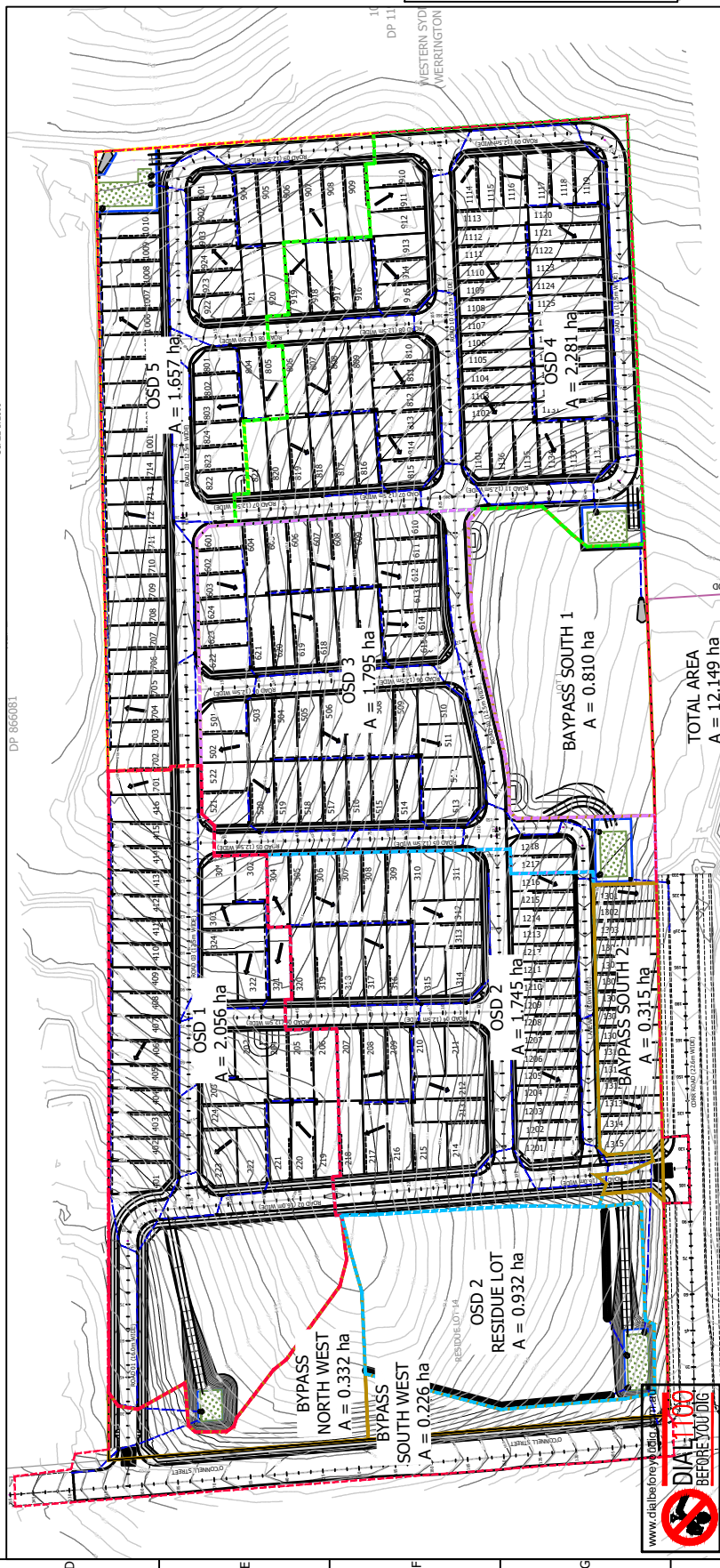
REVISION	DESCRIPTION	DATE	BY	SITE DESCRIPTION	SUBDIVISION OF LOT 3 DP 110393	BAR SCALES	1:1000 AT ALL	SURVEY	HEIGHT ADJUSTMENT	LOCALITY	AUTORITY RESPONSIBILITY	PROJECT MANAGERS - SURVEYORS - PLANNERS - ENGINEERS	PROJECT	DRAWING NUMBER
A	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021										GROUP DEVELOPMENT SERVICES PTY LTD PO Box 498, Penrith Hills NSW 2151 Phone: +61 2 9484 0355 Email: info@gsd.com.au Project No: 22902-2020 www.gsdltd.com.au	46 O'CONNELL STREET CADDENS DA ENGINEERING	100
B	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021											PLAN OF SUBDIVISION - OVERALL PLAN	
C	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021												
D	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021												
E	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021												
F	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021												
G	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021												
H	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021												

FILE LOCATION: CADDENS\NELS\GROUP DEVELOPMENT SERVICES\VIS TEAM - DOCUMENTS\CURRENT PROJECTS\PROJ-46-46 O'CONNELL ST CADDENS\DA ENGINEERING\PROJ-46-46 O'CONNELL ST CADDENS-DA ENG-REV-BUILDING-100 -PROJ-46-46-PLAN DATE 5/4/2021 10:58 AM

APPENDIX C CATCHMENT PLANS



PRE-DEVELOPMENT CATCHMENT PLAN
SCALE 1:2000



LEGEND

- LIMIT WORKS - CURRENT APPLICATION
- DESIGN CONTOUR - MAJOR
- DESIGN CONTOUR - MINOR
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- JUNCTION PIT
- GRADED INLET PIT
- KEB INLET PIT (ON GRADE)
- KEB INLET PIT (AT SAG)
- CATCHMENT BOUNDARY OSD 1
- CATCHMENT BOUNDARY OSD 2
- CATCHMENT BOUNDARY OSD 3
- CATCHMENT BOUNDARY OSD 4
- CATCHMENT BOUNDARY OSD 5
- CATCHMENT BOUNDARY BYPASS
- CONTOUR INTERVAL - 0.5m

DA SUBMISSION
NOT FOR CONSTRUCTION

PROJECT: 46 O'CONNELL STREET CADDENS
DA ENGINEERING
STORMWATER DRAINAGE CATCHMENT PLAN

GROUP DEVELOPMENT SERVICES PTY LTD
PO Box 984, Parramatta NSW 2150
Phone: +61 2 9484 0355
Email: info@groupds.com.au
Project No: GDS 2292 2/20
www.groupds.com.au

gds

PROJECT MANAGERS • SURVEYORS • PLANNERS • ENGINEERS

REVISION	DESCRIPTION	DATE	BY	DATE	DESCRIPTION
A	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021			
B	ISSUED FOR DA ENGINEERING APPROVAL	06/05/2021			

NOTE: BOUNDARY AND LOT DIMENSIONS, ALIGNMENTS AND AREAS ARE PROFESSIONAL AND SHOWN TO NEAREST DECIMAL PLACE AS SHOWN. THESE ARE APPROXIMATE DIMENSIONS AND ARE NOT TO BE USED FOR CONSTRUCTION PURPOSES.

DATE: 31/07/2020

SCALE: 1:2000 AT A1

SCALE: 1:1000 AT A1

BAR SCALES

0 10 20 30 40 50 60 70 80 90 100

0 10 20 30 40 50 60 70 80 90 100

0 10 20 30 40 50 60 70 80 90 100

0 10 20 30 40 50 60 70 80 90 100

APPENDIX D MUSICLINK REPORT

MUSIC-*link* Report

Project Details		Company Details	
Project:	Stormwater Quality (WSUD) assessment Report 46-66 O'Connell St Caddens	Company:	Group Development Services (GDS)
Report Export Date:	4/05/2021	Contact:	Melissa Diaz
Catchment Name:	P00361 - O'Connell St -MM- MUSIC Model [01]	Address:	
Catchment Area:	11.978ha	Phone:	02-99801000
Impervious Area*:	64.88%	Email:	melissa@gdsland.com.au
Rainfall Station:	67113 PENRITH		
Modelling Time-step:	6 Minutes		
Modelling Period:	1/01/1999 - 31/12/2008 11:54:00 PM		
Mean Annual Rainfall:	691mm		
Evapotranspiration:	1158mm		
MUSIC Version:	6.3.0		
MUSIC-link data Version:	6.33		
Study Area:	Penrith		
Scenario:	Penrith Development		

* takes into account area from all source nodes that link to the chosen reporting node, excluding Import Data Nodes

Treatment Train Effectiveness		Treatment Nodes		Source Nodes	
Node: Post-Development Node	Reduction	Node Type	Number	Node Type	Number
Flow	4.4%	Rain Water Tank Node	5	Urban Source Node	28
TSS	85.1%	Bio Retention Node	5		
TP	68.3%				
TN	53.3%				
GP	96.7%				

Comments

NOTE: A successful self-validation check of your model does not constitute an approved model by Penrith City Council
MUSIC-*link* now in MUSIC by eWater – leading software for modelling stormwater solutions

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Bio	Cat1 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat1 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat2 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat2 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat3 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat3 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat4 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat4 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat5 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat5 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Post	Post-Development Node	% Load Reduction	None	None	4.4
Post	Post-Development Node	GP % Load Reduction	90	None	96.7
Post	Post-Development Node	TN % Load Reduction	45	None	53.3
Post	Post-Development Node	TP % Load Reduction	60	None	68.3
Post	Post-Development Node	TSS % Load Reduction	85	None	85.1
Rain	Cat1 - Rainwater Tank	% Reuse Demand Met	80	None	100
Rain	Cat2 - Rainwater Tank	% Reuse Demand Met	80	None	100
Rain	Cat3 - Rainwater Tank	% Reuse Demand Met	80	None	100
Rain	Cat4 - Rainwater Tank	% Reuse Demand Met	80	None	100
Rain	Cat5 - Rainwater Tank	% Reuse Demand Met	80	None	100
Urban	Baypass South 2 (0.315 ha)	Area Impervious (ha)	None	None	0.077
Urban	Baypass South 2 (0.315 ha)	Area Pervious (ha)	None	None	0.237
Urban	Baypass South 2 (0.315 ha)	Total Area (ha)	None	None	0.315
Urban	Bypass South 1 (0.810 ha)	Area Impervious (ha)	None	None	0.041
Urban	Bypass South 1 (0.810 ha)	Area Pervious (ha)	None	None	0.768
Urban	Bypass South 1 (0.810 ha)	Total Area (ha)	None	None	0.81
Urban	Bypass South West (0.226 ha)	Area Impervious (ha)	None	None	0.011
Urban	Bypass South West (0.226 ha)	Area Pervious (ha)	None	None	0.214
Urban	Bypass South West (0.226 ha)	Total Area (ha)	None	None	0.226
Urban	Ca3 - Lot area (0.491 ha)	Area Impervious (ha)	None	None	0.2455
Urban	Ca3 - Lot area (0.491 ha)	Area Pervious (ha)	None	None	0.2455
Urban	Ca3 - Lot area (0.491 ha)	Total Area (ha)	None	None	0.491
Urban	Ca3 - Road (0.495 ha)	Area Impervious (ha)	None	None	0.471
Urban	Ca3 - Road (0.495 ha)	Area Pervious (ha)	None	None	0.023
Urban	Ca3 - Road (0.495 ha)	Total Area (ha)	None	None	0.495
Urban	Ca3 - Roof Bypass RWT (0.368 ha)	Area Impervious (ha)	None	None	0.368
Urban	Ca3 - Roof Bypass RWT (0.368 ha)	Area Pervious (ha)	None	None	0
Urban	Ca3 - Roof Bypass RWT (0.368 ha)	Total Area (ha)	None	None	0.368
Urban	Ca3 - Roof to RWT (0.368 ha)	Area Impervious (ha)	None	None	0.368
Urban	Ca3 - Roof to RWT (0.368 ha)	Area Pervious (ha)	None	None	0

Only certain parameters are reported when they pass validation

NOTE: A successful self-validation check of your model does not constitute an approved model by Penrith City Council
MUSIC-*link* now in MUSIC by eWater – leading software for modelling stormwater solutions

Node Type	Node Name	Parameter	Min	Max	Actual
Urban	Ca3 - Roof to RWT (0.368 ha)	Total Area (ha)	None	None	0.368
Urban	Cat 1 - B2 Bypass Treatment (0.296 ha)	Area ImperVIOUS (ha)	None	None	0.015
Urban	Cat 1 - B2 Bypass Treatment (0.296 ha)	Area PervIOUS (ha)	None	None	0.280
Urban	Cat 1 - B2 Bypass Treatment (0.296 ha)	Total Area (ha)	None	None	0.296
Urban	Cat 2 - Bypass Treatment (0.035 ha)	Area ImperVIOUS (ha)	None	None	0.001
Urban	Cat 2 - Bypass Treatment (0.035 ha)	Area PervIOUS (ha)	None	None	0.033
Urban	Cat 2 - Bypass Treatment (0.035 ha)	Total Area (ha)	None	None	0.035
Urban	Cat1 - Lot area (.385 ha)	Area ImperVIOUS (ha)	None	None	0.192
Urban	Cat1 - Lot area (.385 ha)	Area PervIOUS (ha)	None	None	0.192
Urban	Cat1 - Lot area (.385 ha)	Total Area (ha)	None	None	0.385
Urban	Cat1 - Residue area/Batter (0.513 ha)	Area ImperVIOUS (ha)	None	None	0.024
Urban	Cat1 - Residue area/Batter (0.513 ha)	Area PervIOUS (ha)	None	None	0.488
Urban	Cat1 - Residue area/Batter (0.513 ha)	Total Area (ha)	None	None	0.513
Urban	Cat1 - Road (0.569 ha)	Area ImperVIOUS (ha)	None	None	0.541
Urban	Cat1 - Road (0.569 ha)	Area PervIOUS (ha)	None	None	0.027
Urban	Cat1 - Road (0.569 ha)	Total Area (ha)	None	None	0.569
Urban	Cat1 - Road Bypass Treatment (0.036 ha)	Area ImperVIOUS (ha)	None	None	0.034
Urban	Cat1 - Road Bypass Treatment (0.036 ha)	Area PervIOUS (ha)	None	None	0.001
Urban	Cat1 - Road Bypass Treatment (0.036 ha)	Total Area (ha)	None	None	0.036
Urban	Cat1 - Roof Bypass RWT (0.289 ha)	Area ImperVIOUS (ha)	None	None	0.289
Urban	Cat1 - Roof Bypass RWT (0.289 ha)	Area PervIOUS (ha)	None	None	0
Urban	Cat1 - Roof Bypass RWT (0.289 ha)	Total Area (ha)	None	None	0.289
Urban	Cat1 - Roof to RWT (0.289 ha)	Area ImperVIOUS (ha)	None	None	0.289
Urban	Cat1 - Roof to RWT (0.289 ha)	Area PervIOUS (ha)	None	None	0
Urban	Cat1 - Roof to RWT (0.289 ha)	Total Area (ha)	None	None	0.289
Urban	Cat2 - Lot area (0.455 ha)	Area ImperVIOUS (ha)	None	None	0.2275
Urban	Cat2 - Lot area (0.455 ha)	Area PervIOUS (ha)	None	None	0.2275
Urban	Cat2 - Lot area (0.455 ha)	Total Area (ha)	None	None	0.455
Urban	Cat2 - Residue area/Batter (0.907)	Area ImperVIOUS (ha)	None	None	0.043
Urban	Cat2 - Residue area/Batter (0.907)	Area PervIOUS (ha)	None	None	0.863
Urban	Cat2 - Residue area/Batter (0.907)	Total Area (ha)	None	None	0.907
Urban	Cat2 - Road (0.608 ha)	Area ImperVIOUS (ha)	None	None	0.578
Urban	Cat2 - Road (0.608 ha)	Area PervIOUS (ha)	None	None	0.029
Urban	Cat2 - Road (0.608 ha)	Total Area (ha)	None	None	0.608
Urban	Cat2 - Roof Bypass RWT (0.341 ha)	Area ImperVIOUS (ha)	None	None	0.341
Urban	Cat2 - Roof Bypass RWT (0.341 ha)	Area PervIOUS (ha)	None	None	0
Urban	Cat2 - Roof Bypass RWT (0.341 ha)	Total Area (ha)	None	None	0.341
Urban	Cat2 - Roof to RWT (0.341 ha)	Area ImperVIOUS (ha)	None	None	0.341
Urban	Cat2 - Roof to RWT (0.341 ha)	Area PervIOUS (ha)	None	None	0
Urban	Cat2 - Roof to RWT (0.341 ha)	Total Area (ha)	None	None	0.341

Only certain parameters are reported when they pass validation

NOTE: A successful self-validation check of your model does not constitute an approved model by Penrith City Council
MUSIC-*link* now in MUSIC by eWater – leading software for modelling stormwater solutions

Node Type	Node Name	Parameter	Min	Max	Actual
Urban	Cat4 - Lot area (0.581 ha)	Area Impervious (ha)	None	None	0.2905
Urban	Cat4 - Lot area (0.581 ha)	Area Pervious (ha)	None	None	0.2905
Urban	Cat4 - Lot area (0.581 ha)	Total Area (ha)	None	None	0.581
Urban	Cat4 - Road (0.788 ha)	Area Impervious (ha)	None	None	0.750
Urban	Cat4 - Road (0.788 ha)	Area Pervious (ha)	None	None	0.037
Urban	Cat4 - Road (0.788 ha)	Total Area (ha)	None	None	0.788
Urban	Cat4 - Roof Bypass RWT (0.436 ha)	Area Impervious (ha)	None	None	0.436
Urban	Cat4 - Roof Bypass RWT (0.436 ha)	Area Pervious (ha)	None	None	0
Urban	Cat4 - Roof Bypass RWT (0.436 ha)	Total Area (ha)	None	None	0.436
Urban	Cat4 - Roof to RWT (0.436 ha)	Area Impervious (ha)	None	None	0.436
Urban	Cat4 - Roof to RWT (0.436 ha)	Area Pervious (ha)	None	None	0
Urban	Cat4 - Roof to RWT (0.436 ha)	Total Area (ha)	None	None	0.436
Urban	Cat5 - Lot area (0.443 ha)	Area Impervious (ha)	None	None	0.2215
Urban	Cat5 - Lot area (0.443 ha)	Area Pervious (ha)	None	None	0.2215
Urban	Cat5 - Lot area (0.443 ha)	Total Area (ha)	None	None	0.443
Urban	Cat5 - Road (0.493 ha)	Area Impervious (ha)	None	None	0.469
Urban	Cat5 - Road (0.493 ha)	Area Pervious (ha)	None	None	0.023
Urban	Cat5 - Road (0.493 ha)	Total Area (ha)	None	None	0.493
Urban	Cat5 - Roof Bypass RWT (0.332 ha)	Area Impervious (ha)	None	None	0.332
Urban	Cat5 - Roof Bypass RWT (0.332 ha)	Area Pervious (ha)	None	None	0
Urban	Cat5 - Roof Bypass RWT (0.332 ha)	Total Area (ha)	None	None	0.332
Urban	Cat5 - Roof to RWT (0.332 ha)	Area Impervious (ha)	None	None	0.332
Urban	Cat5 - Roof to RWT (0.332 ha)	Area Pervious (ha)	None	None	0
Urban	Cat5 - Roof to RWT (0.332 ha)	Total Area (ha)	None	None	0.332

Only certain parameters are reported when they pass validation

APPENDIX E THE INSPECTION AND MAINTENANCE SCHEDULE

Table 1- Inspection and Maintenance Schedule

Bio-retention Element	Potential Concerns	Inspection	Frequency	Maintenance Required
FILTER MEDIA TASKS				
Filter Media	Sediment deposition	Check for accumulation of sediments near inlets.	4 times per year and after all major storm events	Remove sediment build-up from inlet areas.
Filter Media	Holes or scour	Check for holes, erosion and scour.	4 times per year and after all major storm events	Infill any holes in the filter media. Provide energy dissipation (e.g. rocks and pebbles at inlet) if necessary.
Filter Media	Filter media surface porosity	Inspect for the accumulation of an impermeable layer (such as oily or clayey sediment) that may have formed on the surface of the filter media. A symptom may be that water remains ponded in the Bio-retention for more than a few hours after a rain event.	4 times per year and after all major storm events	Repair minor accumulations by raking away any mulch on the surface and scarifying the surface of the filter media between plants.
Filter Media	Litter control	Check for litter (including organic litter e.g. mulching, decaying leaves) in and around treatment areas.	4 times per year and after all major storm events	Remove both organic and anthropogenic litter to ensure flow paths and infiltration through the filter media are not hindered.
HORTICULTURAL TASKS				
Turf/grass	Pests and diseases	Assess plants for disease, pest infection, stunted growth or senescent (i.e. ageing) grass.	4 times per year and after all major storm events	Treat or replace as necessary. Any noticeable issues with the grass should be referred to an appropriate landscape architect and/or ecologist.
Turf/grass	mowing of the Bio-retention's grass	Reduced gross density.	4 times per year and after all major storm events	If mowing occurs during the wet season the clippings should be collected to prevent mobilisation by subsequent rain events. Care should be taken to prevent rutting when mowing the Bio-retention if it is wet.

Bio-retention Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Bio-retention Surface Layer	Weeds	It is important to identify the presence of any rapidly spreading weeds as they occur. The presence of such weeds can reduce dominant species distribution and diminish aesthetics. Weed species can also compromise the system's long-term performance.	4 times per year and after all major storm events	Inspect for and manually remove weed species. Application of herbicide should be limited to a wand or restrictive spot spraying due to the fact that Bio-retentions directly drain to downstream watercourses.
Bio-retention Surface Layer	Lack of water	Check for turf condition (e.g. stunted growth, unhealthy appearance). Filter media could also reveal flaking or cracks.	4 times per year and in dry season	Irrigate following extended dry periods.
DRAINAGE TASKS				
Subsoil Drainage	Inefficient operation of subsoil drainage due to Blockage	Ensure that perforated pipes are not blocked to prevent filter media and plants from becoming waterlogged. A small steady clear flow of water may be observed discharging from the perforated pipe at its connection into the downstream pit some hours after rainfall. Note that smaller rainfall events after dry weather may be completely absorbed by the filter media and not result in flow. Remote camera (e.g. CCTV) inspection of pipelines for blockage and structural integrity could be useful.	2-3 times per year and after all major storm events	Rod and flush subsoil drainage lines to prevent build-up of sediment.
OSD TANKS Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Outlet	Accumulation of sediments in the Input/ Output Pits	Check for build-up of sediments and litter inside pit. Check condition of pit lid.	2-3 times per year and after all major storm events	Accumulated sediments and debris to be removed in order for the systems to function.

APPENDIX F IN SITU MONITORING OF HYDRAULIC CONDUCTIVITY

CONDITION ASSESSMENT AND PERFORMANCE EVALUATION OF BIORETENTION SYSTEMS

PRACTICE NOTE 1: *In Situ* Measurement of Hydraulic Conductivity

Belinda Hatt, Sebastien Le Coustumer

April 2008

The Facility for Advancing Water Biofiltration (FAWB) aims to deliver its research findings in a variety of forms in order to facilitate widespread and successful implementation of biofiltration technologies. This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is the first in a series of Practice Notes being developed to assist practitioners with the assessment of construction and operation of biofiltration systems.

Disclaimer: Information contained in this Practice Note is believed to be correct at the time of publication, however neither the Facility for Advancing Water Biofiltration nor its industry partners accept liability for any loss or damage resulting from its use.

1. SCOPE OF THE DOCUMENT

This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is designed to complement FAWB's Guidelines for Soil Filter Media in Bioretention Systems, Version 2.01 (visit <http://www.monash.edu.au/fawb/publications/index.html> for a copy of these guidelines). However, the recommendations contained within this document are more widely applicable to assessing the hydraulic conductivity of filter media in existing biofiltration systems.

For new systems, this Practice Note **does not** remove the need to conduct laboratory testing of filter media prior to installation.

2. DETERMINATION OF HYDRAULIC CONDUCTIVITY

The recommended method for determining *in situ* hydraulic conductivity uses a single ring infiltrometer under constant head. The single ring infiltrometer consists of a small plastic or metal ring that is driven 50 mm into the soil filter media. It is a constant head test that is conducted for two different pressure heads (50 mm and 150 mm). The head is kept constant during all the experiments by pouring water into the ring. The frequency of readings of the volume poured depends on the filter media, but typically varies from 30 seconds to 5 minutes. The experiment is stopped when the infiltration rate is considered steady (i.e., when the volume poured per time interval remains constant for at least 30 minutes). This method has been used extensively (e.g. Reynolds and Elrick, 1990; Youngs *et al.*, 1993).

Note: This method measures the hydraulic conductivity at the surface of the soil filter media. In most cases, it is this top layer which controls the hydraulic conductivity of the system as a whole (i.e., the underlying drainage layer has a flow capacity several orders of magnitude higher than the filter media), as it is this layer where fine sediment will generally be deposited to form a "clogging layer". However this shallow test would not be appropriate for systems where the controlling layer

is not the surface layer (e.g. where migration of fine material down through the filter media has caused clogging within the media). In this case, a ‘deep ring’ method is required; for further information on this method, please consult FAWB’s report “Hydraulic performance of biofilter systems for stormwater management: lessons from a field study”, available at www.monash.edu.au/fawb/publications/index.html.

2.1 Selection of monitoring points

For bioretention systems with a surface area less than 50 m², *in situ* hydraulic conductivity testing should be conducted at three points that are spatially distributed (Figure 1). For systems with a surface area greater than 50 m², an extra monitoring point should be added for every additional 100 m². It is **essential** that the monitoring point is flat and level. Vegetation should not be included in monitoring points.



Figure 1. Spatially distributed monitoring points

2.2 Apparatus

The following is required:

- 100 mm diameter PVC rings with a height of at least 220 mm. The bottom edge of the ring should be bevelled and the inside of the ring should be marked to indicate 50 mm and 150 mm above the filter media surface (Figure 2).
- 40 L water
- 100 mL, 250 mL and 1000 mL measuring cylinders
- Stopwatch
- Thermometer

- Measuring tape
- Spirit level
- Hammer
- Block of wood, approximately 200 x 200 mm

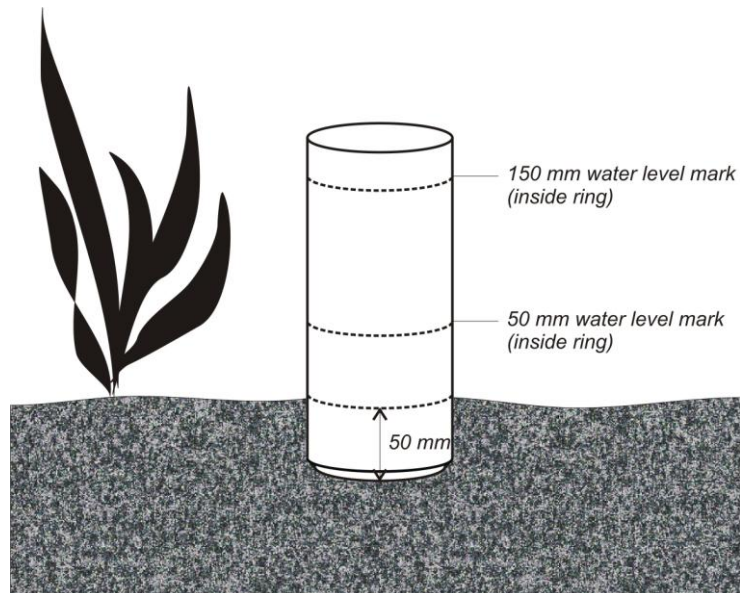


Figure 2. Diagram of single ring infiltrometer

2.3 Procedure

- Carefully scrape away any surface covering (e.g. mulch, gravel, leaves) **without disturbing** the soil filter media surface (Figure 3b).
- Locate the ring on the surface of the soil (Figure 3c), and then place the block of wood on top of the ring. Gently tap with the hammer to drive the ring 50 mm into the filter media (Figure 3d). Use the spirit level to check that the ring is level.

Note: It is **essential** that this the ring is driven in slowly and carefully to minimise disturbance of the filter media profile.

- Record the initial water temperature.
- Fill the 1000 mL measuring cylinder.
- Using a different pouring apparatus, slowly fill the ring to a ponding depth of 50 mm, taking care to minimise disturbance of the soil surface (Figure 3f). Start the stopwatch when the water level reaches 50 mm.
- Using the 1000 mL measuring cylinder, maintain the water level at 50 mm (Figure 3g). After 30 seconds, record the volume poured.
- Maintain the water level at 50 mm, recording the time interval and volume required to do so.

Note: The time interval between recordings will be determined by the infiltration capacity of the filter media. For fast draining media, the time interval should not be greater than one minute however, for slow draining media, the time between recordings may be up to five minutes.

Note: The smallest measuring cylinder that can pour the volume required to maintain a constant water level for the measured time interval should be used for greater accuracy. For example, if the volume poured over one minute is 750 mL, then the 1000 mL measuring cylinder should be used. Similarly, if the volume poured is 50 mL, then the 100 mL measuring cylinder should be used.

- h. Continue to repeat Step f until the infiltration rate is steady i.e., the volume poured per time interval remains constant for at least 30 minutes.
- i. Fill the ring to a ponding depth of 150 mm (Figure 3h). Restart the stopwatch. Repeat steps e – g for this ponding depth.

Note: Since the filter media is already saturated, the time required to reach steady infiltration should be less than for the first ponding depth.

- j. Record the final water temperature.
- k. Enter the temperature, time, and volume data into a calculation spreadsheet (see “Practice Note 1_Single Ring Infiltration Test_Example Calculations.xls”, available at www.monash.edu.au/fawb/publications/index.html, as an example).

2.4 Calculations

In order to calculate K_{fs} a ‘Gardner’s’ behaviour for the soil should be assumed (Gardner, 1958 in Youngs *et al.*, 1993):

$$K(h) = K_{fs} e^{\alpha h} \quad \text{Eqn. 1}$$

where K is the hydraulic conductivity, α is a soil pore structure parameter (large for sands and small for clay), and h is the negative pressure head. K_{fs} is then found using the following analytical expression (for a steady flow) (Reynolds and Elrick, 1990):

$$K_{fs} = \frac{G}{a} \left(\frac{Q_2 - Q_1}{H_2 - H_1} \right) \quad \text{Eqn. 2}$$

where a is the ring radius, H_1 and H_2 are the first (50 mm) and second (150 mm) pressure heads, respectively, Q_1 and Q_2 are the steady flows for the first and second pressure heads, respectively, and G is a shape factor estimated as:

$$G = 0.316 \frac{d}{a} + 0.184 \quad \text{Eqn. 3}$$

where d is the depth of insertion of the ring and a is the ring radius.

G is nearly independent of soil hydraulic conductivity (i.e. K_{fs} and α) and ponding, if the ponding is greater than 50 mm.

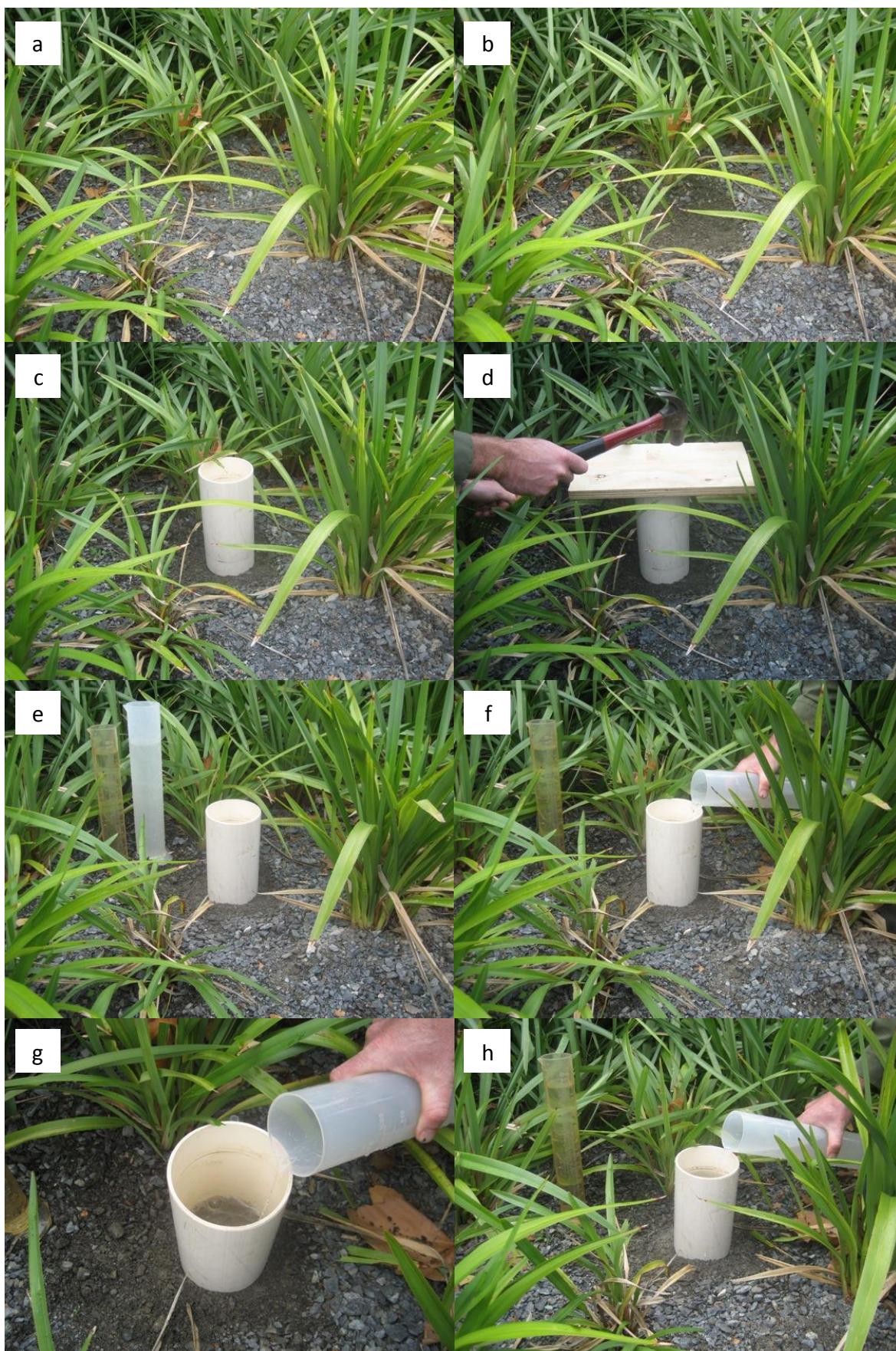


Figure 3. Measuring hydraulic conductivity

The possible limitations of the test are (Reynolds *et al.*, 2000): (1) the relatively small sample size due to the size of the ring, (2) soil disturbance during installation of the ring (compaction of the soil), and (3) possible edge flow during the experiments.

3 INTERPRETATION OF RESULTS

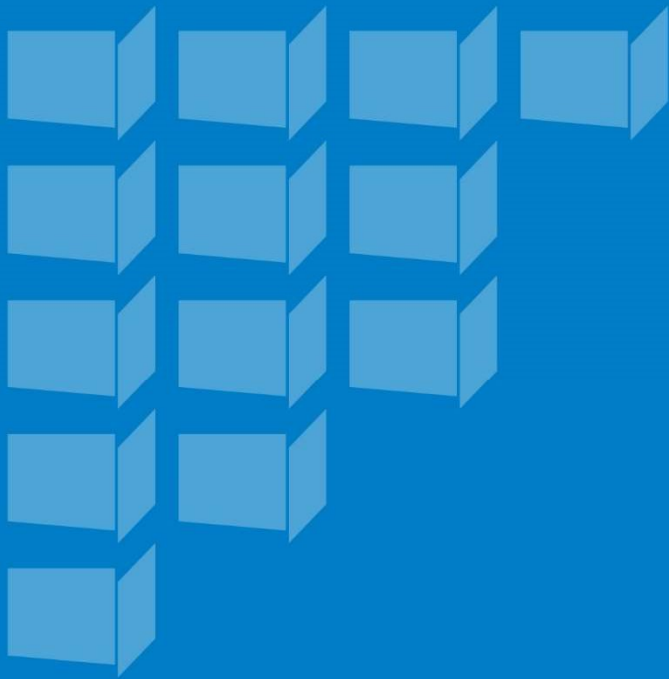
This test method has been shown to be relatively comparable to laboratory test methods (Le Coustumer *et al.*, 2008), taking into account the inherent variability in hydraulic conductivity testing and the heterogeneity of natural soil-based filter media. While correlation between the two test methods is low, results are not statistically different. In light of this, laboratory and field results are deemed comparable if they are within 50% of each other. In the same way, replicate field results are considered comparable if they differ by less than 50%. Where this is not the case, this is likely to be due to a localised inconsistency in the filter media, therefore additional measurement should be conducted at different monitoring points until comparable results are achieved. If this is not achieved, then an area-weighted average value may need to be calculated.

4 MONITORING FREQUENCY

Field testing of hydraulic conductivity should be carried out at least twice: (1) One month following commencement of operation, and (2) In the second year of operation to assess the impact of vegetation on hydraulic conductivity. Following this, hydraulic conductivity testing should be conducted every two years or when there has been a significant change in catchment characteristics (e.g., construction without appropriate sediment control).

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