Water Sensitive Urban Design for the Coastal Dry Tropics (Townsville): Design Objectives for Stormwater Management

Prepared for
Townsville City Council

Prepared by
AECOM + McGarry and Eadie

April 2011

This publication was funded by the former Townsville and Thuringowa City Councils, the Queensland Environmental Protection Agency and the Australian Government's Coastal Catchment Initiative through the Department of Environment, Water, Heritage and the Arts.

Report Title	Water Sensitive Urban Design for the Coastal Dry Tropics (Townsville): Design Objectives for Stormwater Management	
Revision	FINAL V01	
Author(s)	Malcolm Eadie	
Approved by	Malcolm Eadie	
Date	April 2011	
Distribution	Electronic Copies to: Townsville City Council	

Table of Contents

1 Introduction

The operational phase WSUD stormwater management design objectives for the Dry Tropics described herein have been derived using the same methods employed by the Queensland Department of Environment and Resource Management (DERM) to establish stormwater management design objectives for protection and enhancement of waterway health for all of Queensland Waters, as described in the new State Planning Policy 4/10 Healthy Waters.

The new SPP 4/10 and its associated guideline and supporting instruments describe the new standards for stormwater management in Queensland to protect and enhance waterway health. This report serves to provide a more detailed description of the technical studies undertaken to derive the operational phase stormwater management objectives for the Dry Tropics region.

The operational phase stormwater management design objectives described herein are intended for application within urban developments throughout the Dry Tropics in accordance with the developments types to which the SPP 4/10 applies. The operational phase stormwater management design objectives focus on stormwater management requirements for the protection of waterway health. Other stormwater management design objectives relating to the construction phase of urban development and for drainage and flooding are not covered here but are nonetheless still important and are intended to apply in concert with the operational phase stormwater management design objectives for waterway health.

2 Stormwater Quality Management Design Objectives

In the past Councils in Queensland have tended to adopt concentration based stormwater management design objectives to regulate urban stormwater discharges to receiving waters. This was done to achieve consistency with the concentration based water quality objectives (WQOs) scheduled in the Environmental Protection (Water) Policy 2009. The new State Planning Policy 4/10 Healthy Waters however recognises that achieving pollutant load reduction targets for urban stormwater runoff based on the principles of 'best practice management' and 'adaptive management' is an acceptable and appropriate means of managing urban stormwater quality for the protection of Environmental Values (EV's) for Queensland waters.

Achieving best practice pollutant load reduction targets has been shown in other parts of Queensland (i.e. South East Queensland) to achieve stormwater discharge concentrations commensurate with the receiving water WQOs scheduled in the EPP (Water), albeit not always in absolute compliance. Notwithstanding, it is now understood and accepted that the scheduled WQOs in the EPP (Water) are derived from ambient (dry weather) condition monitoring of reference streams and thus do not fully account for the higher concentrations observed in periods of wet weather flows (i.e. when most stormwater runoff is generated). Therefore, the scheduled WQO's cannot be applied directly to stormwater runoff as a compliance standard. Factors such as dilution through the mixing of stormwater inputs within a receiving water as well as the in-stream nutrient processing capacity (assimilation capacity) of the receiving waterway further adds to the difficulties in applying the scheduled WQOs as stormwater discharge targets.

Pollutant load reduction objectives also overcome some of the ambiguities, and thus misuse, of concentration based urban stormwater quality management objectives. For example, a typical approach used by councils for setting concentration based stormwater quality management objectives is to set a target median (50th percentile) pollutant concentration. However, stormwater runoff is highly ephemeral with "zero" flow for a substantial proportion of the time. The definition of the median concentration is therefore ambiguous in this instance. This ambiguity is commonly resolved by taking the median concentration during periods when flow is non-zero. However, since demonstration of compliance of a proposed stormwater management system relies on numerical modelling, the median concentration can be highly sensitive to the adopted model parameters. For example, adjusting model parameters to generate a long period of very low baseflow can make it easier for development proponents to demonstrate compliance with the target median concentrations, while the majority of pollutant load and the higher concentrations are actually discharged during events.

For the reasons outlined above, and for consistency with the new SPP 4/10, best practice pollutant load reduction targets are recommended for the Dry Tropics.

2.1 Best Practice Pollutant Load Reduction Targets for use in the Dry Tropics

The recommended best practice pollutant load reduction targets for the Dry Tropics are shown in Table 2.1 and represent minimum required reductions in the average annual pollutant loads generated from an unmitigated development.

Table 2.1 Recommended Pollutant Load Reduction Targets for Dry Tropics

Region	**[1]Minimum reduction in mean annual pollutant loads from unmitigated development (%)**			
	Suspended solids (TSS)	**Total phosphorus (TP)**	**Total nitrogen (TN)**	**Gross Pollutants > 5mm**
Dry Tropics	80	65	40	90

The pollutant load reduction targets in Table 2.1 do not relate to the maintenance of pollutant loads generated from pre-developed land uses but rather reflect the level of pollutant removal that can be reasonably expected to be achieved from the adoption of current best practice stormwater management infrastructure operating within new developments. Best practice in this instance refers to stormwater quality management infrastructure designed and constructed to [2]contemporary design standards and sized to operate at the technology's reasonable limit of economic performance as defined by the 'point of diminishing return' on treatment performance curves derived from predictive modelling (refer to Appendix A).

In addition to the adoption of best practice, two other principles underpin the recommended pollutant load reduction targets for the Dry Tropics. These are:

- The targets need to be applicable to a wide range of typical urban development types;
- The targets need to be achievable by at least two best practice 'treatment train' solutions; and

With regard to second of these underpinning principles, ensuring at least two design solutions are available to attain compliance with the targets provides a degree of design flexibility and makes allowance for situations where physical site conditions may preclude the use of a particular stormwater treatment technology.

In contemporary urban stormwater management practice two technologies tend to dominate the management of suspended sediments and nutrients for protection of waterway health. These are bioretention systems and constructed stormwater wetlands. Both of these systems can be implemented in the Dry Tropics with careful adaptation to suit the Dry Tropics conditions (refer to the most recent version of the Dry Tropics WSUD Technical Design Guidelines).

For bioretention systems, best practice performance as defined by the "point of diminishing return" on performance curves derived from predictive modelling is easily discernable (Appendix A) and generally correlates with the bioretention treatment area sized at 1.5% of its contributing catchment area.

For constructed wetlands however, best practice treatment performance is more difficult to discern from performance curves derived from predictive modelling (Appendix A). Therefore, a practical measure of best practice has been adopted for constructed wetlands based on a practical upper limit size for a constructed wetland being not more than 5% of its contributing catchment area. At this size, a constructed wetland would accommodate typically not more than 50% of the normal provision of open space within urban developments (based on a 10% provision of open space).

It should be noted that a constructed wetland sized at 5% of its contributing catchment area would not, on its own, achieve the pollutant load reduction targets listed in Table 2.1. However, if operating as a treatment element with a 'treatment train', where sediment and nutrient removal is also being

---

[1] It is expected that application of best practice designed stormwater treatment technologies configured in an appropriately sequenced 'treatment train' will exceed the design objectives presented in Table 2.1

[2] Contemporary design standards for stormwater management infrastructure can be found in the most recent revision of the Dry Tropics WSUD Technical Design Guidelines (TCC).

effected by other treatment elements such as rainwater tanks and conveyance swales, then it is possible to achieve the targets listed in Table 2.1. Depending on the effectiveness of the other treatment elements in the ‘treatment train’ it may be possible to adopt a constructed wetland that is smaller than 5% of its contributing catchment. Predictive models should be used to demonstrate the performance of the ‘treatment train’ and thus optimise the size of the constructed wetland treatment element.

3 Water Quantity Design Objectives

Stormwater quantity management for waterway health enhancement focuses on the management of frequent urban stormwater flows that cause disturbance to aquatic habitats and aquatic ecosystem health. This is distinct from urban stormwater quantity management for flood management purposes which is concerned with the management of less frequent, more extreme stormwater flows that cause nuisance flooding and potential flood damages. The later is an important part of integrated stormwater management and should in no way be compromised in pursuit of the management of more frequent flows for waterway health enhancement.

Two stormwater quantity management design (performance) objectives are recommended in the new SPP 4/10 - Healthy Waters for application in the Dry Tropics. These are:

- A Frequent Flow Management Design Objective.
- A Waterway Stability Management Design Objective.

These are discussed in more detail in the following sections.

3.1 Frequent Flow Management Design Objective

This objective aims to protect in-stream ecosystems from the significant effects of increased runoff frequency by capturing the initial portion of runoff from impervious areas. This approach ensures that the frequency of hydraulic disturbance to in-stream ecosystems in developed catchments is similar to pre-developed catchment conditions.

The application of the Frequent Flow Objective is intended only within catchments contributing stormwater runoff to un-lined open channels, or non-tidal waterways and wetlands.

The spatial distribution of the required runoff capture volume may be adapted to suit individual site conditions, provided that the required runoff capture volume from all impervious areas is captured before leaving the site. Implementing the required runoff capture volume will reduce pollutant load, providing a synergistic benefit for water quality. Hence there may be opportunity to incorporate the required runoff capture volume within stormwater quality treatment measures, potentially eliminating the need for separate additional storage to meet the frequent flow management design objective.

Since the Frequent Flow Objective requires that the required runoff capture volume be available each day, the management system (whether infiltration, evapotranspiration, reuse, or discharge via bioretention) must be capable of draining the captured stormwater within 24 hours. If the ecology of the receiving water is identified as having sensitivity to a change in the baseflow regime then it may not be acceptable for the runoff capture volume to be discharged via a bioretention system. Conversely, where there is no ecological sensitivity to a change in the baseflow regime it is acceptable to discharge the runoff capture volume through a bioretention system. It has been found through technical studies (Water by Design 2009) that a bioretention system sized to meet best practice load reduction targets will also satisfy the Frequent Flow Objective without the need for any additional extended detention storage.

Numerical modeling studies were undertaken to define an appropriate design runoff capture depth for use in the Frequent Flow Management design objective for the Dry Tropics. The numerical modeling approach was based on the modeling undertaken for the objectives determined for SEQ as described in WSUD: "Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007" (SEQ Healthy Waterways 2007).

The design runoff capture depth for the Dry Tropics was selected to provide a similar frequency of surface runoff for small rainfall events and to achieve a similar overall annual volume of runoff (AVR) to an un-developed catchment. The resultant design objective is as follows:

Capture and manage the following design runoff capture depth (mm/day) from <u>all impervious surfaces of the proposed development</u>:

- **with a total fraction impervious of 0% to 40%: Capture at least the first 10mm of runoff from impervious surfaces.**

- **with a total fraction impervious of >40%: Capture at least the first 15mm of runoff from impervious surfaces.**

Table 3.1 shows the result summary of annual volume of runoff (AVR) calculations which helped to determine the recommended design runoff capture depths. Results presented in this table as well as the flow duration curves in Appendix B indicate that these daily runoff capture depths do not achieve 100% replication of [3]pre-development hydrology, but they do significantly reduce the frequency of surface runoff events and overall volumetric runoff coefficients. This is especially evident when comparing the AVR and flow duration curves calculated for impervious areas with no runoff capture and management.

Capturing and managing the first 20mm of surface runoff from impervious surfaces would achieve close to "pre-developed" catchment hydrology and <u>where practical</u> this should be pursued by development proponents.

(Details on the numerical modelling methodology and the resultant flow duration curves are provided in Appendix B).

The following two references provide further discussion on the Frequent Flow Objective and guidance on how to demonstrate compliance with the Frequent Flow Objective:

- WSUD: "Developing Design Objectives for Water Sensitive Developments in South East Queensland – Version 2, 8th November 2007" (SEQ Healthy Waterways 2007).

- Meeting the proposed stormwater management design objectives in Queensland – A Business Case, Version 1 (Water by Design 2009)

[3] Pre-development hydrology was measured as the runoff (surface flow and baseflow) generated from a 100% pervious catchment assuming urban pervious and not forested catchment conditions.

Table 3.1 Summary of design objectives for management of stormwater quantity. Frequent flow management objectives for developments with differing proportions of impervious area are shown as bold, italicised values.

Region	Rainfall Station	Modelling Period	Daily Capture and Management (mm/day)	Undeveloped (0%) AVR (ML/day)	20% Impervious AVR (ML/day)	40% Impervious AVR (ML/day)	60% Impervious AVR (ML/day)	80% Impervious AVR (ML/day)
"Dry" Tropics	TOWNSVILLE	1/1/1970- 31/21/1983	10mm	4.64	5.09	5.54	5.99	6.45
		Fourteen Years	15mm	4.64	4.86	5.08	5.31	5.53
			20mm	4.64	4.68	4.72	4.76	4.81

3.2 Waterway Stability Management Design Objective

Urbanisation typically increases the duration of sediment-transporting flow in urban streams, often leading to increased rates of bed and bank erosion. The purpose of this design objective is to limit changes in downstream sediment transport potential by attenuating flows of intermediate magnitude. These events are responsible for a large proportion of total sediment movement in streams.

Details of the technical studies undertaken to develop the waterway stability management design objective for South East Queensland are provided in Appendix B and C of "WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007" (SEQ HWP 2007). These same technical studies have not yet been undertaken for the Dry Tropics. TCC is therefore encouraged to undertake similar technical studies to those undertaken in SEQ to confirm the appropriateness of the SEQ waterway stability management design objective for the Dry Tropics. In the interim, it is recommended that the SEQ waterway stability management design objective be applied in the Dry Tropics.

Waterways Stability Management Design Objective: Limit the post-development peak 1 year Average Recurrence Interval (ARI) event discharge within the receiving waterway to the pre-development peak 1 year Average Recurrence Interval (ARI) event discharge.

4 Summary

This report summarises the technical studies undertaken to derive WSUD stormwater management design objectives for the Dry Tropics. The proposed design objectives were derived using the same technical methods employed for derivation of WSUD design objectives for urban developments in South East Queensland as described in “WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland – Version 2, 8th November 2007” (SEQ HWP 2007).

The three proposed WSUD design objectives are:

- A **Stormwater Quality Design Objective**. This objective aims to protect receiving water quality by limiting the quantity of key pollutants discharged in stormwater from urban development.
- Stormwater Quantity Design Objectives being:
  - A **Frequent Flow Management Design Objective**. This objective aims to protect in-stream ecosystems from the significant effects of increased runoff frequency by capturing the initial portion of runoff from impervious areas. This approach ensures that the frequency of hydraulic disturbance to in-stream ecosystems in developed catchments is similar to predevelopment conditions.
  - A **Waterway Stability Management Design Objective**. This objective aims to prevent exacerbated in-stream erosion downstream of urban areas by controlling the magnitude and duration of sediment-transporting flows

The performance measures/targets for each of these objectives are presented in Table 4.1 and have been derived to reflect the different climatic regions throughout Queensland.

Table 4.1 - Summary of WSUD Objectives

Design Objective	Performance Measure/Target
Stormwater Quality	Stormwater discharged from development areas to be treated in accordance with best practice for each climatic region (refer Table 2.1).
Waterway Stability	Limit the post-development peak one-year Average Recurrence Interval (ARI) event discharge to the receiving waterway to the pre-development peak one-year Average Recurrence Interval (ARI) event discharge.
Frequent Flow	Capture and manage the following design runoff capture depth (mm/day) from all impervious areas such that the frequency of surface runoff is the same as pre-development conditions: • with a total fraction impervious of 0% to 40%: Capture at least the first 10mm of runoff from impervious surfaces. • with a total fraction impervious of >40%: Capture at least the first 15mm of runoff from impervious surfaces. Note, Runoff capture capacity needs to be replenished within 24 hours of the runoff event.

5 References

Australian and New Zealand Environment and Conservation Council (ANZECC 2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality Australian Water Association and New Zealand Ministry for the Environment.*

Engineers Australia (2005), *"Australian Runoff Quality"*, Wong, T.H.F. (ed).

South East Queensland Healthy Waterways Partnership (SEQ HWP 2006), *"WSUD Technical Design Guidelines for South East Queensland".*

South East Queensland Healthy Waterways Partnership (SEQ HWP 2007), *WSUD: "Developing Design Objectives for Water Sensitive Developments in South East Queensland - Version 2, 8th November 2007"*

Department of Environment and Resource Management 2010 *State Planning Policy 4/10 - Healthy Waters*

Victorian Stormwater Committee 1999*, Urban Stormwater - Best Practice Environmental Management Guidelines*

Water Sensitive Urban Design - *Developing Design Objectives for Water Sensitive Urban Developments in South East Queensland (SEQ Healthy Waterways 2006).*

Water by Design *2009 'Meeting the proposed stormwater management design objectives in Queensland - A business Case, Version 1'*

Appendix A: Derivation of Stormwater Quality Design Objectives

The derivation of "best practice" load reduction targets for the Dry Tropics used predictive modeling techniques employing continuous simulation based on a continuous period of typical climatic conditions.

Australian Runoff Quality (2005, p.7-5) states that the ANZECC Guidelines propose the application of physico-chemical conceptual time series models as a means of summarising our best understanding of the pathways and transformation processes of key stressors such as TSS, TP and TN. The computer model MUSIC (Model for Urban Stormwater Improvement Conceptualisation - Version 3.01) developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH) is one such conceptual model.

MUSIC represents our current best understanding of the transformation of rainfall to runoff (surface and baseflow) in urban environments, the generation of key stormwater pollutants (stressors) in surface flows and base flows from various land surfaces, and the removal of key pollutants (stressors) from urban stormwater runoff by contemporary best practice stormwater treatment technologies. For this reason the MUSIC model was used to derive the "best practice" load reduction targets for Queensland.

The MUSIC models were configured as follows:

- 1ha residential catchment (with and without rainwater tanks) and 1ha industrial catchment (without rainwater tanks). The following disaggregation of surfaces (including % impervious) was employed:

  Residential

  - 0.4ha roof area (100% impervious)
  - 0.08ha ground level impervious (100% impervious)
  - 0.32ha ground level pervious (0% impervious)
  - 0.2ha road reserve (60% impervious)

  Industrial

  - 0.5ha roof area (100% impervious)
  - 0.2ha ground level impervious (100% impervious)
  - 0.1ha ground level pervious (0% impervious)
  - 0.2ha road reserve (60% impervious)

- Climatic time series at six minute time steps for each climatic region. The data used from the Bureau of Meteorology is shown below in Table A1.

Table A1: Summary of rainfall data used for each climatic region

	Rainfall station	Period of rainfall data
Dry Tropics	TOWNSVILLE	1/1/1970- 31/12/1983 (Fourteen years)

- Pervious area soil moisture store parameters based on the MUSIC model default values. The MUSIC model default values are the values calibrated by the former Cooperative Research Centre for Catchment Hydrology (CRCCH) for Brisbane. Insufficient information on the hydrology of local soils was available to allow locally specific pervious area moisture store parameters to be used. The contribution of pervious areas to urban stormwater runoff volumes and pollutant loads is typically only small when compared to impervious surfaces and therefore it was not deemed necessary to pursue in any further detail derivation of locally relevant soil moisture store parameters.

- The storm flow pollution generation parameters for each surface type were derived from *Gold Coast City Council's Stormwater Quality Management Guidelines*, April 2006 (GCCC 2006) as reproduced in Table A2. The baseflow pollution generation parameters were based on *Guidelines for Pollutant Export Modelling in Brisbane Version 8,* April 2006 (BCC 2006).

- Stormwater quality treatment performance parameters for constructed wetlands and bioretention were derived from performance monitoring data collected from across Australia and internationally by the CRCCH (refer to MUSIC Version 3.01 User Manual, Appendix F). Insufficient local stormwater treatment performance data was available for these two treatment technologies to allow for specific local performance data sets to be used for the derivation of the guideline values for each climatic region.

- The following design layouts for bioretention systems and constructed wetlands were modeled:

    - Bioretention with 0.3m extended detention; 200mm/hr hydraulic conductivity and 0.8m filter media depth.

    - Bioretention (as above) and rainwater tanks capturing runoff from half of the roof area in the contributing catchment (residential catchment only). Regions that are currently exempt from Queensland Development Code MP 4.2 were modeled without rainwater tanks.

    - Wetland with 0.5m extended detention, 48 hours detention time and 0.3m permanent pool. This wetland design layout is best suited to regions with a less extreme seasonal climate pattern (typically south of Mackay)

    - Wetland (as above) and rainwater tanks capturing runoff from half of the roof area in the contributing catchment (residential catchment only). Regions that are currently exempt from Queensland Development Code MP 4.2 were modeled without rainwater tanks.

- Wetland with 0.5m extended detention, 48 hours detention time and 0.6m permanent pool. This wetland design layout is best suited to regions with an extreme seasonal climate pattern (e.g. Townsville).

- Wetland with 0.5m extended detention, 48 hours detention time, 0.6m permanent pool and rainwater tanks capturing runoff from half of the roof area in the contributing catchment (residential catchment only). Regions that are currently exempt from Queensland Development Code MP 4.2 were modeled without rainwater tanks.

Table A3 summarises the “best practice” load reduction results obtained from the MUSIC model. The actual performance curves for the Dry Tropics are provided following Table A3. The yellow highlighted cells in Table A3 indicate the scenarios that are most relevant to the Dry Tropics region with the lowest load reduction values from these selected as the recommended design objectives for the region. In this way, there are at least two stormwater treatment technologies available to comply with the recommended design objectives and compliance can be demonstrated for a range of development types from highly impervious industrial development through to typical urban residential developments.

Table A2: Summary of storm flow mean pollutant concentration

Land Use Category	TSS Concentration *Log10 mg/L*	Source	TP Concentration *Log10 mg/L*	Source	TN Concentration *Log10 mg/L*	Source
Urban Residential						
Roads	2.43	Fletcher et al. value for TSS from roads	-0.30	Fletcher et al. value for TP from roads	0.26	BCC value for TN from residential catchment
Roofs	1.30	Fletcher et al. value for TSS from roofs	-0.89	Fletcher et al. value for TP from roofs	0.26	BCC value for TN from residential catchment
Other Impervious Areas	2.18	BCC value for TSS from residential catchment	-0.47	BCC value for TP from residential catchment	0.26	BCC value for TN from residential catchment
Other Pervious Areas	2.18	BCC value for TSS from residential catchment	-0.47	BCC value for TP from residential catchment	0.26	BCC value for TN from residential catchment
Industrial						
Roads	2.43	Fletcher et al. value for TSS from roads	-0.30	Fletcher et al. value for TP from roads	0.25	BCC value for TN from industrial catchment
Roofs	1.30	Fletcher et al. value for TSS from roofs	-0.89	Fletcher et al. value for TP from roofs	0.25	BCC value for TN from industrial catchment
Other Impervious Areas	2.43[A]	Fletcher et al. value for TSS from roads	-0.30[A]	Fletcher et al. value for TP from roads	0.25	BCC value for TN from industrial catchment
Other Pervious Areas	2.18[B]	BCC value for TSS from residential catchment	-0.47[B]	BCC value for TP from residential catchment	0.25	BCC value for TN from industrial catchment
Commercial						
Roads	2.43	Fletcher et al. value for TSS from roads	-0.30	Fletcher et al. value for TP from roads	0.37	BCC value for TN from commercial catchment
Roofs	1.30	Fletcher et al. value for TSS from roofs	-0.89	Fletcher et al. value for TP from roofs	0.37	BCC value for TN from commercial catchment
Other Impervious Areas	2.43[A]	Fletcher et al. value for TSS from roads	-0.30[A]	Fletcher et al. value for TP from roads	0.37	BCC value for TN from commercial catchment
Other Pervious Areas	2.18[B]	BCC value for TSS from residential catchment	-0.47[B]	BCC value for TP from residential catchment	0.37	BCC value for TN from commercial catchment

[A] - The TSS and TP concentrations for roads have been applied to the "other impervious areas" for industrial and commercial land uses because these areas are likely to largely comprise car parks and other heavy use areas.

[B] - It is considered appropriate to apply consistent TSS and TP concentrations to the "other pervious areas" (i.e. landscape areas, parklands) and the BCC concentrations for residential catchments are considered to be the most representative of "other pervious areas".

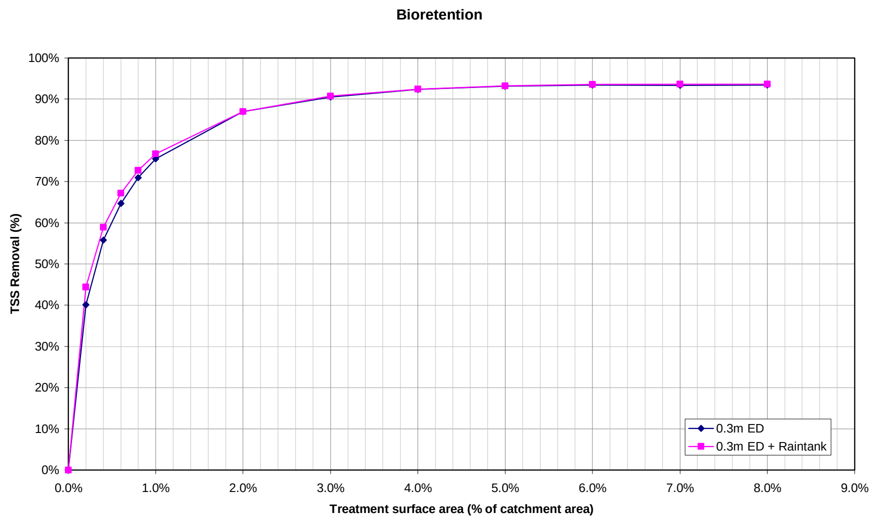
Table A3: Load reduction targets for Dry Tropics

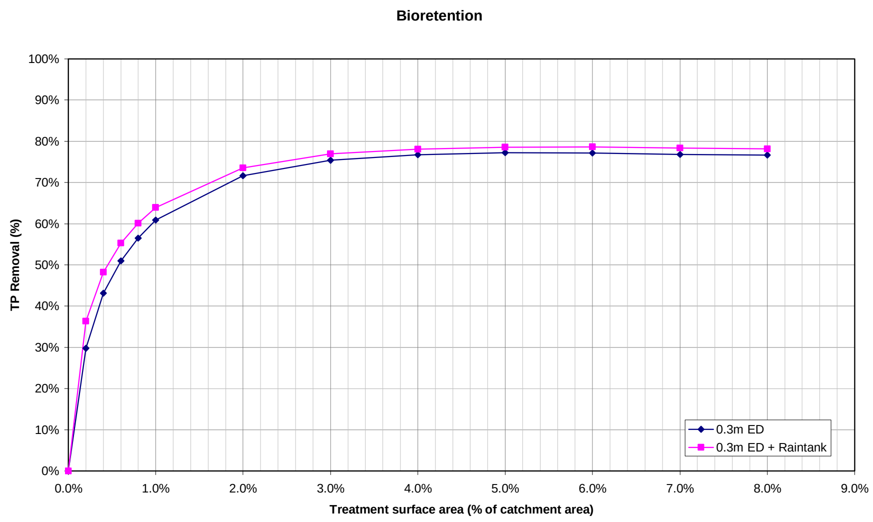
Region	**Rainfall Station**	**% Pollutant Load Reduction**								
		Bioretention @ 1.5%			*Bioretention @ 1.5%*			*Selected Target Values*		
		Residential - no rainwater tanks			Industrial - no rainwater tanks					
		TSS	**TP**	**TN**	**TSS**	**TP**	**TN**	**TSS**	**TP**	**TN**
Dry Tropics	Townsville	81	66	42	80	66	40	80	65	40

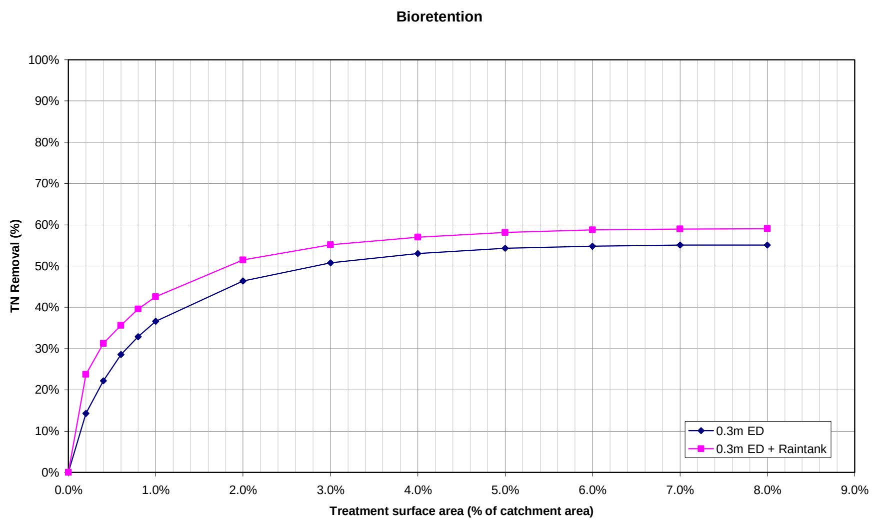
Treatment Performance curves for Dry Tropics

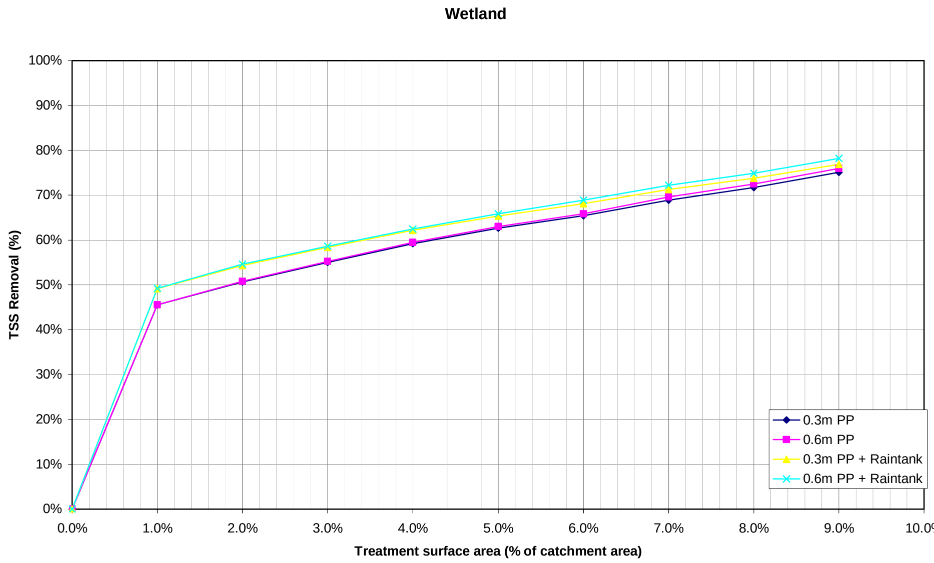
"Dry" Tropics: Townsville

Residential

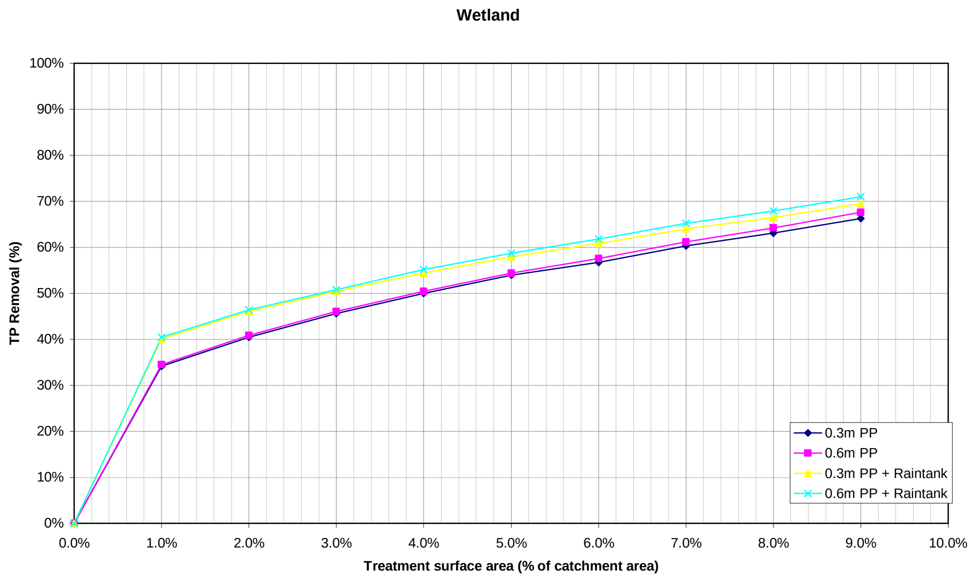




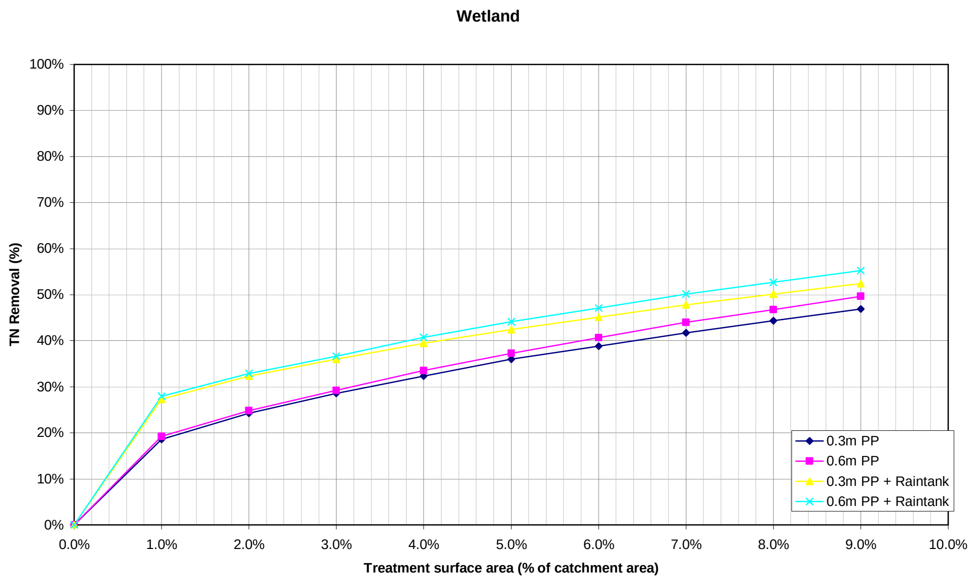




Wetland
TSS Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
10.0%
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP
0.3m PP + Raintank
0.6m PP + Raintank

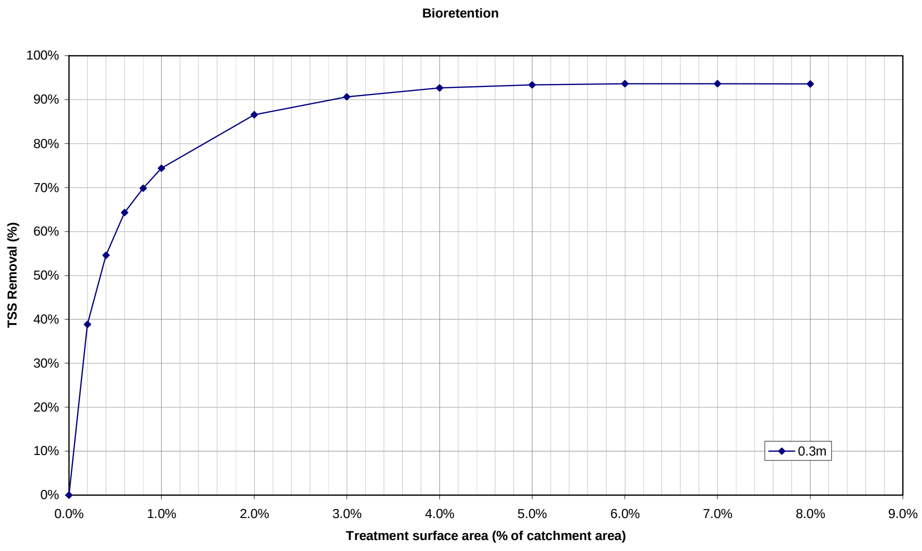


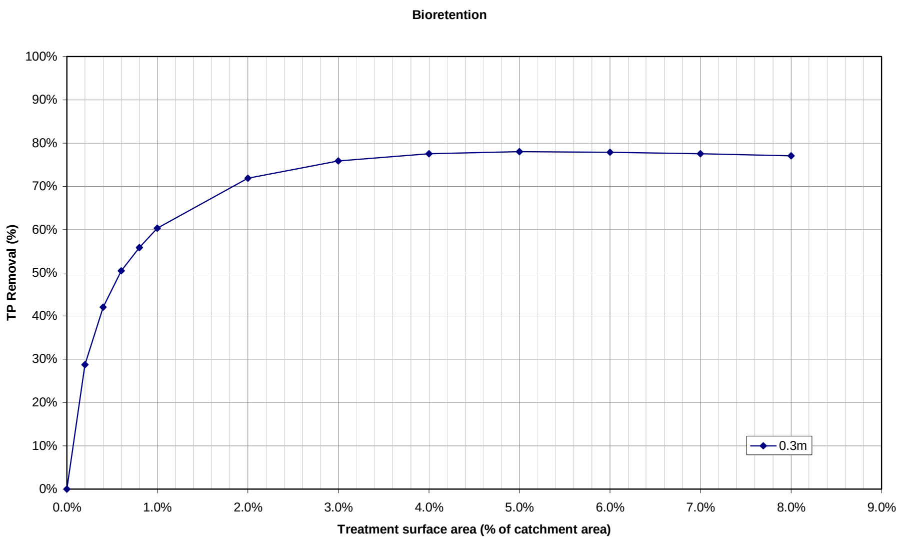
Wetland
TP Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
10.0%
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP
0.3m PP + Raintank
0.6m PP + Raintank

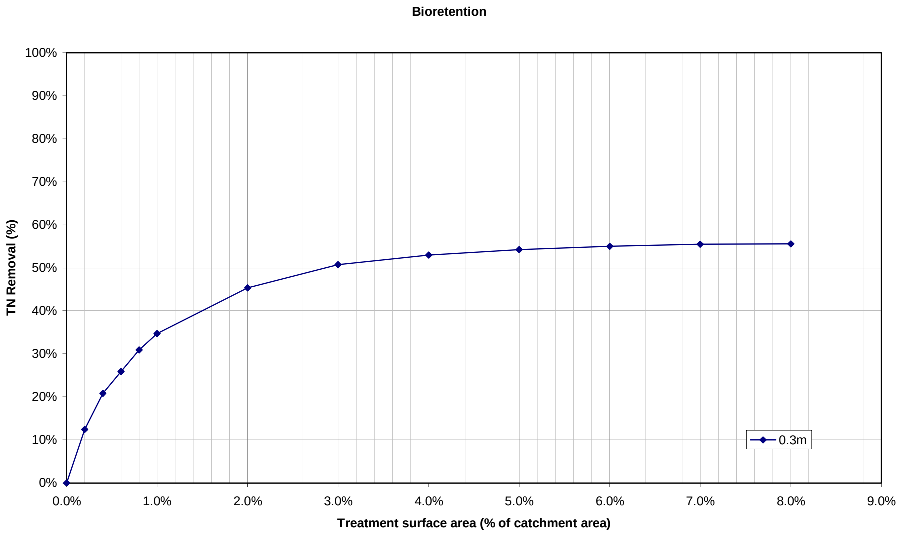


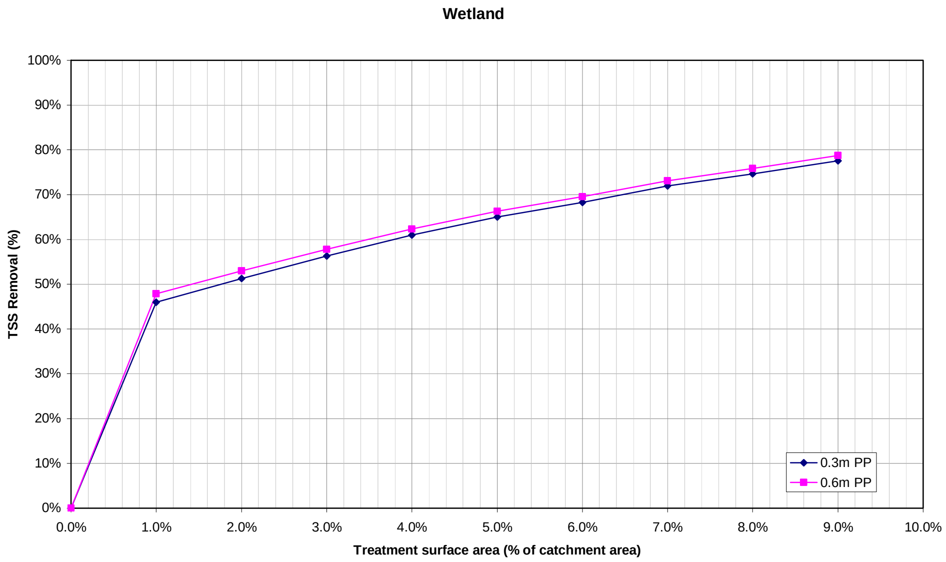
Wetland
TN Removal (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
10.0%
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP
0.3m PP + Raintank
0.6m PP + Raintank

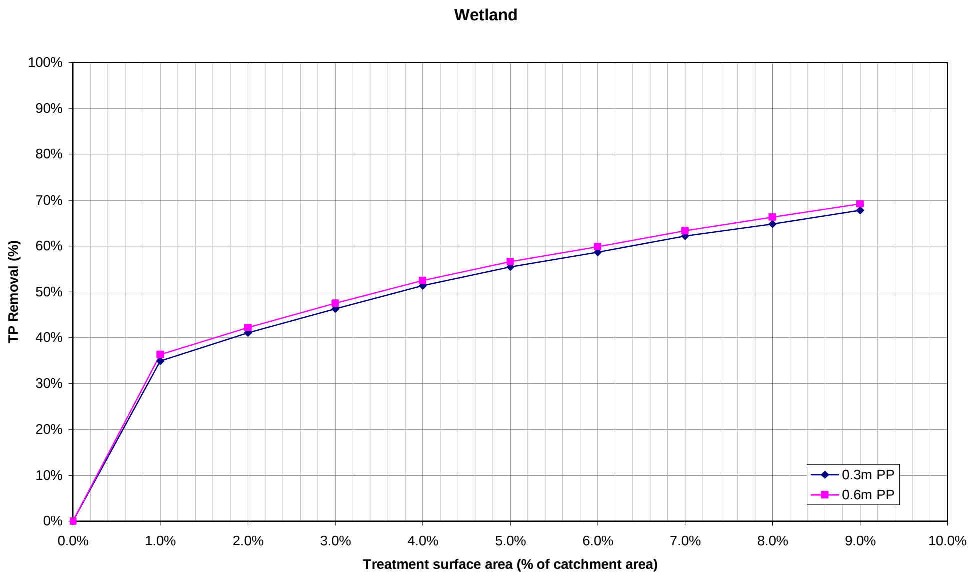
Industrial

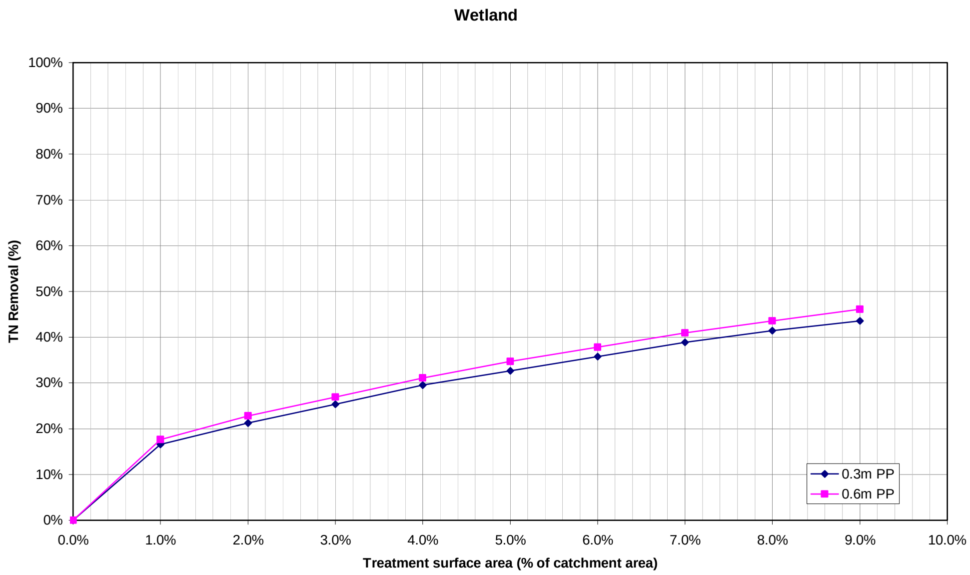

Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TSS Removal (%)
0.3m
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)


Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TP Removal (%)
0.3m
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)


Bioretention
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TN Removal (%)
0.3m
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Treatment surface area (% of catchment area)


Wetland
TSS Removal (%)
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP


Wetland
TP Removal (%)
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP


Wetland
TN Removal (%)
Treatment surface area (% of catchment area)
0.3m PP
0.6m PP

Appendix B: Derivation of Water Quantity Design Objectives – frequent flow management objective

Numerical modelling studies were undertaken to establish appropriate design capture volumes to achieve the proposed frequent flow objective for Dry Tropics. The capture volume was selected to provide a similar frequency of surface runoff form small rainfall events and to achieve a similar overall volumetric runoff coefficient to an undeveloped site.

Preliminary analysis was undertaken using MUSIC and the River Analysis Package (RAP) to determine:

- Surface runoff characteristics under "pre-development" catchment conditions
- Surface runoff characteristics under different "post-development" conditions with differing initial capture and management rates

The analysis was undertaken using 6 minute rainfall data from each climatic region. The data used from the Bureau of Meteorology is shown below.

	Rainfall station	Period of rainfall data
Dry Tropics	TOWNSVILLE	1/1/1970- 31/12/1983 (Fourteen years)

The soil moisture parameters were based on the MUSIC model defaults.

Pre-development
The pre-developed catchment was modelled as an urban catchment with 0% impervious areas.

Post-development
The post development catchment was modelled as urban catchments with the following proportion of impervious area:

- 20%
- 40%
- 60%
- 80%

Each of these scenarios was run with capture and management of the first 0, 5, 10, 15 and 25mm of daily runoff from impervious areas. The Annual Volumetric Runoff (AVR) calculations for each of these. are shown below.

Flow duration curves are also attached showing the "pre-development" condition (0% impervious), impervious runoff with no capture as well as with 5mm, 10mm, 15mm and 20mm daily runoff capture rates for each climatic region. The X-axis is the percentage of time exceeded (expressed as a proportion, not as percentage). Where the flow duration curves depart from the "pre-development" condition reveals the frequency of occurrence of surface runoff events.

The results presented in this section demonstrate that the required capture volume increases with the proportion of impervious area.

AVR Calculations for Dry Tropics

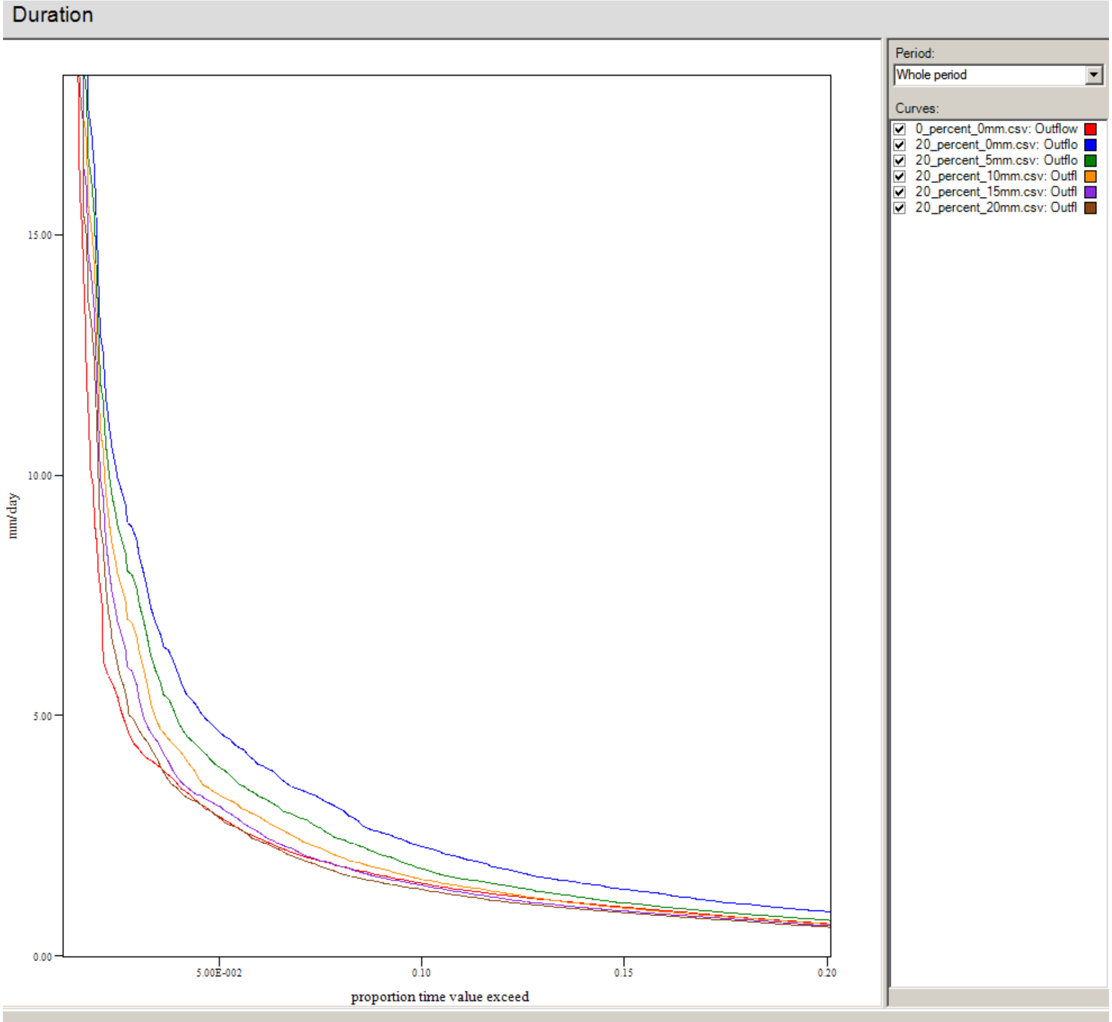
(a summary of these results in presented in section 3 of this report)

"Dry" Tropics: Townsville

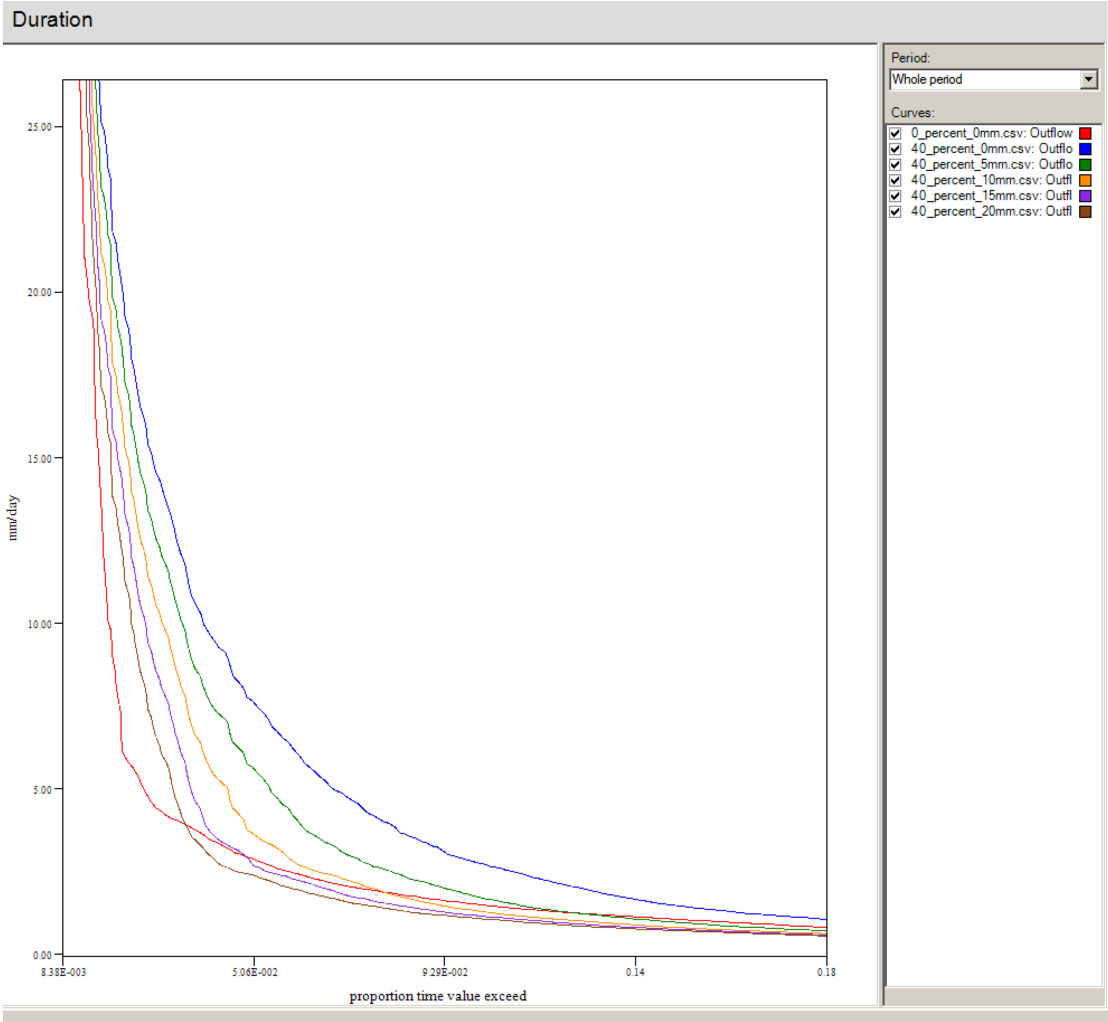
Total Fraction Impervious %	Daily Capture and Management mm/day	Target AVR (pre-development) ML/day	Actual AVR ML/year
20	0	4.64	5.88
	5	4.64	5.4
	10	4.64	5.09
	15	4.64	4.86
	20	4.64	4.68
40	0	4.64	7.12
	5	4.64	6.16
	10	4.64	5.54
	15	4.64	5.08
	20	4.64	4.72
60	0	4.64	8.35
	5	4.64	6.92
	10	4.64	5.99
	15	4.64	5.31
	20	4.64	4.76
80	0	4.64	9.59
	5	4.64	7.69
	10	4.64	6.45
	15	4.64	5.53
	20	4.64	4.81

Flow Duration Curves for Dry Tropics

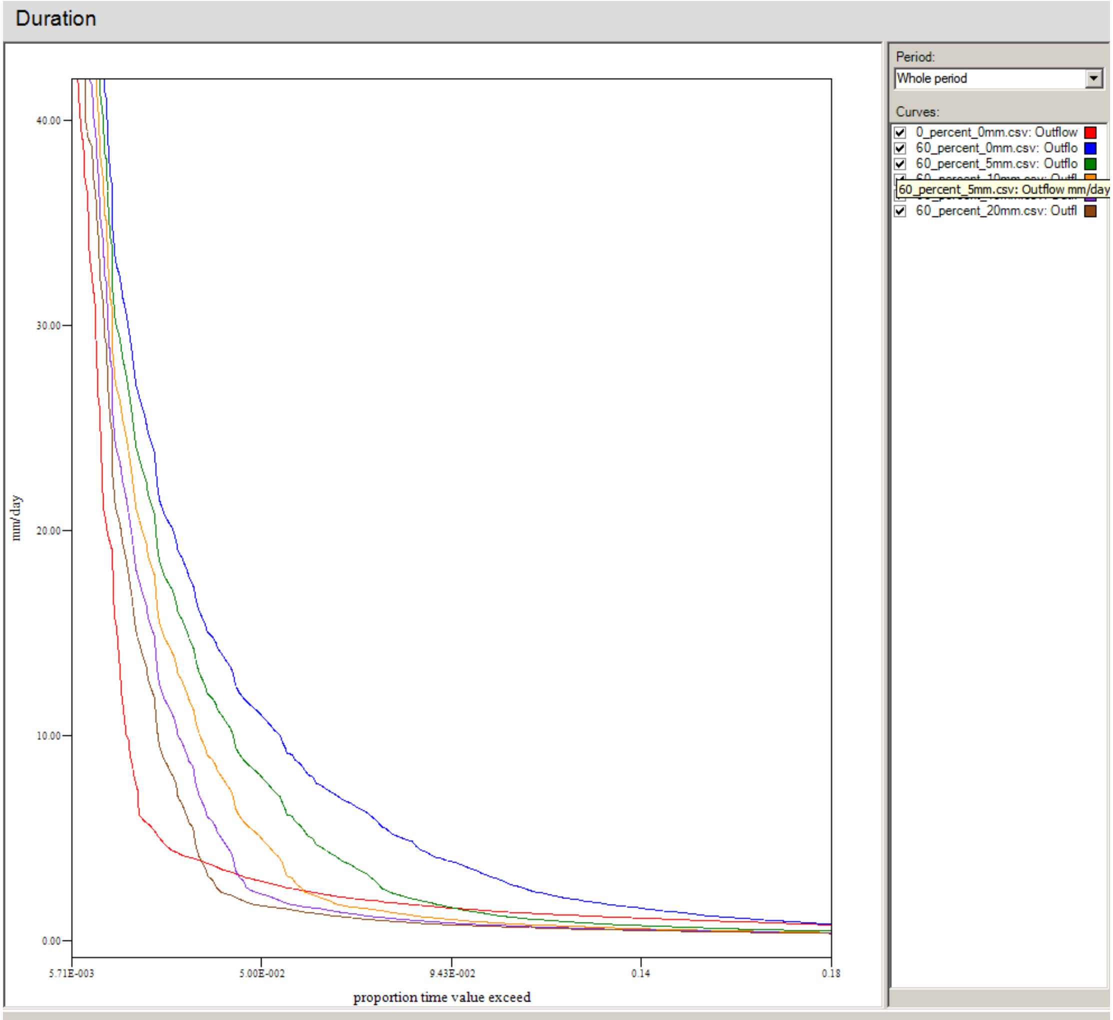
"Dry" Tropics: Townsville



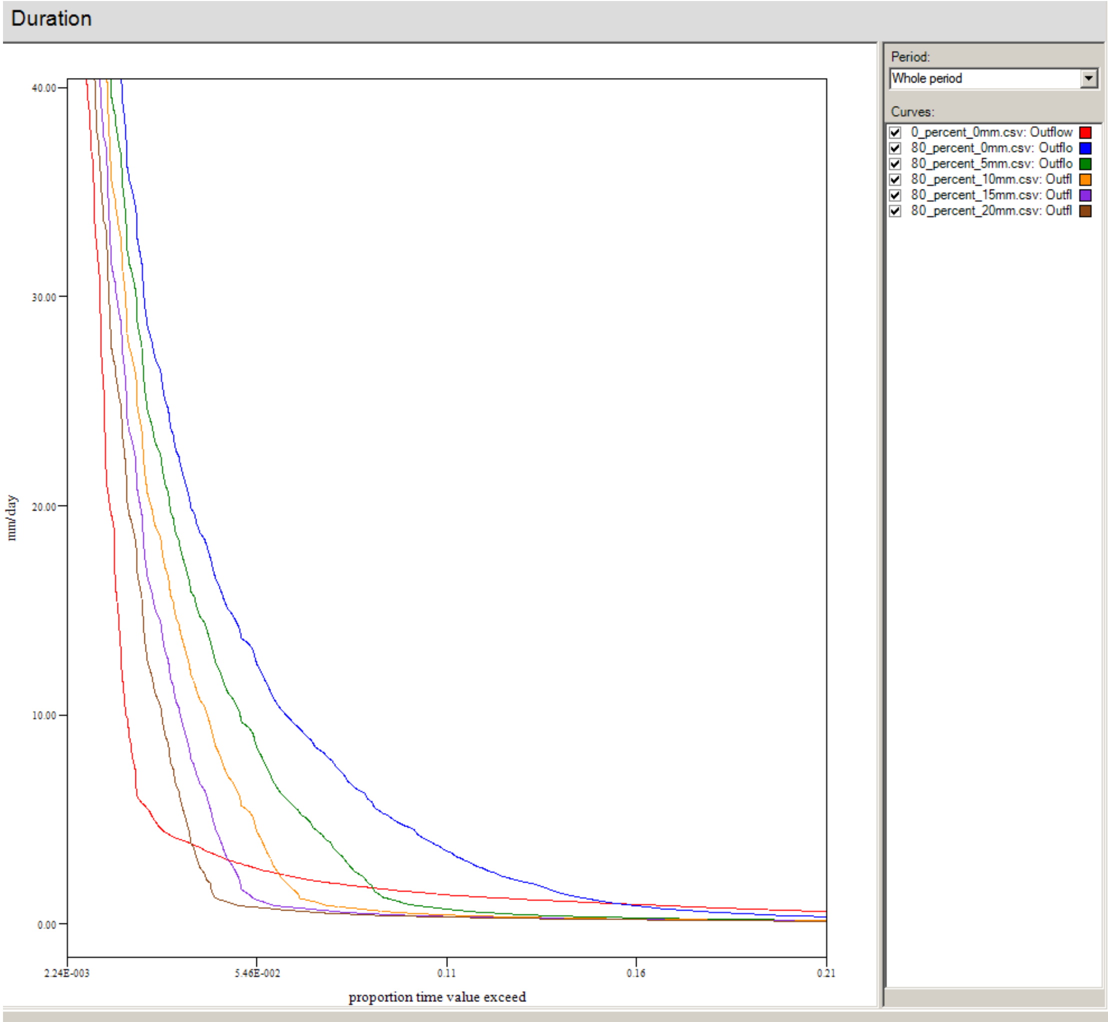
Townsville – 20% Total Impervious Flow Duration Curves



Townsville - 40% Total Impervious Flow Duration Curves



Townsville – 60% Total Impervious Flow Duration Curves



Townsville – 80% Total Impervious Flow Duration Curves