BLIGH TANNER

Townsville Regional Stormwater Strategy

Part 1: Literature Review and Consultation

Part 2: Analysis Report

Part 3: Recommended Strategy

DATE. JUNE 2016

CLIENT. TOWNSVILLE REGIONAL COUNCIL

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1 INTRODUCTION

1.1 Purpose

By implementing this strategy, stormwater quality will be managed in a way that is more cost effective for Council and developers, while achieving improved environmental outcomes when compared with the status quo.

1.2 Context

The context for the Townsville stormwater strategy is outlined below, using an adapted version of the PESTLE framework (considering political, economic, social, technological, legislative, environmental factors), with additional regard for indigenous issues.

1.2.1 Political

Townsville City Council, like all Local Governments in Queensland, has Councillors who are democratically elected every three years. This requires Councillors to make decisions in the best long term interests of the community while also attending to the short term interests of their electors.

1.2.2 Economic

Townsville is the largest city in North Australia, and one of the fastest growing cities in the state of Queensland in terms of population. At 30 June 2014, the estimated resident population of Townsville was 192,308 people, about 4% of the Queensland total. Townsville's population in 2036 is projected to be close to 300,000 people (Queensland Population Projections, 2013 edition, TCC Estimates).

Townsville has a diverse economy in which significant industries include retail trade, health and education services, government administration and defence, construction, mining, manufacturing, and property and business services[1].

Affordable housing is a critical issue for the social and economic development of the community. Achieving more cost effective stormwater management can contribute to more affordable housing, while healthier waterways assists with tourism.

1.2.3 Social

The Townsville Community Plan 2011 – 2021 provides a useful guide to the social context. It seeks that in 2021, the Townsville community will be defined by the statement:

> *Townsville is the northern gateway to Queensland. Our well-built city connects people to their community, via an active lifestyle that is enjoyed by all who live and visit. We are leaders of positive environmental action. We are acclaimed for our business entrepreneurship, government enterprise, innovation, technology and cultural stewardship*

1.2.4 Technological

A variety of stormwater treatment technologies have emerged over the last twenty years. Constructed wetlands and bioretention systems have had patchy success in Townsville, with a number of early trials failing for various flaws in design and construction, and questions remain about the appropriateness and long term performance of such measures in the dry tropics. Ongoing experimentation is occurring

[1] Townsville.qld.gov.au accessed 17th August 2015

with saturated zone bioretention systems, while parts of the industry continue to investigate new technologies.

High efficiency sediment basins, using automatically dosed flocculants, are one such innovation that has the potential to greatly improve the effectiveness of sediment basins on construction sites.

A suite of proprietary filters are also emerging, although performance claims are clouded by a lack of independent testing, and ongoing maintenance and the high cost of such devices remain as key concerns.

Council officers and local researchers are pioneering the use of low cost environmental sensor technology that has the potential to greatly reduce the cost of data collection, which could result in far more environmental data being collected and lead to better understanding of water quality issues and more targeted investment of resources in improving water quality outcomes.

1.2.5 Legislative

The State Planning Policy (2014)(SPP) specifies the default load-based reduction targets for stormwater quality management in the various climatic regions of Queensland. Those targets are based on how well bioretention systems can improve the quality of urban stormwater runoff, without the treatment systems becoming excessively large (i.e. where further increases in the size of the bioretention system would lead to diminishing water quality benefits). The targets do not necessarily achieve a no-worsening of pollutant loads compared to current or natural catchment conditions.

Table 1-1 Stormwater quality targets (Minimum reductions in mean annual load from unmitigated development)

	TSS	TP	TN	Gross Pollutants
SPP Targets (Dry tropics)	80%	60%	40%	90%
Townsville Targets[2]	80%	65%	40%	90%

In developing those targets, the following was not explicitly taken into account:

- The actual needs of various waterway types (lakes, streams, rivers, estuaries and coastal waters)
- The real costs to developers, especially the value of land occupied by treatment measures
- Site constraints (including physical constraints and conflicting design standards for other urban infrastructure)
- The net maintenance burden to local government and how this might be funded
- How the necessary investment in long-term capacity building might be funded
- The alternative strategies that might exist to improve stormwater quality outcomes.

While the performance of some water sensitive design practices in improving water quality is relatively well established, there is a lack of evidence about the measurable benefits in improving waterway health. There is a lack of consensus amongst ecologists about what factors are critical in achieving healthy waterways in urban environments (a range of factors are acknowledged, including instream habitat, riparian cover, water quality and hydrology).

In response to concerns about the poor on-ground outcomes being driven by the SPP targets, Water by Design recently released the Living Waterways framework as a mechanism for demonstrating environmental best practice management and compliance with the A01.1 of the SP code. This has been endorsed by the Department of Heritage Protection and is expected to be formally referenced in the SPP when it is next updated.

[2] Planning Scheme Policy SC6.4.3.9.2 Introducing water sensitive urban design

1.2.6 Environmental

The Townsville region supports an amazing diversity of animals and plants. This diversity can be explained by the range of bioregions and habitats found in the area, including the Wet Tropics, the Einasleigh Uplands, the Townsville Plains Province of the Northern Brigalow and the Dry Tropics Coast bioregions. In the low lying coastal plain there are a number of rivers, creeks and freshwater wetlands. Hills and mountains rise out of the coastal plan, creating distinctive landmarks such as Castle Hill. The long coastline features beaches, mangrove estuaries, saltpans and coastal swamps. The region is also home to internationally-recognised and significant areas such as the Wet Tropics World Heritage Area and the Bowling Green Bay Wetlands, as well as many other locally significant areas. Magnetic Island is located in the internationally-renowned Great Barrier Reef World Heritage Area.

1.2.7 Indigenous

For thousands of years the Wulgurukaba and Bindal people utilised and cared for the Townsville environment. For the Aboriginal community, land and water have a spiritual meaning. The Dreaming tells of the journey and the actions of ancestral beings who created the natural world. Dreaming is never-ending and links the past with the present to determine the future. It is the natural world; the mountains, rivers, fauna and flora, land and country to which Aborigines belong, which is the link between the people and the Dreaming. The indigenous history demonstrates that the region can sustain long term human occupation when it exists in balance with the environment.

2 APPROACH

The intention for this Strategy has been to tailor it to the specific needs and circumstances in Townsville. It has sought to develop a fundamental understanding of local stormwater issues and then derive appropriate responses to those which can be reasonably and practically implemented by Council.

The Strategy has been developed as follows:

- A literature review was undertaken to summarise relevant existing information to help ensure the strategy is developed mindful of the extent of existing knowledge and information.
- Industry and Council stakeholders were consulted:
  - An extended field trip with a Council officer experienced in water sensitive urban design to inspect a range of stormwater quality assets, as well as potential sites for regional treatment
  - A one hour workshop with Council staff
  - Extended interviews with external stakeholders on the 29th April 2015 at Council offices, with interviews conducted by Alan Hoban (Bligh Tanner) and Wesley Bailey and Amanda Rebgetz (Council). The purpose of these interviews was to listen to views and perspectives of key stakeholders about stormwater management issues, so that the Regional Stormwater Treatment Strategy is able to be developed in consideration of these matters. Interviews ran for 30 – 40 minutes duration.
- The outcomes of the above two activities are summarised in a separate document.
- Desktop analyses, including modelling and GIS analysis, were undertaken to understand the scale of impact associated with future urbanisation, and to understand what that means spatially.
- A further two-day field trip helped validate the desktop analyses and build a better understanding of natural ecology, waterway issues and potential site specific responses.
- Preliminary findings were discussed at a small Council workshop to test some of the key themes in the Strategy.
- A Preliminary Draft Report was circulated to Council officers for comment.
- A draft Executive Summary was circulated to senior managers for comment.
- Council Executive Managers were briefed on 10th December 2015, and the strategy adjusted to reflect their input.
- A Draft Report was then prepared and reviewed by Council officers.
- This Final Report was then prepared.

3 STORMWATER IMPACTS

There is almost no local research on the impacts of urban runoff on waterways, although it is generally accepted that urbanisation leads to a decline in the health of urban streams. Water quality is but one of the factors relevant to healthy aquatic environments.

3.1 Frequent Flow

Frequent flows are the flows in waterways resulting minor rainfall events. In urbanised catchments, small amounts of rainfall can lead to direct and rapid streamflow responses, whereas in natural catchments such rainfall is often intercepted, evaporated or infiltrated. These frequent flows arising from urbanisation are hypothesized to have a significant impact on waterway health, and McGarry and Eadie (2011) recommended specific frequent flow objectives be adopted by Townsville City Council.

This hypothesis is largely based on research on streams in temperate climates, such as Walsh et. al. (2009), which found a very strong correlation between impervious area and stream health as measured by macroinvertebrate diversity and abundance.

No comparable research in the dry tropics has been identified.

McIntosh et al. (2013) sought to validate the hypothesis in South East Queensland (SEQ) and concluded that total impervious area, 'either lumped or weighted to mimic the effect of directly connected impervious area (DCIA), was not observed to exert a strong impact on any ecological variables'. A possible reason for the difference in findings between Melbourne and SEQ research is that waterways in the subtropics experience a high degree of variability in stream flow including large episodic events, and so the impact of subsequent urbanisation is less pronounced than in locations with more benign rainfall. Having more pronounced seasonality and rainfall intensity than SEQ (as described in Chapter 5), it is likely that a similar relationship would be found in the Dry Tropics.

The precautionary principle would suggest a 'first do no harm' approach until further scientific evidence is obtained, however given the impracticability and large cost of managing frequent flows on most development sites, and the questions raised about its relevance in the sub tropics, it is difficult to justify the application of a frequent flow objective in the dry tropics at this point in time.

Frequent flow management, as a tool to mitigate ecosystem disruption, should not be confused with hydrologic management from a geomorphic stability perspective, which is likely to be important in Townsville and is addressed by this strategy.

3.2 Construction Phase Impacts

Any discussion about stormwater quality should be mindful of the evidence indicating that construction sites contribute many times more sediment than established urban areas, yet currently erosion and sediment control practise across Queensland is very poor. Not only does sediment laden construction site runoff pose an acute risk to ecosystem health, it is also a main cause of damage to stormwater quality assets.

4 LOCAL ISSUES

This chapter provides an overview of key local issues relevant to the Regional Stormwater Strategy. There is further discussion of these issues in the Literature Review and Stakeholder Consultation Report. Climate and hydrology are described in Chapter 5 and stormwater quality in Chapter 6.

4.1 Topography

Large parts of Townsville's urban footprint are on the flat coastal plain. As a result, a lot of stormwater drainage is constrained by the available grade and this can make it difficult to install end-of-pipe stormwater quality measures that need an elevation difference to move water through them, such as bioretention systems, wetlands and proprietary filters.

4.2 Receiving Environments

4.2.1 Environmental Context

A broad range of wetland and waterway types occur within the Townsville area including coral reef, estuaries and tidal lakes, ephemeral creek, freshwater lakes and upland swamps and include the World Heritage Listed Great Barrier Reef Marine Park, RAMSAR listed wetlands and state significant native vegetation and fauna species.

Despite extensive urbanisation and agricultural development, Townsville retains extensive natural areas highly valued by the community for recreation, amenity, conservation and cultural values. A significant example is the Townsville Town Common, an extensive estuarine-freshwater complex within the Bohle River Catchment which is popular with residents, tourists and ecologists. The Bohle River, Ross River and Alligator Creek are popular for swimming and recreational fishing, while the tidal reaches are used for commercial fishing.

As in many parts of Australia, wetlands and waterways within the Townsville LGA have been dammed, modified, filled and drained to enable agricultural and urban development, to reduce the impacts of flooding and secure water supplies. This has resulted in significant changes in the hydrological, chemical and biological processes needed to sustain aquatic ecosystems and in many instances a loss of habitat and biodiversity. Weed invasion is particularly conspicuous within the LGA with significant species including Para Grass (*Urochloa mutica*), Guinea Grass (*Panicum maximum*), Hymenachne (*Hymenachne amplexicaulis*), Salvinia (*Salvinia molesta*), Chinese Apple (*Zizyphus mauritiana*), and others.

Weed invasion is often associated with eutrophic (nutrient rich) and/or sediment laden stormwater discharge and along with clearing has enabled dominance of grass species, notably Para Grass and Guinea Grass, through large parts of the LGA. Prominent examples include Bohle River wetlands, upstream of the Bruce Highway, large parts of the Ross River, Whites Creek and Horseshoe Bay Lagoon.

Lucas (1996) summarises some key wetlands, foreshore and waterway areas and completed a rapid assessment of a number of these areas to determine appropriate management and rehabilitation strategies, as well as important environmental values requiring protection as urban development occurs.

Despite significant environmental issues, there remain very large areas of the LGA in a relatively natural state or sufficiently intact that essential hydrological and biological processes still occur and should be protected when considering stormwater management strategies. From south to north through the LGA, the key catchments are Reid-Haughton River, Alligator Creek, Stuart Creek, Ross River and Ross

Creek, and the Bohle River. Stuart Creek in particular is relevant to this study as it is expected to have significant urbanisation and has significant environmental values in many of its reaches, and potential for recovery in impaired reaches.

The Townsville LGA sits within the Brigalow Belt biogeographic region – an Open woodland/grassland dominated by the brigalow tree (*Acacia harpophylla*) covering over 36 million hectares (WWF, 2008). Within this system dominant aquatic ecosystems include palustrine, lacustrine, riverine, inter-tidal, estuarine and marine systems which encompass numerous vegetation types, a number of which are listed as vulnerable or endangered under Queensland legislation. Dominant riverine and wetland vegetation communities are listed within Table 4-1, and supported by typical images in Figure 4-1.

This information is a summary only and does not capture the full range of natural (and artificial) features, it does however highlight the broad ecosystem types which require consideration when developing a stormwater strategy.

Table 4-1– Summary of wetland and riverine Regional Ecosystems within the Townsville area

Regional Ecosystem(s)	**Description**	**Issues for stormwater management**
RE 11.1.3, 11.2.3, 11.3.27	Freshwater wetlands dominated by macrophytes , and emergent aquatics (water lilies, water ribbon) with fringing tree species such as Paperbark	Susceptible to sediment runoff and weed invasion (e.g. Para Grass and Salvinia). Susceptible to increasing salinity associated with drainage works which can enable Typha, Saltwater Couch and other salt tolerant species.
RE 11.3.12	Paperbark swamp occurs along ephemeral creeklines e.g. Stuart Creek with a sparse understorey and canopy dominated by Paperbark, Lophostemon and Ironbark.	Strongly groundwater dependent, sand/cobble stream beds highly susceptible to changes in sediment regime and concentrated stormwater discharge.
RE 11.3.12, 11.1.3, 11.2.3,	Supratidal zone transitioning between freshwater and tidal areas. Very flat topography creates shallow broad drainage swales dominated by Blady Grass, Paperbark and Cabbage Palm, transitioning to Phragmites, Saltwater Couch and Halosarcia	Susceptible to concentrated stormwater discharge, invasion by Para Grass and sedimentation.
RE 11.3.9, 11.3.12	Riverine forest including Eucalyptus platyphylla, Corymbia tessellaris, Eucalyptus tereticornis, Acacia spp., Pandanus spp., Callistemon spp., Lomandra longifolia	Groundwater dependent ecosystem adapted to periods of flooding and prolonged drying. Occurs along ephemeral and permanent creeks and rivers.
RE 11.3.11	Riparian thicket forest- includes tall canopy species including Brachychiton, Mallotus phillipensis, Streblus	Susceptible to weed invasion, and concentrated stormwater discharge.
RE 11.1.4, 11.1.1, 11.1.2	Marine ecosystems including seagrass, mangrove and saltmarsh communities on foreshore sand and mudflats.	Susceptible to concentrated discharge of freshwater, sediment runoff and weed incursion.


Ephemeral creek (Rocky Springs)


Freshwater wetland (Bohle River)


Riparian forest (North Shore Estate)


Upland stream (Alligator Creek)


Mangrove Forest (source TCC)


Intertidal zones (Source TCC)

Figure 4-1 Dominant aquatic ecosystems affected by stormwater discharge.

4.2.2 Geomorphology - Stream Types Across Townsville

Creek characteristics are created by climate and stream flows in combination with topography and the erosion potential of soil types (Fryirs and Brierley, 2013). Townsville is situated in the dry tropics with a subhumid to seasonally semi-arid climate where periods of prolonged dry are followed by periods of intense rainfall. This means that many streams and rivers within the LGA flow intermittently, subsurface or during significant storm events associated with the wet season.

There are a variety of stream types across Townsville which will respond in varying ways to stormwater discharge from urban and agricultural land uses.

Upland creeks are typically bedrock controlled and incised, with flood waterways often ephemeral, sandy, broad and shallow. The exception being in modified creeks improved for drainage where a combination of vegetation clearing and drainage improvement works can create significantly incised and entrenched streams with rates of change which far exceed those observed at any period previously (Maunsell, 2002).

There is a typical waterway transition from upland (volcanic alluvium) to andesitic regolith, alluvial sand and gravels to clay-rich alluvium landscapes. Within each location the stream character is determined by typical channel geometry, sediment type, vegetation, bed slope and planform character and are the basis for characterising stream types (e.g. Rosgen, 1996; Brierley and Fryirs, 2005).

Many waterways within Townsville have been altered substantially from their original form (Maunsell, 2002; Hopley, 1978), through a combination of channel straightening, vegetation clearance and changes in hydrology, but for the purposes of this strategy, four broad categories of stream are discussed for ease of reference and to enable general comment on their character, form and susceptibility to change. There are numerous additional categories and subcategories of stream type that could be identified within a detailed geomorphic investigation. The four categories are summarised in Table 4-2 below.

Table 4-2 Broad stream types in the Townsville area

Stream type	Key characteristics	Sediment requirements	Susceptibility to stormwater discharge
Upland streams	Bed rock controlled, high slope, very high flow energy, very resilience to disturbance.	Low	Low
Lowland streams	Bedrock, pool and riffle streams with high flow energy and reasonable resilience to disturbance.	Low to moderate	Low
Floodplain sandy-cobble streams	Sand dominated wide, shallow streams, often ephemeral with vegetation instream	Moderate to high	Very High
Coastal alluvium streams	Wide shallow vegetated swales with sand and accumulated organic matter.	Moderate to high	Moderate - High

The resilience of streams – or ability to cope with land use and hydrological changes varies considerably for different stream types. For example bed-rock controlled streams in upland locations are far less susceptible to an increase in discharge or an increase in sediment supply, while alluvial sand systems can be very susceptible to a change in sediment supply, with a decrease in the supply of sediment potentially leading to creek bed and bank scour and incision. Additionally, drainage works which concentrate stormwater flows and limit bank overtopping onto adjoining floodplains creates additional scour and deepening of streams, often removing habitat, reducing base flows, and potentially exacerbating flooding in downstream locations.

4.3 Soils

There are generally three types of soil in the area:

- Near the coast the soil is exceptionally sandy and has poor nutrient and water retention.
- On the hills surrounding Townsville is a thin layer of granite soil over granite rock. This soil has poor fertility and moisture holding capacity, and is highly erodible.

- The floodplains have sodic clay which is exceptionally hard during the dry season and waterlogged during the wet season. This soil erodes easily and has a high salt content which can retard the growth of many plants.

4.3.1 Sediment Supply

Hopely (1978) estimated the sediment yield within the Townsville areas to be approximately $40m^3/km^2/yr$ and potentially 100 times higher in very wet years. However, there will be significant variations within and across catchments in response to soils types, landuse, and vegetation cover.

Ideally, sediment supply and the current influence this has on stream health would inform development planning and design, however there is a paucity of data and a low capacity in the industry to understand such issues.

Typically within urban development, beyond the construction phase, supply of sediment is reduced within urban streams. In combination with an increase in the intensity and frequency of stormwater discharge, this leads to general channel enlargement.

Prevention of soil erosion represents a significant challenge across much of the Townsville LGA with potential problems for urban development including poor drainage, waterlogging, depressiveness, poor load bearing capacity, and susceptibility to gully erosion. Many existing developments exhibit induced high salinities within subsoils due to de-watering via excavation of deep drainage lines. Lowered water tables have implications for groundwater dependent ecosystems proximate to existing or proposed urban areas.

4.4 Groundwater

Groundwater quality is complex and varies even at the sub-catchment scale due to varying soil types, underlying geology, and climate. Shallow groundwater generally reflects the composition of soils and regolith which previous studies have shown to be largely bed-rock dependent and will naturally create significant variations in water quality relative to ANZECC (2000) guidelines (C&R, 2007).
Groundwater supplies are often ephemeral and rely on periodic recharge, although some aquifers do possess a baseflow from rock fissures.

Groundwater quality is variable on a seasonal basis. For example the Rocky Springs development investigation area (C&R, 2007) shows lowest conductivity at the end of the wet season and the opposite in the late dry season (November/December). Flora and fauna assemblages are adapted to these natural cycles of variation in water quality and availability and the incidence of lowered groundwater tables and saline discharge from exposed subsoils would have significant negative consequences for a range of biota.

4.5 Watercycle Management

Townsville residents consume approximately 4 times more water per person than in most major cities[3], as shown in Figure 4-2. Local consumption is estimated to be 745 L/person/day[4], excluding heavy industry.

[3] http://www.townsville.qld.gov.au/resident/water/Pages/consumption.aspx#waterconsumptiongraphs
[4] Regional Water Supply Security Assessment

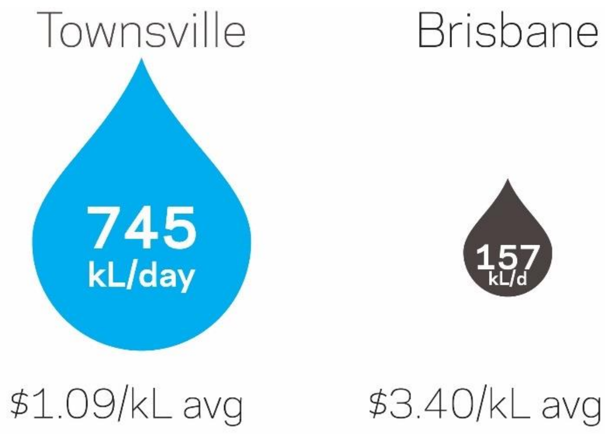


Figure 4-2 Comparison of Townsville and Brisbane water consumption and price

Currently, Townsville has two water billing plans: a fixed allocation, or two-part tariff plan. Using the fixed allocation plan, an average Townsville household consuming 680 kL/household/year would pay $739 per year. Comparatively, using the Queensland Urban Utilities (QUU) tiered consumption system for SEQ, the same annual consumption would cost $2570 per year.

On average, about 70% of total household water usage in Townsville is used to maintain lawns and gardens[5]. This results in an internal demand of approximately 220 L/person/day and an external demand of approximately 530 L/person/day. By comparison, SEQ studies undertaken during the drought in 2011 and 2012 recorded an average consumption of 140 L/person/day, with only 10 L/person/day for irrigation.

This high consumption has led to the planning of a second water supply pipeline from the Burdekin River, which is expensive infrastructure.

In new estates, high rates of irrigation also appear to be contributing to trickle flows in the stormwater system which, at least in one instance, was leading to ponding in the fore-bay of a bioretention system and fostering the growth of *typha,* a tall invasive native wetland plant . Anecdotal evidence also suggests that excessive lawn clippings are being dumped in and around stormwater systems, leading to higher organic loads and smothering of vegetation.

Wastewater management has not been considered as part of this strategy – and should be considered as part of a broader total watercycle planning activity.

[5] http://www.townsville.qld.gov.au/resident/water/Pages/consumption.aspx#waterconsumptiongraphs

5 CLIMATE AND HYDROLOGY

Townsville is one of the driest locations along the Queensland coast, in both the wet and dry seasons. Rainfall is highly variable, including monsoonal downpours as well as very long periods with almost no rainfall. Evaporation rates are very high throughout the year. Overall, the majority of rainfall occurs in large rainfall events which are challenging to manage from a stormwater quality perspective. Many climate change models predict Townsville could experience the biggest declines in rainfall of any location on the east coast of Australia.

5.1 Climatic Overview

Townsville is located in the dry tropics, and is characterised by highly seasonal rainfall and high levels of evaporation. It is one of the driest locations along the Queensland coast in both the wet and dry seasons (Figure 5-1 and Figure 5-2), with a mean annual rainfall of about 1142 mm.

Much of Queensland's stormwater quality policy and practice is based on experiences in South East Queensland (SEQ), so in this chapter, Townsville data were compared with Brisbane to better understand how relevant the SEQ experience is to local conditions.

Townsville is a very dry location, with high evaporation (Figure 5-1), and a mean annual rainfall of about 1142 mm which is higher than Brisbane's 994 mm. However, Townsville's weather is highly variable between years, and is subject to flashy rain, with large storm events and long dry spells. On average, Townsville has 93 days of rain compared with 126 rain days in Brisbane. This means compared with Brisbane, it is more difficult to treat significant proportions of mean annual runoff in Townsville, and it is more difficult to do this with vegetated stormwater treatment systems. These statistics are summarised in Table 5-1. It should be noted that the Townsville data set is from the Townsville airport, which on average receives less rainfall than other locations within Townsville.

Further understanding Townsville's climate requires understanding the rainfall patterns from year to year. By looking at a time series of Townsville's daily rainfall from 2000 to 2013, it is clear that the wet seasons are highly variable, with some years receiving heavy rain throughout the summer months, and others receiving low rainfall, or several extreme storm events.

Table 5-1 Annual rainfall summary statistics for Townsville Airport and Brisbane

	Townsville Airport (1990 – 2013)		**Brisbane (2000 – 2013)**	
	Annual Rainfall (mm/year)	Rain Days (days/year)	Annual Rainfall (mm/year)	Rain Days (days/year)
Mean	1142.7	93.2	993.9	126.1
Median	1013.4	93	1058.9	124.5
Standard Deviation	581.5	20.6	284.3	16.7

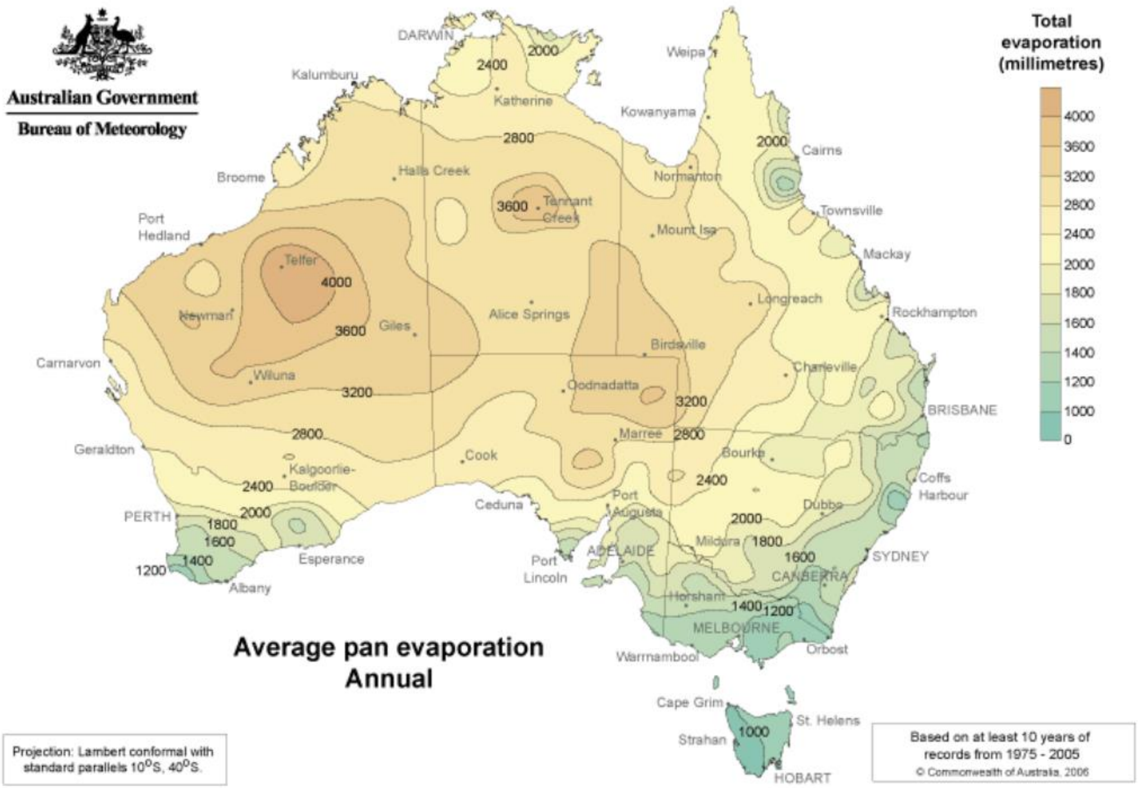


Figure 5-1 Average pan evaporation (showing Townsville has the highest evaporation rates along the east coast of Australia).

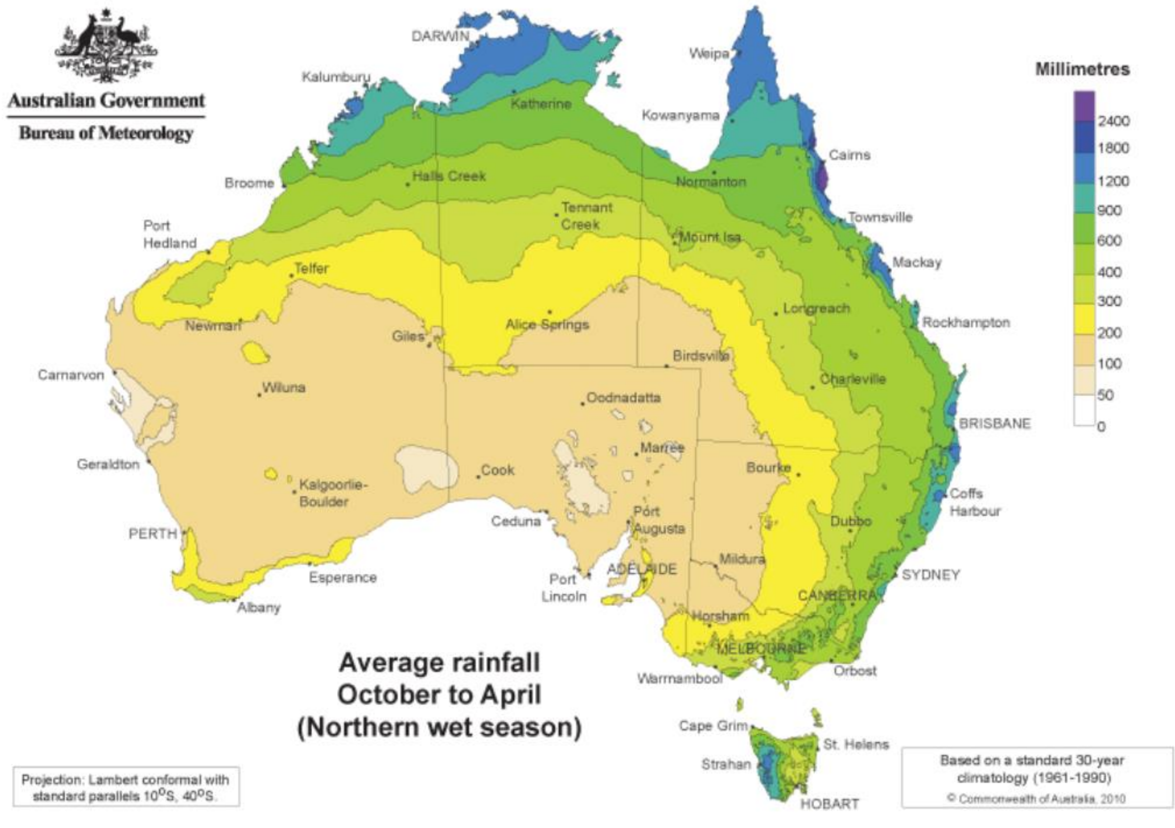


Figure 5-2 Average wet season rainfall (showing that even in the wet season, Townsville is among the driest locations along the Queensland coast).

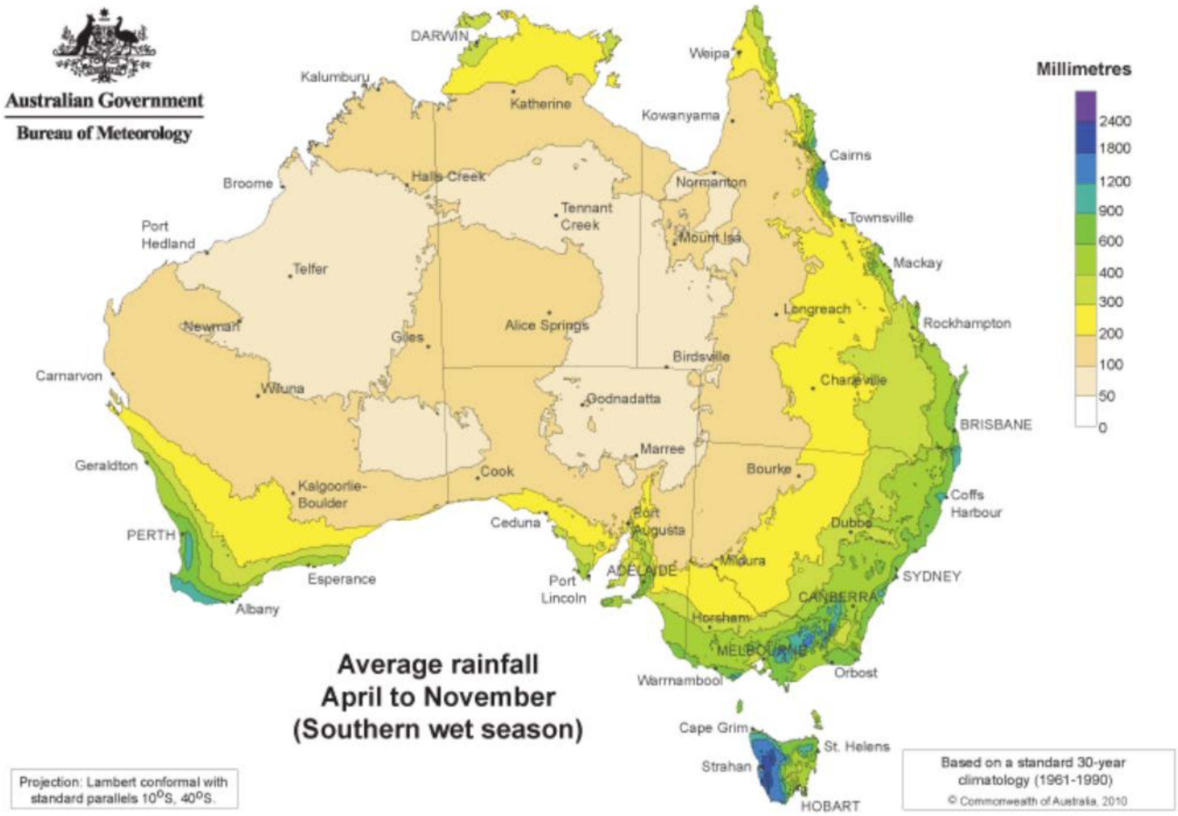


Figure 5-3 Average dry season rainfall (showing Townsville is one of the driest locations along the east coast of Australia during April – November).

5.2 Variability and Seasonality

Townsville has highly variable rainfall. The inter-annual variability is highlighted in Figure 5-4 and Figure 5-5, showing annual rainfall ranging from less than 200 mm/yr in 2003, to over 2,000 mm/yr in 2000.

Monthly rainfall totals (Figure 5-6) highlight the strong seasonality with very low rainfall in May – October compared with the November – April period. However average monthly rainfall totals mask the high variability, which is highlighted in the box plot (Figure 5-7).

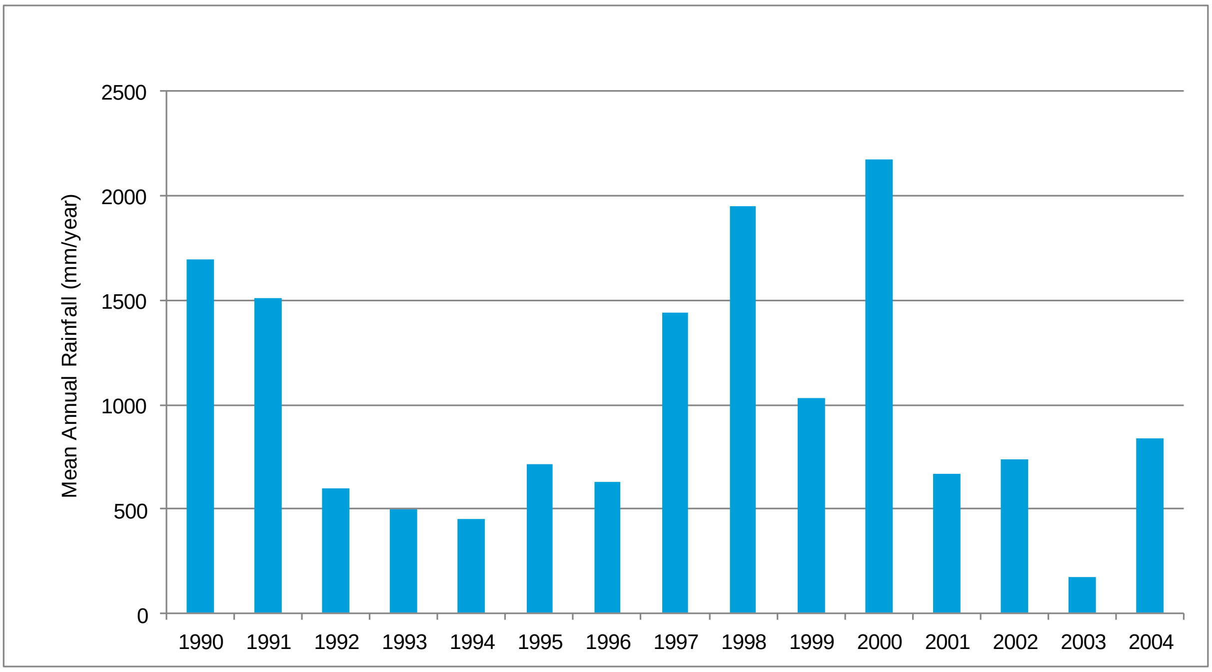


Figure 5-4 Annual rainfall totals (Townsville BOM Station 32040)

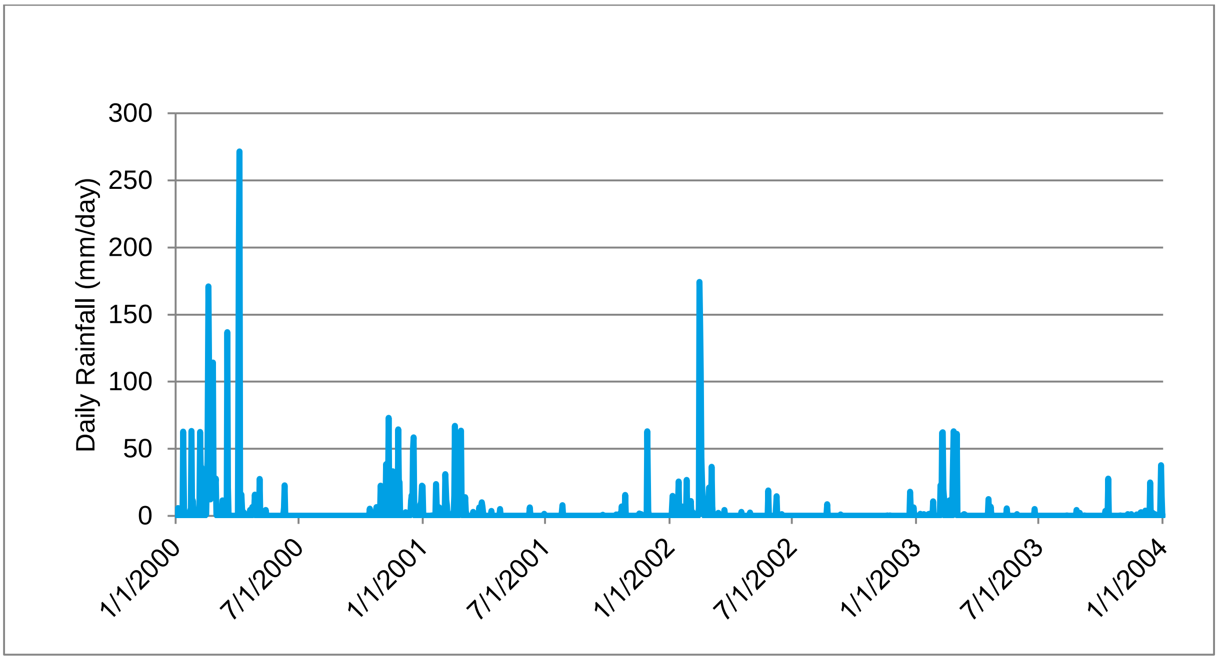


Figure 5-5 Rainfall time series, highlighting the significant variability within and between years.

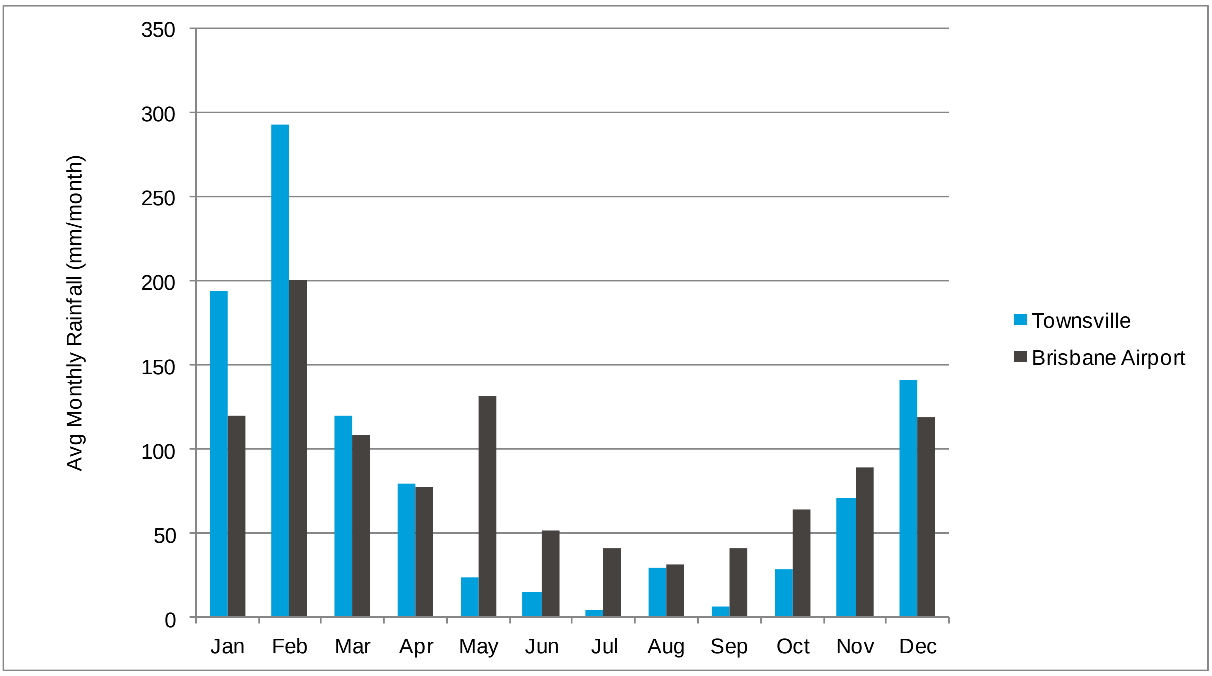


Figure 5-6 Monthly rainfall totals

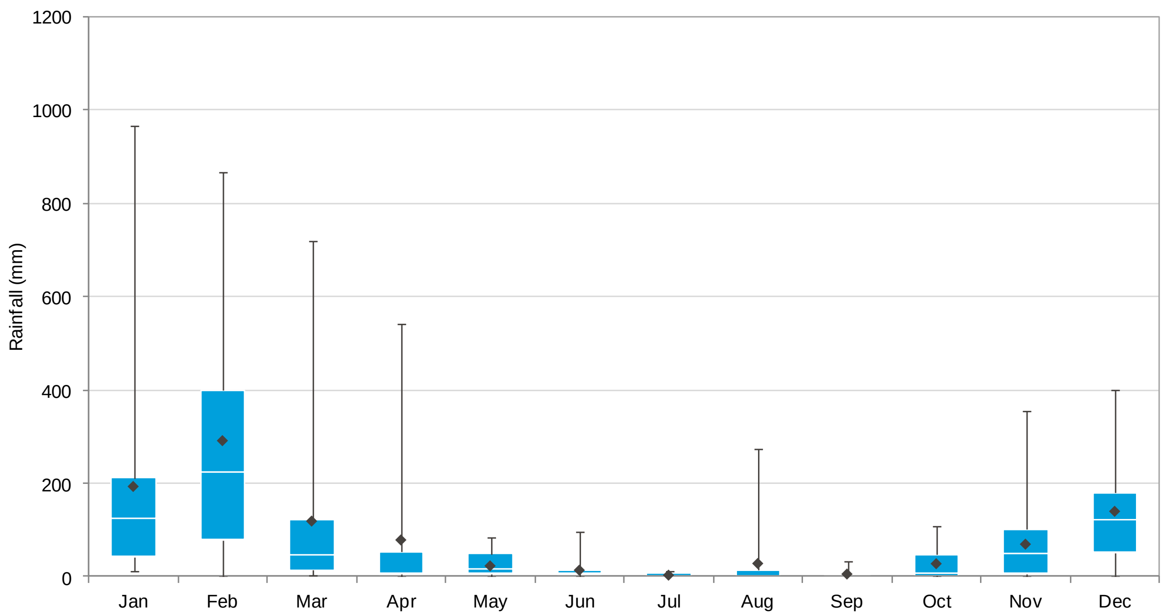


Figure 5-7 Monthly rainfall variability (Townsville BOM Station 32040)

5.3 Rainfall Intensity

Rainfall intensity considers the amount of rain falling within a given time period, and is relevant because some stakeholders have concerns that common stormwater treatment measures will be overwhelmed by the large downpours during the Townsville wet season.

Rainfall intensity has been analysed by examining fifteen years of pluviograph data (1990 – 2005), and analysing rainfall percentiles, excluding zero rainfall days. A comparison of Townsville and Brisbane rainfall is shown in Figure 5-8.

It shows that, in Townsville, rainfall tends to occur in large rainfall events. Rainfall events up to 10 mm/day account for about 13% of mean annual rainfall (22% in Brisbane), and that 20% of mean annual runoff occurs in rainfall events exceeding 130 mm/day (56 mm/day in Brisbane).

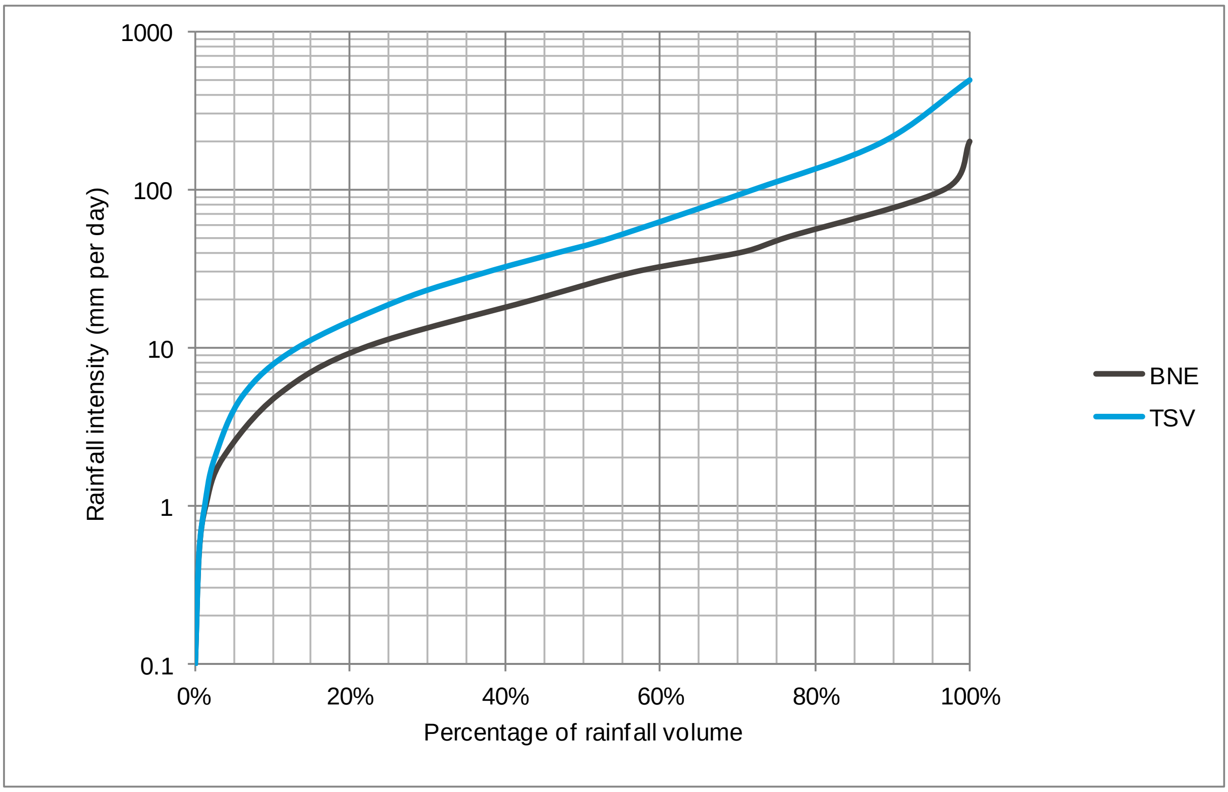


Figure 5-8 Rainfall intensity (mm/day)

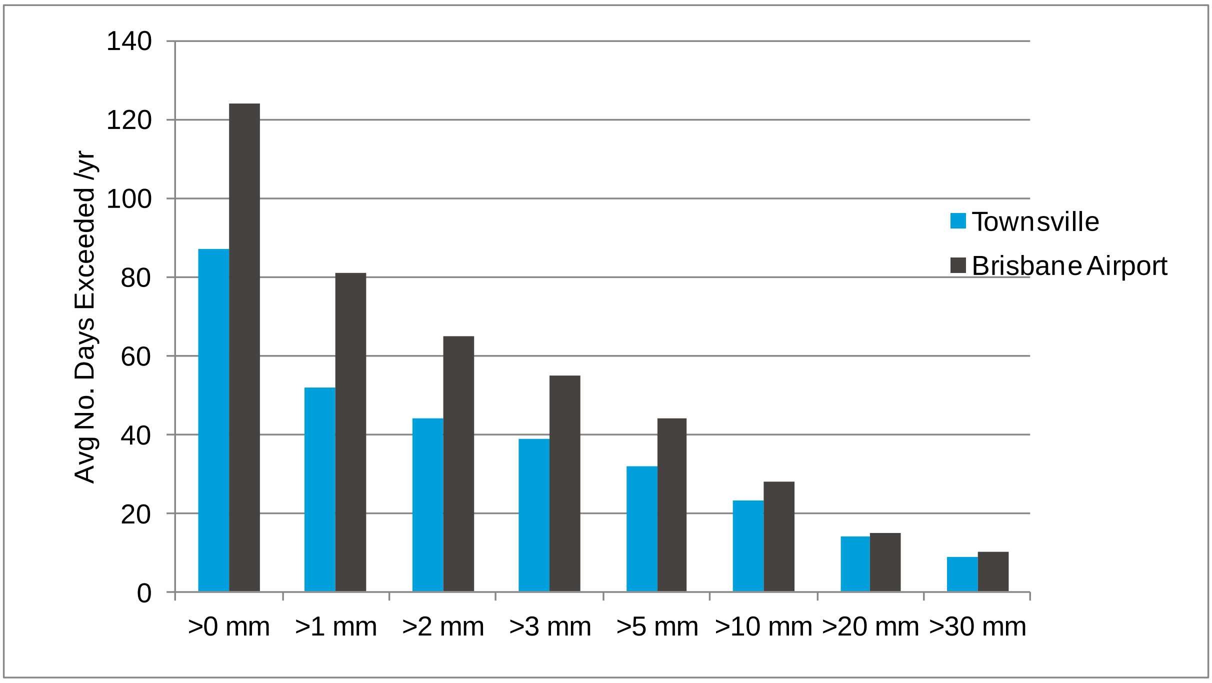


Figure 5-9 Raindays per year for various rainfall intensities.

5.4 Dry Spells

Townsville often experiences prolonged dry periods during the winter months. The results of a dry spells analysis are shown in Figure 5-10 below, which are based on a rainfall threshold of 2 mm, as at least a couple of millimetres of rain is needed to cause any appreciable wetting. The results show that it is not uncommon to have dry periods longer than 100 days. There is also considerable evapotranspiration occurring during these periods, leading to significant water deficits in shallow soil storages.

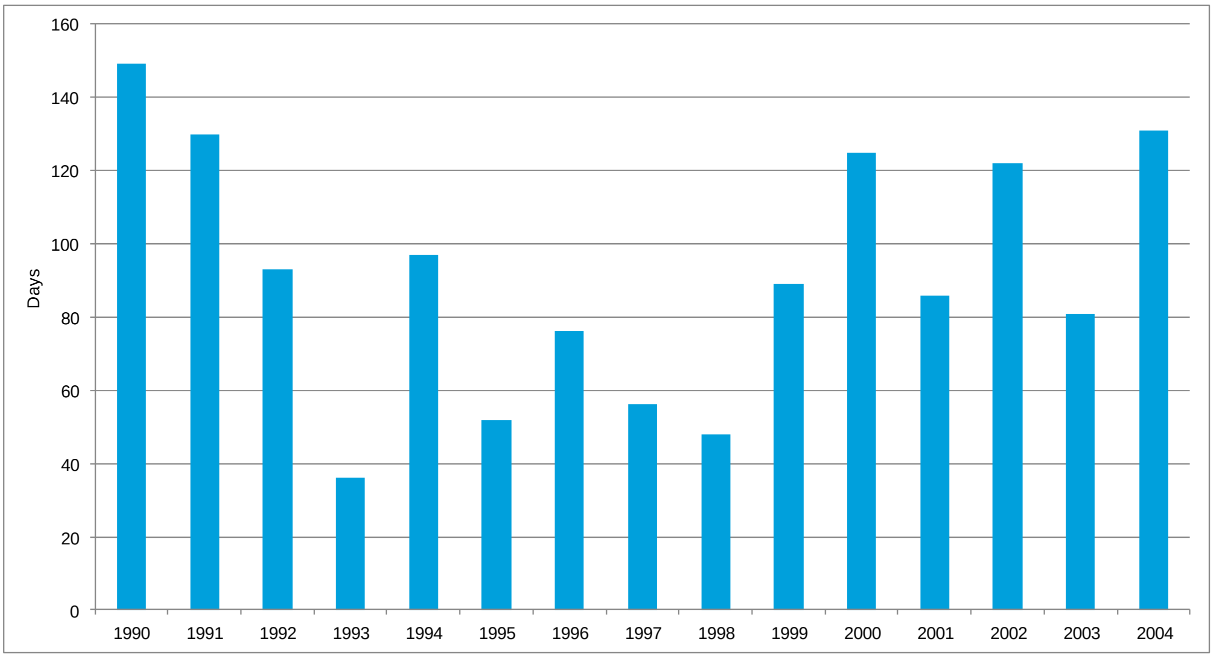


Figure 5-10 Dry spells analysis (showing number of days between rainfall events of at least 2 mm)

Dry spells are exacerbated by evaporation rates which vary from high during the dry season to very high during the wet season (Figure 5-11). As shown previously in Figure 5-3, Townsville has some of the highest evaporation rates of anywhere along the east coast of Australia. This makes it particularly challenging to establish and maintain vegetated stormwater treatment systems in the area.

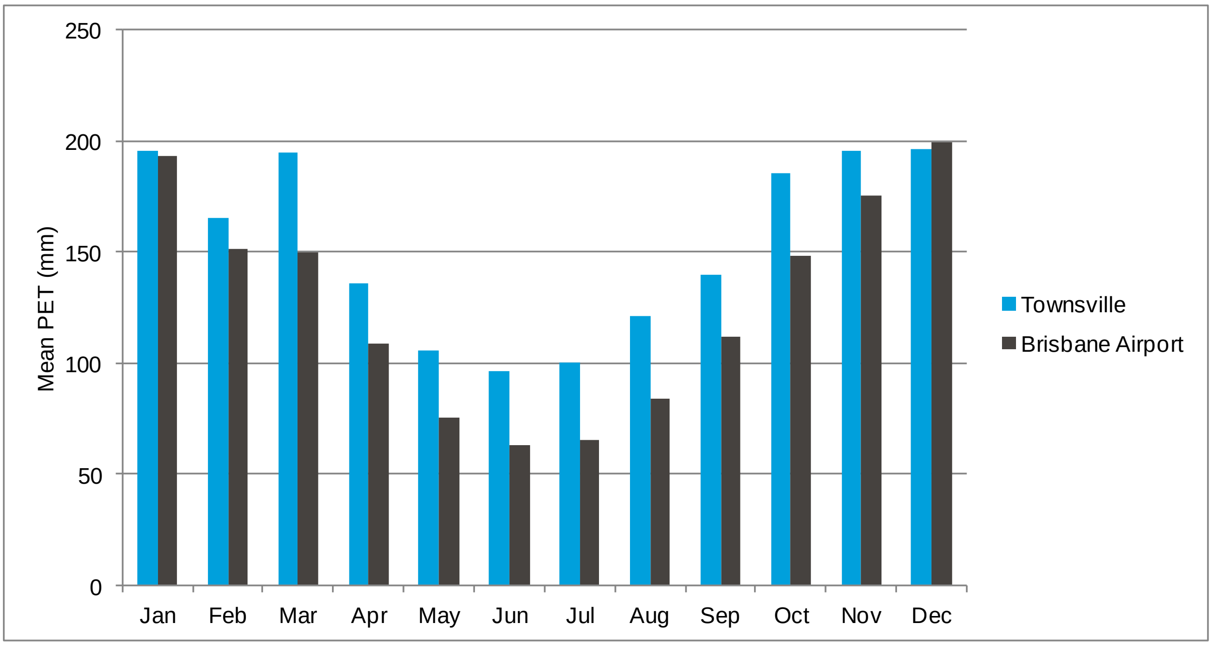


Figure 5-11 Average monthly evaporation

5.5 Climate Change

Climate change has the potential to cause severe impacts on the local climate. While there are a range of possible global emissions scenarios and general circulation models (GCMs), most of the models predict that Townsville is likely to experience the greatest reduction in average rainfall of anywhere along the east coast of Australia, such as the projection shown in Figure 5-12.

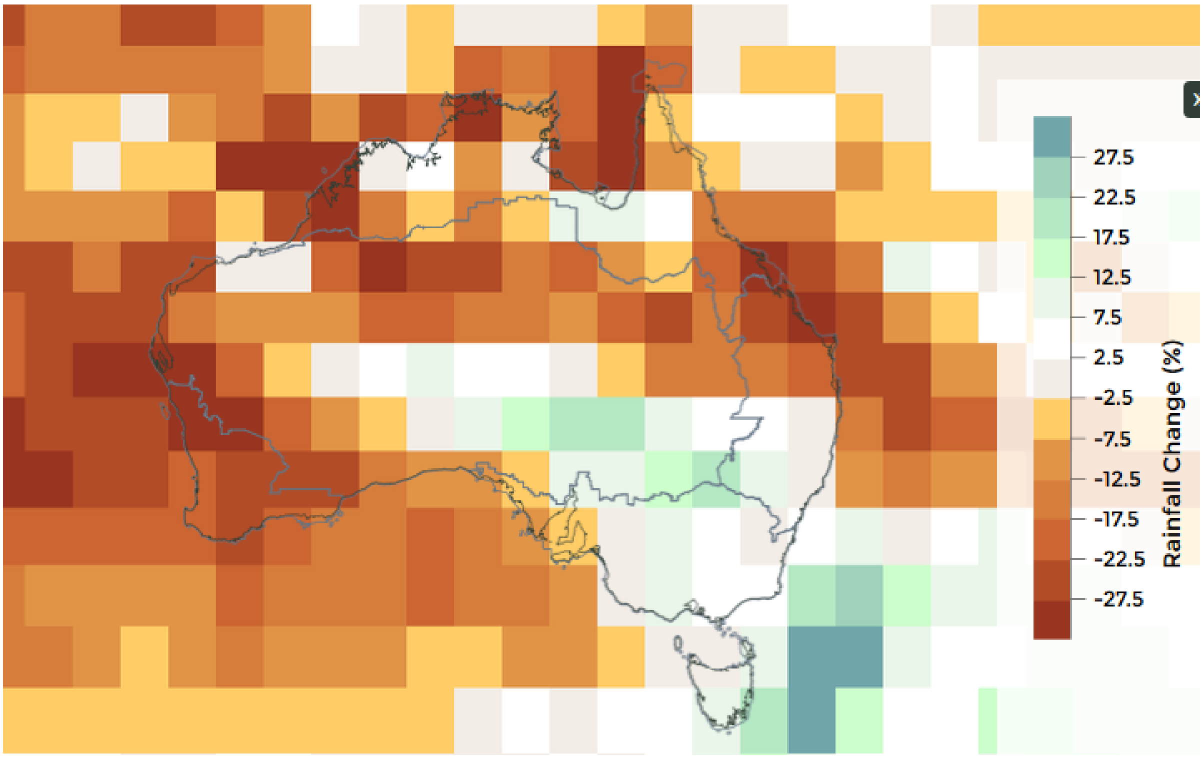


Figure 5-12 Climate change projects for the dry season (May – Oct) for 2070 (based on Emissions scenario RCP4.5 of the CanESM2 model, change relative to 1986 – 2005 data. Source: [http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/map-explorer/)](http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/map-explorer/)

More detailed analysis of climate change impacts could be undertaken using the Consistent Climate Change Scenarios available through the Queensland Government's Long Paddock service[6] using the methods outlined in Hoban et al 2015.

[6] https://www.longpaddock.qld.gov.au/climateprojections/ accessed 2nd July 2015

6 STORMWATER QUALITY

This chapter describes the locally available stormwater quality data. There is only limited data available, yet they raise some interesting questions for stormwater quality management, as they show land development on hillslopes generates very high sediment loads, emphasising the importance of erosion and sediment control. The data also show much lower levels of nutrients (phosphorus and nitrogen) in local urban stormwater runoff than is found in other published results from around Australia. The reason for this discrepancy needs to be better understood before significant investment is made in seeking to manage nutrients in urban runoff. Sediment management should therefore be the initial focus of the strategy as a no-regrets measure, and in managing sediment a range of other sediment-bound contaminants such as heavy metals are also likely to be reduced.

6.1 Data Availability and Limitations

A limited amount of local stormwater quality data have been collected. This data is derived from focused monitoring programs over two wet seasons, and is summarised in the following reports by the Australian Centre for Tropical Freshwater Ecology (ACTFR):

1. ACTFR (2007) Event-based water quality monitoring of the Ross and Black River Basins during the 2006/07 wet season.
2. ACTFR (2008) Water Quality Monitoring of the Black Ross Basins: 2007/08

The first year included more sites and the report was more comprehensive, whereas in the second year, fewer sites were sampled (due to budget constraints), although the same sites were used in the abridged monitoring program in the second year.

Given the highly stochastic nature of stormwater events, and contaminant concentrations, the limited data set represents a very high source of uncertainty.

The Executive Summary to the first report above notes:

> *This was a short term study that utilised only a few sites per catchment. A low resolution monitoring program of this kind does not provide a definitive basis for assessing risks, especially within complex urban sub-catchments that contain a diversity of potential pollutant sources. Nevertheless, it proved possible to identify some key differences in the amounts and concentrations of contaminants that were transported from sub-catchments with different dominant land uses.'*

No dry weather concentration data has been identified to characterise the quality of base flows.

There is no data on turbidity (NTU) in the dataset. While TSS (measured in mg/L) provides a useful indication of sediment loads, in catchments where there are dispersive soils there can be very high levels of turbidity associated with low-moderate TSS loads, as the fine clays held in suspension play a key role in restricting light penetration into the water column, yet have comparatively little mass.

Even with the limitations noted above, it is important to ensure local data is taken into account where it is available.

6.2 Data Analysis and Overview

Data from "Townsville all WQ data 2 years 06-08" spreadsheet[7] was analysed. Monitoring sites were assigned a typical land use, based on previous Council designations where available, or else based on a review of aerial photography of the area upstream of the monitoring site.

Townsville data was then compared with the reported event mean concentration data in the MUSIC Modelling Guidelines (Water by Design 2010)—which are based on a combination of Brisbane City Council monitoring data and Australian data—and Australian Runoff Quality (ARQ)(Engineers Australian 2006). These are plotted below for TSS, TP and TN in Figure 6-1, Figure 6-2 and Figure 6-3 respectively.

About the box plots

All Townsville data has been included in the figures, and the red points indicate outlying data. The Australian Runoff Quality (ARQ) and Water by Design (WbD) values are plotted from already summarised information – hence it is not possible to include the error bars and outlying data. The centre line in each box plot indicates the median value, and the upper and lower extent of the boxes represents the 75th percentile and 25th percentile respectively.

6.2.1 Total Suspended Solids (TSS)

The Townsville data is generally consistent with the ARQ and WbD values (Figure 6-1). On initial examination, the greenspace values appear to be lower than the Australian averages – however, the upper Townsville greenspace interquartile range overlaps both the ARQ and WbD data for forest.

The Townsville rural residential also falls below the ARQ and WbD data ranges. However, it is interesting to note that the outliers for the rural residential TSS Townsville data fall within the WbD rural residential range. This may be more reflective of the small dataset, and should be viewed with caution.

Note the high TSS loads associated with hillslope development. The respective data represents 12 individual samples. This reflects active development rather than established urban areas, and there is not an equivalent dataset in ARQ or WbD as construction phase impacts are often disregarded in stormwater quality planning (see, for example, Hoban 2012). This highlights the importance of considering construction phase water quality impacts within the scope of the Regional Stormwater Strategy.

[7] Spreadsheet provided by Council.

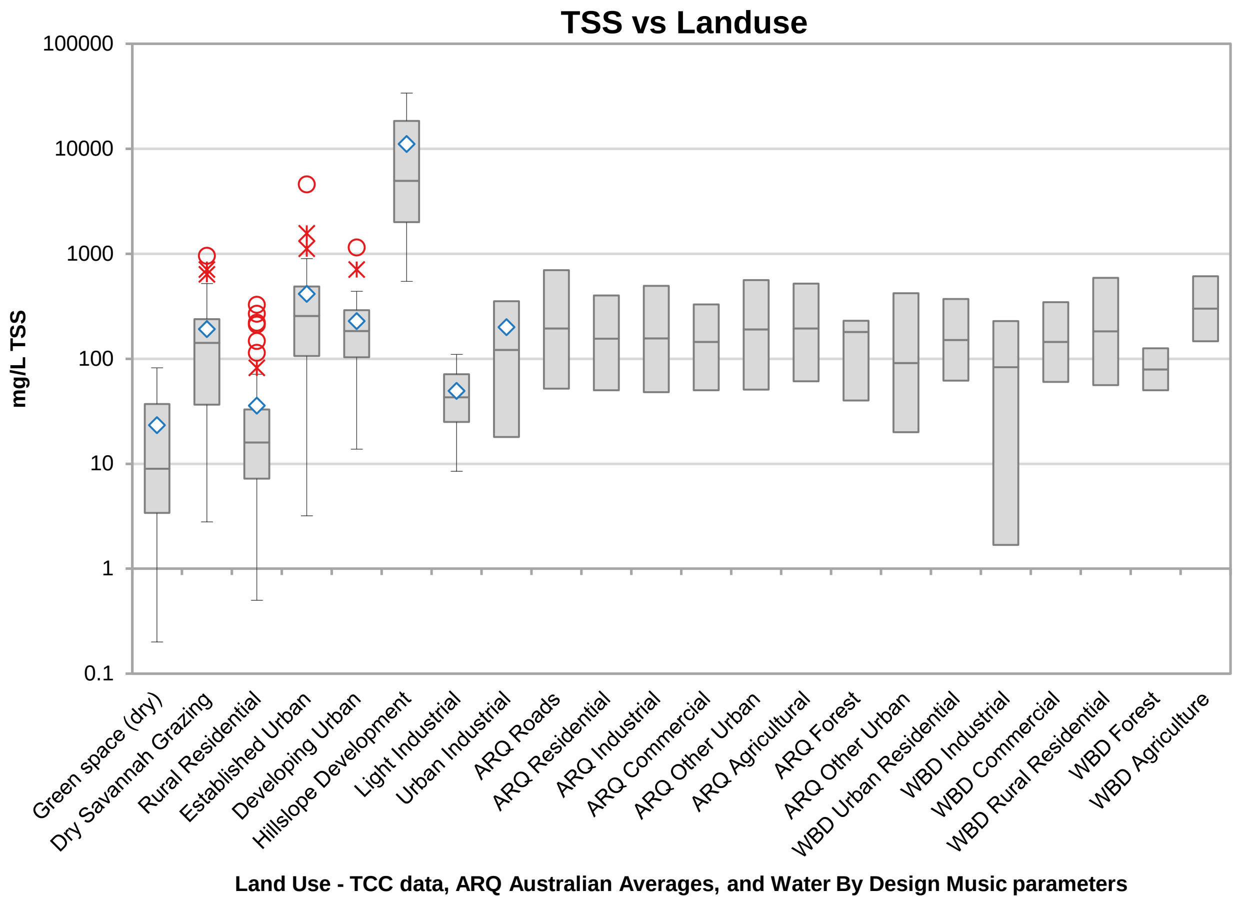


Figure 6-1 Comparison of Townsville stormwater quality data with other datasets (Total Suspended Solids)

6.2.2 Total Phosphorus (TP)

Local Total Phosphorus values generally fall within the ARQ and WbD concentration envelopes, but at the lower bound (Figure 6-2). Further sampling is recommended to verify whether there is a significant difference in TP concentrations in local stormwater.

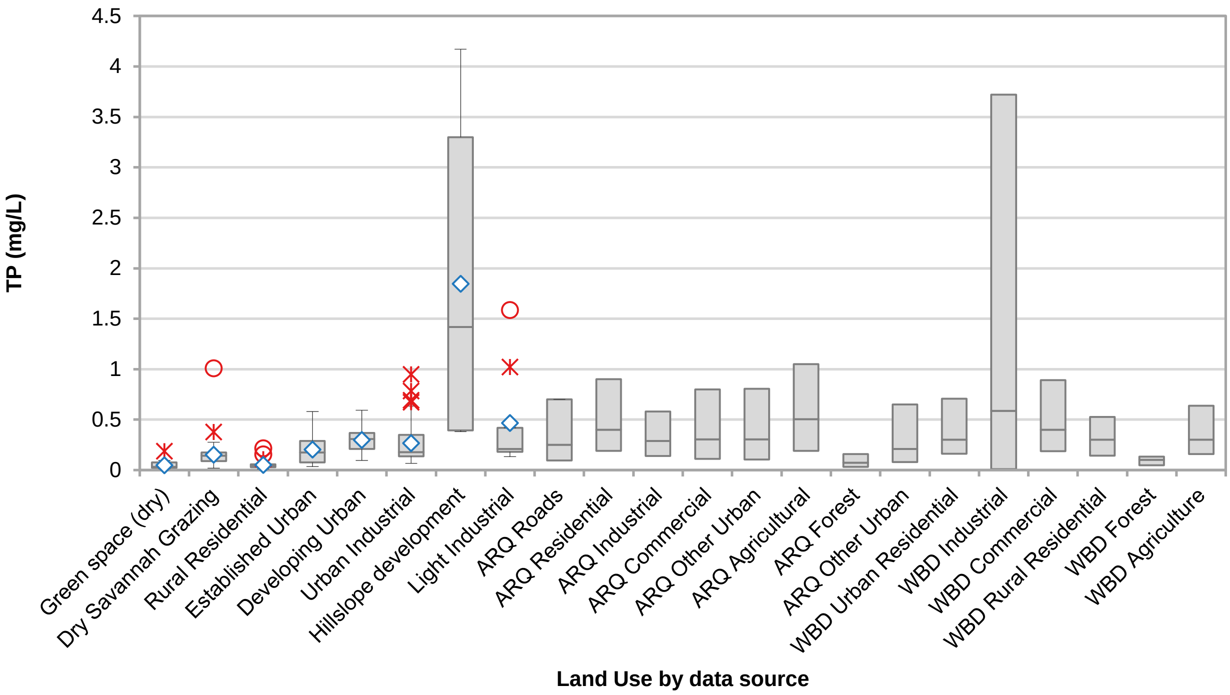


Figure 6-2 Comparison of Townsville stormwater quality data with other datasets (Total Phosphorus)

6.2.3 Total Nitrogen (TN)

Total Nitrogen values for Townsville are consistently lower than the ARQ and WbD values – and could be an order of magnitude lower (Figure 6-3). This is a significant finding.

As with the TSS data, the upper outliers of this dataset overlap the ARQ and WbD values, and a larger dataset is required before making definitive statements. The dominant source of nitrogen in urban stormwater is atmospherically derived nitrogen in rainfall (Engineers Australian 2006), and so it would be unusual to see such low nitrogen values in urban stormwater.

Possible explanations for the low TP and TN values include:

1. The data is incorrect, possibly due to systemic or experimental errors with sampling, analysis or reporting. ACTFR reports have been reviewed, and direct contact made with the researchers involved, and on that basis there is no reason to expect errors of more than 25%.
2. The data is correct, but not representative of local stormwater, possibly because preceding rainfall reduced pollutant loads. However, this seems unlikely as ACTFR (2007) reports: ‘No significant rain fell in the catchment during the beginning of the wet season (i.e. <30 mm from September 2006) before this period. The smaller event of the two occurred from the 20th to the 24th of January, which is considered the first flush event of the season’.
3. The data is representative of local stormwater, and there are some local phenomena that lead to lower TP and TN concentrations in urban stormwater in Townsville.

<u>Further water quality monitoring is essential to resolve this issue, as the management implications are potentially significant.</u>

TN is most commonly managed using biological processes of nitrification and de-nitrification, typically using vegetated stormwater management systems such as bioretention and wetland systems. TN can also be managed by reducing runoff volumes with infiltration or roof/stormwater harvesting.

Vegetated systems have been problematic in Townsville, in part due to the challenges of sustaining vegetation during the lengthy dry season, and managing excessive weed growth when it does rain (catchment and soil conditions are also one of the reasons that vegetated systems are problematic in Townsville). If nitrogen concentrations were in fact found to be low, TN management would be less important and the management emphasis could focus on sediment and phosphorus which are simpler and more cost effective to manage.

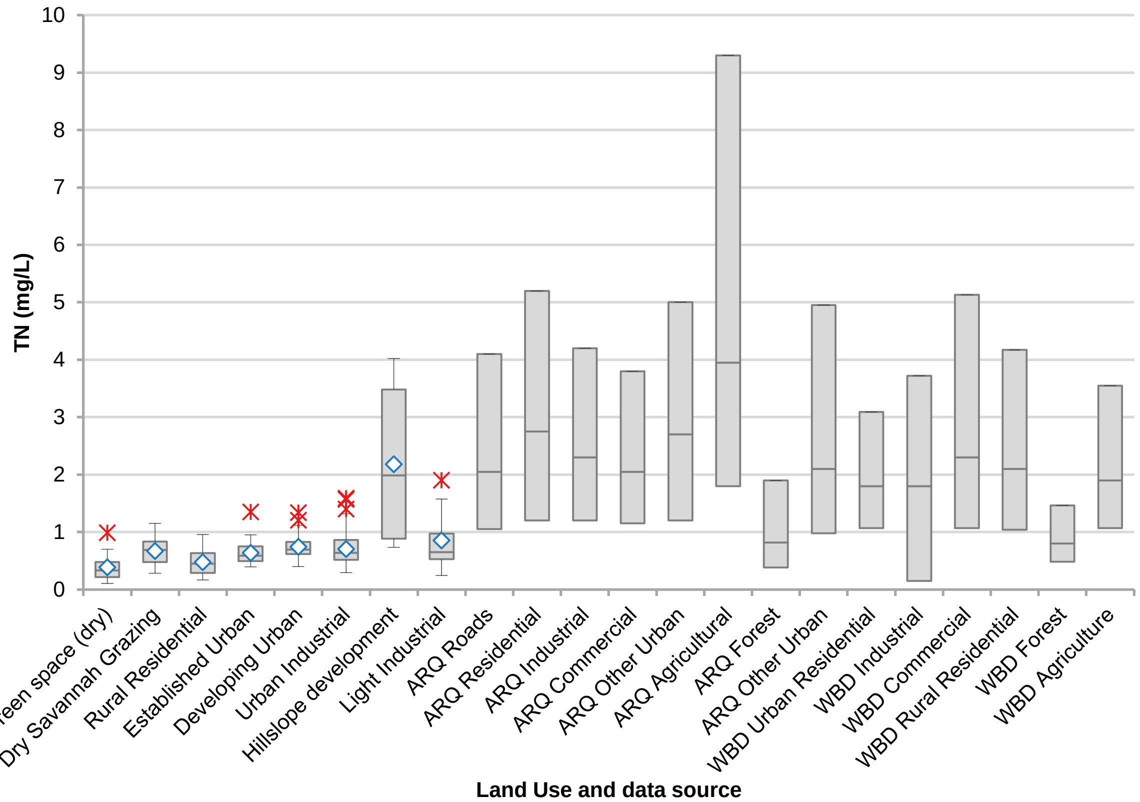


Figure 6-3 Comparison of Townsville stormwater quality data with other datasets (Total Nitrogen)

6.3 Construction Phase Impacts (TSS)

There is limited data in the literature on TSS, TN and TP loads from construction sites.

- Local monitoring downstream of land development recorded TSS values of 6000 mg/L (coastal plain) and 11,000 mg/L (hill slope development). It is unclear how much additional catchment was contributing runoff to the monitoring sites, as both locations are classified as urban/developing urban (Lewis et al., 2008) and there is no readily available aerial imagery at that date.
- Brisbane City Council undertook a monitoring program of a 17 ha construction site at Cannon Hill over 18 months, gathering over 30 samples. It measured concentrations of TSS at 5300 mg/L, TP at 0.9 mg/L and TN at 4.4 mg/L (Tony Weber Pers. Comm.). Such concentrations are likely to be influenced by a broad suite of site specific factors (slope, exposed soil types, management practices, vegetation cover etc.) and it isn't necessarily valid to translate this data to other sites. A senior Brisbane City Council ESC officer considers these results to be unreliable and an underestimate of actual sediment concentrations.
- Field data gathered by the Dept. Environment and Resource Management (DERM) measured sediment deposition rates in a 200 m reach of waterway downstream of an active construction site and measured depositions equating to 285 T/ha/yr (Ted Gardner, Pers. Comm.).

- Field monitoring undertaken as part of an audit by Healthy Waterways Ltd in 2013/14 found 4 of 70 sites were compliant with current standards. Of 21 site runoff samples, the best water quality was found to be 680 NTU, 20 times the legal limit. TSS was recorded up to 25000 mg/L. Healthy Waterways' Scientific Expert Panel suggests a sediment loading rate of 25 Tonnes/Ha based on a TSS value of about 5000 mg/L and a construction window of two years, although such estimates are considered to be at the low end of the range (Andrew O'Neill, pers comm.)

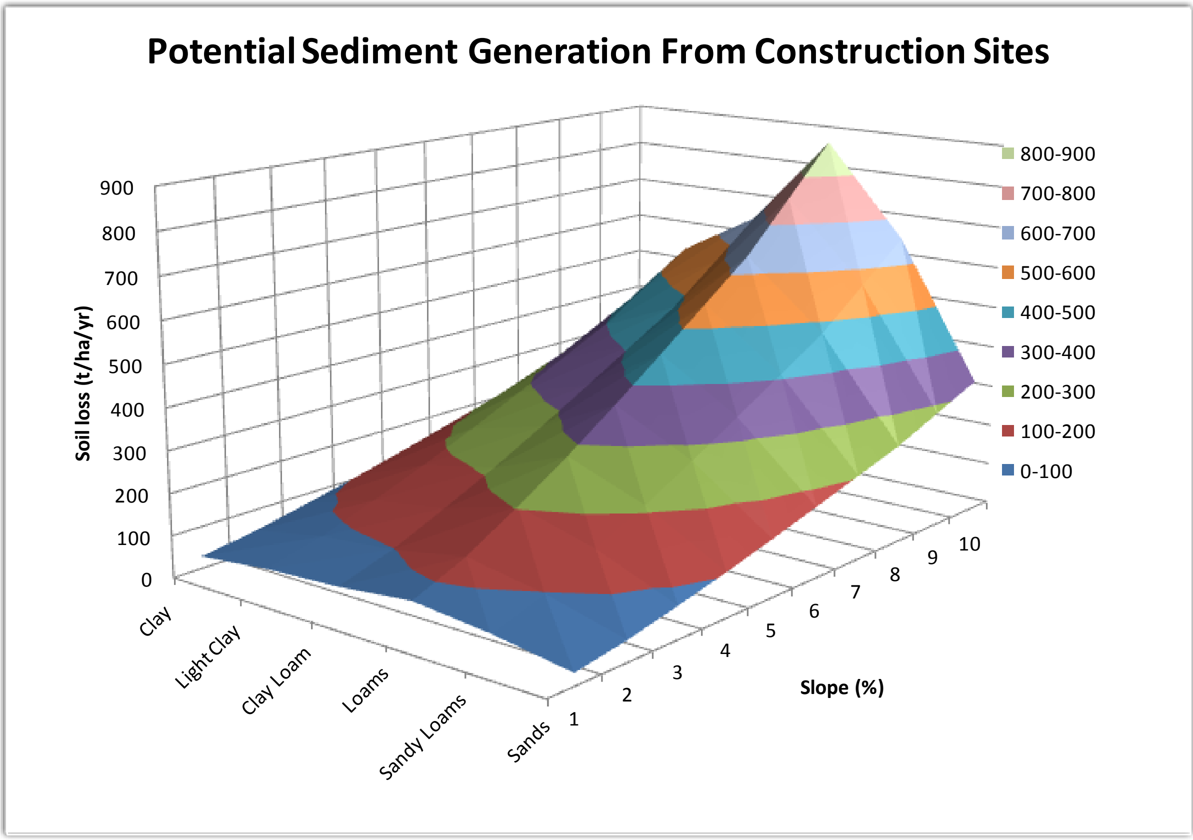
The Revised Universal Soil Loss Equation (RUSLE)[8] has been used to further assist with estimating potential soil loss, with key RUSLE parameters shown in Table 6-1 below, and results presented in Figure 6-4. Note that RUSLE estimates total soil loss, which includes TSS and bed-load. RUSLE is only a general approximation method for sheet erosion, and does not properly account for rill and gully erosion.

Table 6-1 - Adopted RUSLE parameters

Parameter	Value	Notes
I (2yr 6 hr)	17.6 mm/hr	Derived from local rainfall intensity-frequency-duration data from the Bureau of Meteorology
Slope	1%	Assumed slope for most development sites on the coastal plain
LS Factor	0.2	Assumes about 100 m of slope at 1%
R Factor	7400	Computed from the above rainfall intensity.
C Factor	1	Assumes bare soil
P Factor	1.3	Assumes no practices
Soil type	Light clay	Based on site observations
Potential soil loss	50 T/ha/yr	

Figure 6-4 Soil loss estimates from construction sites in Townsville using RUSLE.

[8] For further background on RUSLE, refer http://www.iwr.msu.edu/rusle/about.htm



Based on the above, a sediment loading rate of 50 tonnes/ha has been adopted. This equates to a sediment concentration of 25,000 mg/L over a six month construction period.

6.3.1 Sediments: Turbidity TSS and Bedload

Sediment can occur in several forms in waterways, and TSS may not necessarily provide useful information on the quantity of sediment or its environmental impact. For example, bed-load sediment can be significant in terms of overall mass of material, and geomorphology of a waterway, but does not get measured in suspended sediment samples.

Also, very fine colloidal material, such as that produced from sodic soils, can often result in significant environmental impact by limiting light penetration, yet has very little overall mass. Recent monitoring undertaken by Bligh Tanner in a waterway with sodic soils across its catchment found turbidity levels as high as 350 NTU could be associated with TSS of 30 mg/L.

6.4 Adopted Pollutant Loads

Pollutant loading rates have been derived using the event mean concentration (EMC) and dry weather concentration (DWC) values outlined in Water by Design (2010). This has been adopted over local data due to the limited local dataset, potential concerns about the reliability of that data, and the lack of DWC values.

MUSIC has been used to simulate local runoff, using local 6 minute pluviograph data from Townsville Station 32040 for the period from 1/01/1990 to 1/01/2005. Rainfall runoff parameters are based on the recommended values in Water by Design (2010) in the absence of local streamflow data to use for calibration. A range of one-hectare nodes, each reflecting a different land use, have been used to derive typical areal loading rates for TSS, TP, and TN, and are summarised in Table 6-2.

Table 6-2 Adopted pollutant loads by land use

TCC Zoning Level 1	**Equivalent Land use in WBD(2010)**	Total Suspended Solids (kg/ha/yr)	Total Phosphorus (kg/ha/yr)	Total Nitrogen (kg/ha/yr)
Centre	Commercial	1270	3.27	21.1
Community Facilities	Commercial	1270	3.27	21.1
Emerging Community	Urban Residential	1450	2.85	14.2
Environmental Management and Conservation	Forest	286	0.317	3.44
General Residential	Urban Residential	1450	2.85	14.2
Industry	Industrial	1920	5.01	29.5
Mixed Use	Commercial	1270	3.27	21.1
No Zone	Forest	286	0.317	3.44
Not Zoned	Forest	286	0.317	3.44
Recreation and Open Space	Open Space	719	1.59	8.58
Rural	Rural Res	2210	2.12	16.7
Rural Residential	Rural Res	2210	2.12	16.7
Special Purpose	Commercial	1270	3.27	21.1
Specialised Centre	Commercial	1270	3.27	21.1
Construction sites	All	24,000		

6.5 Other Contaminants

Stormwater contains a wide range of contaminants, yet TSS, TP, and TN, along with gross pollutants, are the primary contaminants regulated by the State Planning Policy and tend to be the focus of stormwater management strategies. The reason the SPP focuses on these pollutants is that they have direct relevance to ecosystems, and also that they serve as surrogates for a range of other contaminants, such that if they are effectively managed, so too will a range of other contaminants. For example, heavy metals typically bind to fine sediments, and so reducing TSS can also lead to reductions in heavy metals.

Nonetheless, it is important to retain an awareness of other contaminants, especially given the environmental sensitivity of the reef and its environs.

Other contaminants include (Engineers Australia 2006):

- Oil and grease
- Turbidity, especially relevant given Townsville’s dispersive soils, which can cause cloudiness in water even at low levels of TSS
- Total organic carbon
- High or low pH
- Heavy metals, including lead, zinc, copper, cadmium, chromium, nickel, iron, manganese and mercury
- Microbiological contaminants, including faecal coliforms
- Biocides, including pesticides and herbicides
- Biological and chemical oxygen demand (BOD and COD).

6.6 Base Flow Water Quality

Townsville's urban drains have an abnormally high base flow resulting from excessive irrigation. No water quality data is available for these flows, although they are expected to contain elevated salinity and nitrates. The base flows could contribute a significant proportion of overall pollutant loads, including chronic loads between storm events.

Monitoring of base flow rates and water quality is needed to better understand its significance in the overall stormwater strategy.

7 GROWTH SCENARIOS

7.1 Future Urban Development

Future urban development has been estimated based on a comparison of:

a) Existing development, based on aerial photography to estimate the existing urban footprint, and using water meters an indicator of whether individual parcels are developed, and

b) Future development, based on Council's current land use zoning.

7.2 Population Growth

Population growth estimates have been obtained from Council for each statistical division through to 2031, which is the adopted planning horizon for this study, and is listed in Table 7-1.

Table 7-1 Adopted population growth estimates

	2015	**2031**	**% Change**
Aitkenvale	5413	5989	11%
Annandale	10958	10882	-1%
Belgian Gardens - Pallarenda	3880	4182	8%
Bohle Plains	7063	12618	79%
Condon - Rasmussen	14514	17641	22%
Cranbrook	6756	6783	0%
Deeragun	25007	45313	81%
Douglas	8678	10173	17%
Garbutt - West End	7471	8911	19%
Gulliver - Currajong - Vincent	8760	8591	-2%
Heatley	4563	4422	-3%
Hermit Park - Rosslea	5706	6213	9%
Hyde Park - Pimlico	5263	5740	9%
Kelso	11497	13149	14%
Kirwan - East	9083	9193	1%
Kirwan - West	18191	18693	3%
Magnetic Island	2672	3266	22%
Mount Louisa	10364	20526	98%
Mundingburra	4154	4347	5%
Northern Beaches	6443	8872	38%
Oonoonba	6186	8796	42%
South Townsville - Railway Estate	5584	6807	22%
Townsville - South	5386	25304	370%
Townsville City - North Ward	11557	22061	91%
Wulguru - Roseneath	6774	7181	6%
Totals	**211,923**	**295,653**	**6%**

7.3 State Planning Policy Thresholds

The stormwater quality targets in the State Planning Policy apply to developments larger than 2500 m^2.

Nearly all the future developable land in Townsville, land zoned as emerging community, or land flagged as vacant in Council' GIS, is above that 2500 m^2 threshold as shown in Figure 7-1 below. This figure is produced by ranking all future development lands by parcel area, and then determining the net proportion of that land which is below key area thresholds.

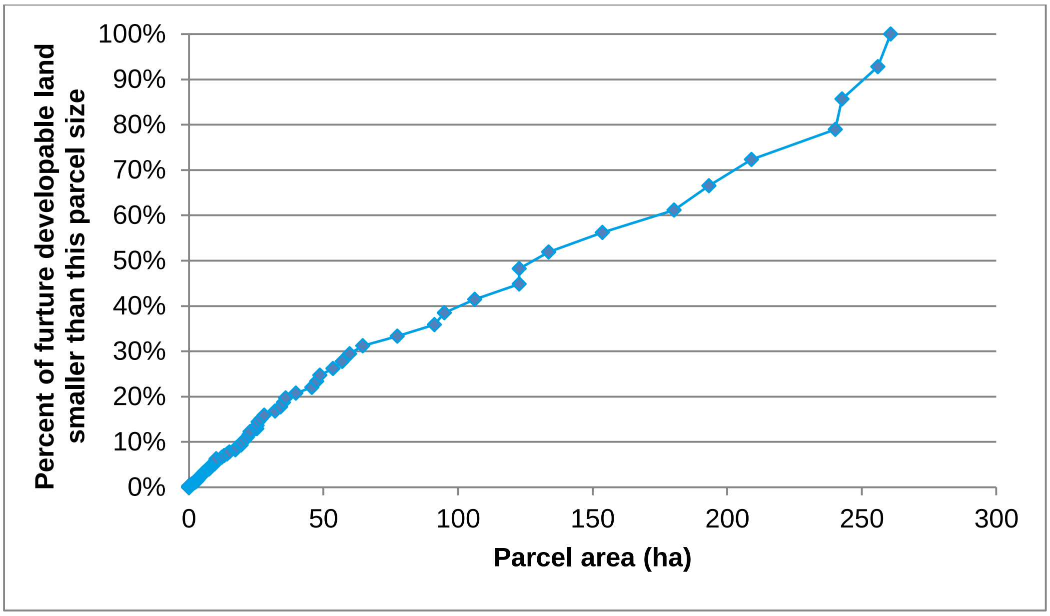


Figure 7-1 Future urban development by parcel size.

8 STORMWATER POLLUTANT LOAD ESTIMATION

8.1 Methods

- Typical stormwater concentrations for TSS, TP, and TN derived from Water by Design (2010) are adopted for seven key land use categories, as described in Table 6-2.
- MUSIC has been run using 15 years of local Townsville rainfall (six-minute time step, 1990 – 2005) to develop typical loading rates (kg/ha/yr) for each of the land uses.
- Each of the 184 property descriptions has been assigned an equivalent land use.
- Each of the land parcels in Council's database (over 81,000) has then been assigned a pollutant rate, by multiplying its area with the pollutant loading (based on the property description). All the parcels within each sub-catchment were added together to get an overall sub-catchment pollutant rate, for TSS, TP, and TN. Existing road reserves and unzoned land have been assigned a pollutant loading rate corresponding to urban residential land use, except for large unzoned parcels that are clearly environmental open space.
- Future loadings are estimated by looking at land which is either flagged as vacant (based on property description) or zoned as emerging community, and then for the future developed state a pollutant loading equivalent to general urban residential land was assigned. The absence of a water meter in the GIS dataset was trialled as an indicator of vacant/undeveloped land, but when compared against aerial photography, there were a large number of clearly developed sites which lacked a water meter entry in the GIS dataset.
- State Planning Policy stormwater quality load reduction targets were then applied to those parcels which develop, provided the parcel is larger than the 2500 m^2 threshold specified in the State Planning Policy.
- Construction phase loads were derived by assuming:
    - a mean annual runoff volume of 4 ML/ha/yr (from MUSIC modelling)
    - a sediment loading rate of 6000 mg/L, which is approximately the average concentration of TSS measured in waters downstream of land development sites in Townsville (ref). This equates to a potential sediment load of 24 tonnes/ha, which is much lower than estimates provided in Hoban (2012).
    - An average duration of active construction of six months (this is a conservative estimate, as most large development sites seek to achieve 80% grass cover at plan sealing).

8.2 Limitations

- There will be some development churn/redevelopment within existing urban areas. This will not significantly change the general pollutant loadings (e.g. Material Change of Use (MCU) from industrial to residential), but will create a construction phase impact which has not been accounted for.
- Properties which straddle a catchment boundary are counted in each sub-catchment, and hence double counted in the overall results. The number of properties this applies to is small compared to the overall area and is therefore negligible.
- The analysis is dependent on the property descriptions in the GIS being reliable and representative of current land use.
- Baseflows are not accounted for as there is currently no reliable data available. Nonetheless, specific baseflow management recommendations are included in this strategy.

8.3 Scenarios

The following scenarios have been examined:

1. Existing
2. Future (ultimate development envisaged under the planning scheme)
3. Future with State Planning Policy stormwater quality targets achieved on applicable development
4. Per scenario 3, with construction phase impacts factored into the analysis.

8.4 Load Estimates

Stormwater pollutant load estimates for the whole of Townsville are presented in Table 8-1 below. Load estimates for each sub catchment are included in Appendix A.

The data shows that future development is likely to result in a marginal increase in pollutant loads. Future TSS loads are forecast to increase by less than 0.5%, with TP and TN increasing by less than 1% (Scenario 2). This increase is generally within the limits of accuracy of the methods used. This minor increase is explained by two factors

- Only a small additional portion of the region (<1.5%) is forecast to become urban; and
- Rural residential land typically has higher pollutant loads than established urban areas, and so the land use change does not necessarily result in additional pollution.

When the SPP targets are met on future applicable development, there will be marginal decrease in pollutant loads.

This analysis suggests that stormwater quality, as addressed by the SPP targets, does not appear to be a significant environmental issue.

Over the next 30 years in Townsville, pollutant loads from construction sites are likely to be greater than that caused by land use change.

Table 8-1 Pollutant Load Estimates

	TSS (T/yr)	TP (T/yr)	TN (T/yr)
Existing Loads	323,803	581	3,236
Future Loads			
Loads	323,819	585	3,252
Change relative to existing	0.31%	0.8%	0.5%
Future Loads, with SPP targets met			
Loads	318,622	575	3,202
Change relative to existing	-1.3%	-1%	-1%
Future loads, plus construction impacts			
Loads	2329,849	*	*
Change relative to existing	2.2%	*	*
Future Loads, with SPP targets met, plus construction impacts			
Loads	324,653	*	*
Change relative to existing	0.6%	*	*

* there is insufficient data to estimate TP and TN loads resulting from construction site activity.

Note that the SPP provides a deemed-to-comply size for bioretention systems at 1.5% of catchment area. To fully meet the adopted targets for Townsville (Table 1-1), a bioretention system would need to be at least 25% larger than that at ~2% of catchment area. Due to the deemed to comply sizing, the actual load reductions achieved may be less than outlined above.

Maps showing the change in TSS loads by subcatchment are included as Appendix B

9 MANAGEMENT OPTIONS

This chapter introduces a range of management options to address stormwater pollution, grouped according to the waste management hierarchy or Avoid, Mitigate, and Offset (Figure 9-1).

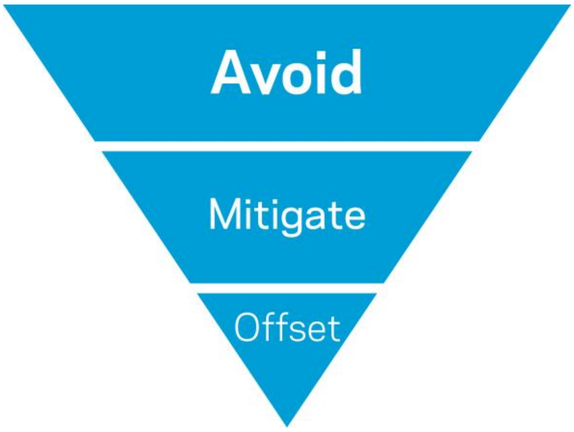


Figure 9-1 Simplified waste management hierarchy

9.1 Avoid/Minimise

The following measures can be used to reduce the generation of stormwater and stormwater pollutants in urban areas.

9.1.1 Urban Design

Urban design influences road and lot layouts and building styles, and has a direct impact on impervious surfaces and the amount of stormwater that is generated. The past several decades in Australia has seen a trend to larger homes being built on smaller lots with lower occupancy rates and smaller backyards (Kelly and Donegan, 2015), while housing models being adopted in the UK are achieving both higher urban densities and larger backyards (Hall, 2010).

Changing urban design and housing designs is a considerable task and urban planning advocates have been trying to affect change for years. Nonetheless, it remains one of the most powerful ways of influencing stormwater outcomes.

For example, building two storey homes instead of sprawling single storey homes can halve the footprint of a house. The smaller roof area and increased garden result in less stormwater runoff, as well as a range of household benefits associated with a larger yard.

9.1.2 Erosion and Sediment Control

Erosion and sediment control (ESC) is a broad term for the suite of practices used to limit sediment laden runoff leaving construction sites. Erosion control should always be considered first, so that soil erosion is avoided or minimised, followed by sediment control which seeks to capture any waterborne (or airborne) sediment. Key practices include avoiding earthworks activities during expected high rainfall periods, careful construction scheduling, maintaining soil cover, sediment fences and sediment basins.

High efficiency sediment basis have significant potential to improve water quality outcomes, as do some of the advanced flocculants now available (subject to them not having adverse toxicity).

9.1.3 Soil investigations

Townsville has some challenging soils (refer section 4.3), with the most challenging soils being sodic marine clays, especially when exposed by excavation for drainage channels, and coupled with elevated water tables from high irrigation.

Past experience in Townsville has shown that if not properly considered, this can lead to:

- Very poor vegetation growth (both understorey and canopy species)
- Accumulations of organic materials which fail to decompose and lead to odorous anoxic conditions
- Bare soils and salt scalds, and
- Poor water quality outcomes.

This issue could be avoided if soil investigations by qualified soil scientists were undertaken as part of land development projects. Such investigations should identify:

- The main soil types and profiles across the site
- How the soils will be impacted by the development
- What measures need to be taken to manage and protect soils and the environment during construction (such as no-go areas, stripping, and stockpile management and protection)
- What the soil profiles will be at the completion of any earthworks
- How the soils are compatible with the hydrology of the site and surrounds
- Any amelioration/additives needed for subsoils and topsoils
- How final soil profiles and types will be compatible with the proposed land uses across the site
- Any residual risks to the development, vegetation and the environment.

9.1.4 Permeable Paving

Permeable pavements can reduce the amount of stormwater runoff and pollutants being generated by urban areas (Sansalone et al., 2012). A range of design options exist, including modular pavers, epoxy-bonded gravels, and confined gravel systems (see Figure 9-2).

Bean et al. (2007) undertook a field survey of permeable pavement surface infiltration rates, looking at concrete grid pavers, permeable interlocking concrete pavers and porous concrete, and found:

- For concrete grid pavers, higher surface infiltration rates can be sustained by regular maintenance using a street sweeper. Removing the top layer of residual material (13 – 19 mm) and replacing with sand can increase infiltration from 49 mm/hr to 86 mm/hr.
- For permeable interlocking concrete pavers and porous concrete, locating the pavement away from areas of disturbed soil was recommended as the accumulation of fine particles dramatically decreased the surface infiltration rates.

Pervious concrete produces higher permeability and better clogging resistance to porous asphalt, and there are significant gains in permeability and clogging resistance found when the porosity was raised beyond 20% (Fwa et al., 2015).

Boogaard et al. (2014) looked at 55 sites located in Netherlands & Australia, ranging from 1 to 12 years old, and tested Australian systems for a 3 month ARI storm. Although infiltration did reduce with age, 90% of pavements were found to perform at this standard. An eight year old permeable interlocking concrete paving system was tested and found to be very effective at filtering and removing sediment from stormwater. While this reduced permeability, the overall infiltration performance of the system was still satisfactory after 8 years of service (Lucke and Beecham, 2011).

Maintenance by vacuuming or sonication (agitation with sound waves) has been found to restore at least 96% of the initial hydraulic conductivity of clogged pavements (Sansalone et al., 2012).

Philadelphia Water has found vacuuming to be effective in maintaining permeability of porous pavements (Stephen White, Philadelphia Water, Pers Comm).

Fine clays and dispersive material in stormwater runoff poses a risk. Permeable pavers have been shown to be effective in reducing turbidity and very fine particles (Sansalone 2012), and over time some of this material may accumulate deeper within the pavement and be difficult to remove.

On the basis of the research above, permeable pavements have potential for use in Townsville, especially in areas with low traffic loads and which are subject to direct rainfall only (rather than being subject to runoff from high sediment areas). Suitable applications include carparks, driveways, and pedestrian areas. The use of permeable paving is consistent with PO7 of the Healthy Waters Code, which seeks to minimise runoff by minimising large areas of impervious material.

Some permeable paving options are cheaper than conventional paving options. So even if infiltration is compromised in the longer term, the use of permeable pavement can still make commercial sense to install.

Figure 9-2 Permeable pavement options

9.1.5 Rainwater Tanks

Rainwater tanks in tropical areas have been linked to the breeding of the dengue vector *Aedes aegypti* mosquito in rainwater tanks with missing or faulty insect screens (Ritchie et al. 2002 as cited in (enHealth, 2004). This issue is addressed by the Queensland Health Regulation (2005) which requires tank openings to be covered with either a brass, copper, aluminium, or stainless steel gauze not coarser than 1 mm aperture measure (Queensland, 2005). Such measures would need to be diligently inspected to ensure compliance. Nonetheless, there remain strong reservations to rainwater tanks in Townsville due to concerns about mosquito breeding.

Rainwater tanks can be a simple lot-scale solution for reducing stormwater runoff, and supplementing mains water supply to households. The effectiveness of rainwater tanks in Townsville has been assessed using MUSIC, with local 6 minute pluviograph data, and a simplified cost analysis.

The performance of a 5 kL rainwater tank using local water consumption demands is shown in Table 9-1). The tanks were found to provide 50 kL annual water yield, equating to 8% of annual demand met, and 49% load reduction.

Table 9-1 Rainwater tank reuse demands (based on 2.5 person detached dwelling in Townsville)

	Townsville local data	**MUSIC Parameter**	**MUSIC Input Value**
Indoor toilet and laundry demand	88 L/person/day	Daily Reuse Demand	0.22 kL/day
Outdoor irrigation demand	530 L/person/day	Annual Reuse Demand	484 kL/yr

As discussed in the Section 4.5, the water price in Townsville is very low compared with most major urban centres. A lower and upper water price range of $1.087 /kL and $3.781 /kL was respectively used in order to assess the cost-effectiveness sensitivity to water price. At current Townsville water prices and consumption rates, rainwater tanks do not appear to be a cost-effective way of addressing stormwater pollutant loads. This does not necessarily mean that rainwater tanks are uneconomical, and a broader economic analysis of rainwater tanks is recommended.
However, the cost-effectiveness was found to be highly sensitive to water prices, especially for TSS removal. For TN, the cost effectiveness to tanks is comparable to bioretention systems.

If water prices were to approach those of SEQ, the benefits of tanks would outweigh the costs, making tanks one of the most cost effective ways of reducing stormwater pollution loads.

A recent innovation is the Talking Tanks concept. Developed by iota, the commercial arm of South East Water, Talking Tanks monitors water levels in a rainwater tank and automatically releases water at a controlled rate if required. The system pre-empts the release of water from set points that are chosen by the user, according to rain or storm predictions which are received via a communications link to the Bureau of Meteorology.

The system developers state “stormwater can increase the risk of overflow into urban waterways and, in some cases, carry litter and pollutants or cause erosion. The system automatically releases water, creates storage capacity and prevents overflows of stormwater. With unique self-learning, these intelligent systems are paving the way forward for efficient management of rainwater tanks”[9].

Note that this does not constitute a proper economic assessment of rainwater tanks because it does not account for potential augmentation of regional infrastructure and the reduced demands on infrastructure demands now and in the future. A proper economic assessment should be undertaken to understand the true cost effectiveness of rainwater tanks in Townsville. That analysis should include the risks of disease and any associated public health costs, any benefits in deferring major water supply augmentations (e.g. the Burdekin pipeline duplication), water quality and hydrology benefits, and impacts on community resilience.

While the costs and benefits of tanks have been investigated previously, there is potential that a new analysis may provide new insights into the role that tanks could play in a total watercycle context. For example:

- ‘Talking tanks’, that can be remotely emptied prior to major storms, could play a role in management of flood events and optimisation of existing drainage assets. This could be increasingly important as climate change and changes to flood estimation techniques alter previous assumptions about flood immunity in urban areas

[9] http://www.iota.net.au/water/tank-talk/ and http://www.sustainabilitymatters.net.au/content/water/article/monitoring-rainwater-with-talking-tanks-789774949, accessed 21 August 2015

- Accounting for the water quality benefits provided by tanks
- Incorporating various water price path scenarios.

9.1.6 Downpipe Diverters

Downpipe diverters are a simple way of adapting existing downpipes so that rainfall is used to water gardens. This uses water that would otherwise create excess stormwater, and instead provides nutrients for gardens. These devices are low cost, would provide some benefit in Townsville's climate, and have wide applicability in that they are easily retrofittable.

A robust design has recently been developed by Melbourne Water (as shown in Figure 9-3) and system packages have been provided to residents via local governments[10]. The device costs $135 each, and installation costs vary depending if installed during initial house construction rather than as a retrofit. Over 500 have been installed in Melbourne to date (see for example Figure 9-4).

It is recommended that downpipe diverters be trialled for a small number of houses in Townsville to investigate their uptake potential and to evaluate the costs, as well as risks in terms of mosquito breeding.

Council could offer the devices for free or for a subsidised cost. A licenced plumber could then install the devices subject to a quick inspection of the site to ensure there would be no nuisance drainage issues. Homeowners would be provided with a factsheet outlining the benefits to their gardens and to the environment, as well as instructions on routine inspections and maintenance.

Alternative options include directly discharging downpipes to pervious areas, and also removing guttering altogether which is a common practice in Darwin.

[10] http://www.portphillip.vic.gov.au/june-2015-media_6087.htm accessed 12th August 2015

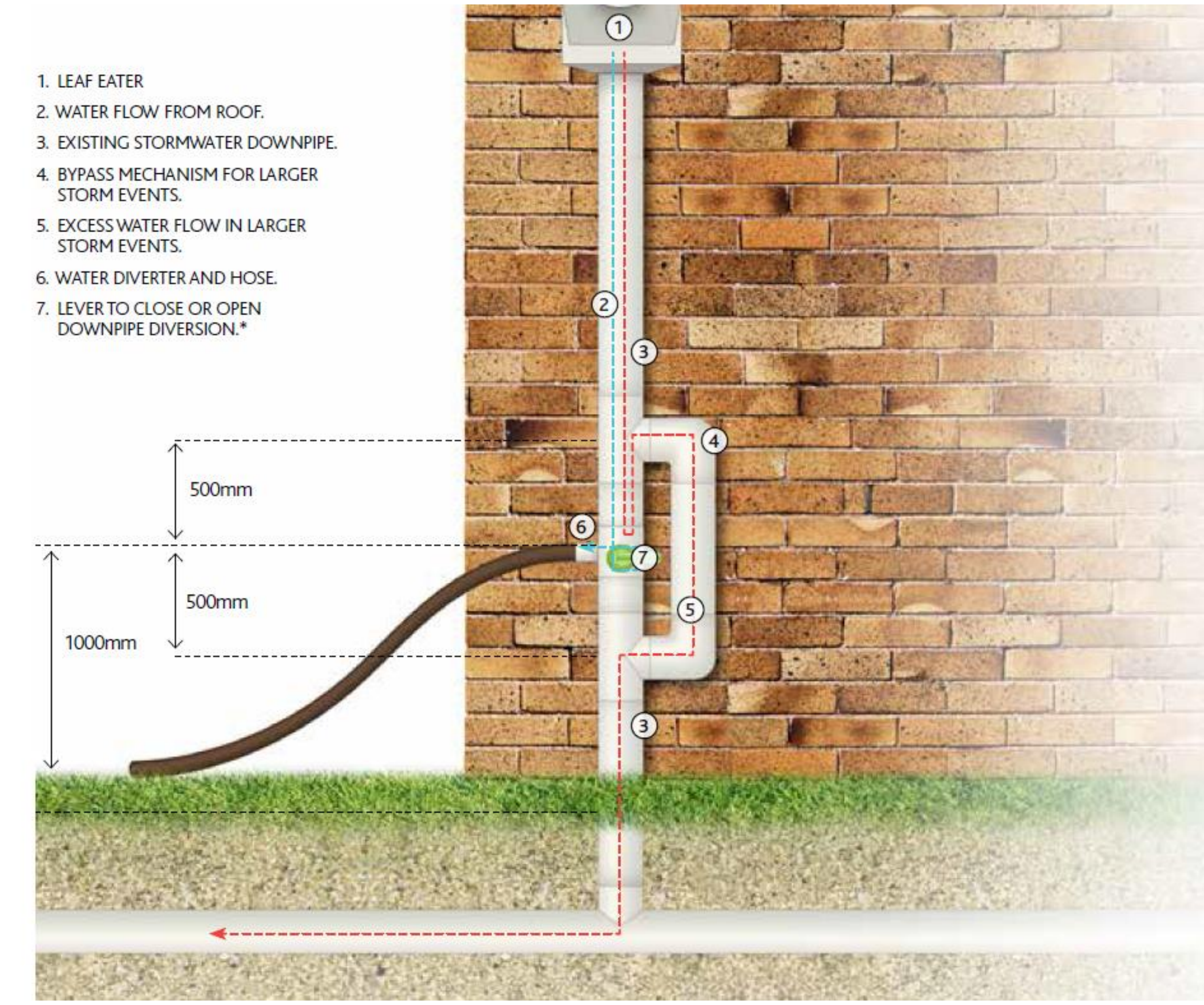


Figure 9-3 Downpipe Diverter typical arrangement Source: Melbourne Water.

Figure 9-4 Downpipe Diverter - Meyer Rafael of St Kilda East says the condition of his soil has already improved after his downpipe diverter was installed. Source: City of Port Phillip.

9.1.7 Irrigation Efficiency

More efficient irrigation can lower water tables and reduce persistent baseflows in stormwater drains, while minimising stress on local water supplies.

In 2015, Townsville Council released a media campaign featuring Bradley the Lawn Tamer, which is designed to help local residents have healthy lawns while using less water. Further information, videos and factsheets are available at: http://tameyourlawn.com.au/.

Evaluation data on this programme could be used to further refine its methods and messaging, and then expand its market penetration.

Further incentives that could be provided include rebates on drought resistant turf species, mulch and soil moisture sensors, and awards and recognition for low water use gardens.

9.1.8 Street Sweeping

Street sweeping can help reduce general litter loads (anthropogenic litter, organic litter and coarse sediment), but is less effective at addressing fine sediment and associated pollutants for example, a study of street sweeping activities in Illinois found mechanical street sweeping at frequencies as great as twice weekly is not effective in reducing the mean concentrations or total loads of pollutants in urban storm runoff (Terstriep et al., 1982).

9.1.9 Litter Control

Queensland appears as one of the worst performers of the mainland states for the presence of litter (McGregor Tan Research. 2012). Queensland's Litter and Illegal Dumping Action Plan (Oct 2013) offer a range of strategies for addressing the barriers and/or reasons used by people who engage in littering and illegal dumping, including education, awareness, targeted compliance and enforcement.

Litter can also be managed through local regulations, for example:

- Plastic bag bans. For example, since 2013 in Tasmania retailers can no longer supply shoppers with non-biodegradable, lightweight plastic shopping bags[11]. The City of Freemantle has a similar law.
- Container deposit schemes, such as that which has operated in South Australia since 1977 and has led to South Australia having the lowest percentage of beverage containers in litter than any other state or territory in Australia[12].

9.2 Mitigation Measures

The following measures can be used to mitigate the level of pollutants in urban stormwater.

9.2.1 Gully Baskets

Gully baskets are simple mesh baskets which can be retrofitted into existing stormwater gully (side entry) pits. When fitted with a 200 micron mesh, they can be an effective way of capturing and storing gross pollutants and particulate-bound pollutants, in a dry state.

Periodic cleanout with a vacuum truck is required. There is currently no scientific studies on the required frequency – although clean out at least twice per year would be a minimum with higher frequency in higher litter generating areas.

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[11] http://www.plasticbags.tas.gov.au/ accessed 22nd July 2015
[12] http://www.epa.sa.gov.au/environmental_info/container_deposit accessed 22nd July 2015

Pollutant removal rates of 51% TSS, 30% TP, and 22% TN are likely (Tonkin and Taylor 2003, Bligh Tanner 2014, Designflow 2015), although actual performance will be sensitive to the particle size composition of local stormwater.

They are best suited to litter hot spot areas such as town centres, commercial areas, around schools, and recreational facilities. Priority areas for gully baskets are shown in Appendix C.

9.2.2 Vegetated Swales

Swales are simple grass or vegetated drainage lines that can be a low cost way of conveying stormwater and helping provide some reduction in stormwater pollutants. They have low upfront costs, and if installed in open space or parkland, maintenance costs are minimised.

There are already a number of existing swales in Townsville which appear to be functioning well with low maintenance requirements. Shallow localised swales appear to work well in the area. Care should be taken to avoid deep swales that intersect poor sodic soils and which have significant base flow. This is to ensure they are easy to mow, avoid boggy conditions, and avoid providing an opportunity for saline groundwater to be expressed.

9.2.3 Gross Pollutant Traps

Leaves and other organic material makes up a large proportion of the gross pollutants in urban stormwater, and forms a substantial ‘bycatch’ in efforts to prevent anthropogenic litter entering waterways.

Queensland appears as one of the worst performers of the mainland states for the presence of litter (McGregor Tan Research. 2012). Queensland’s Litter and Illegal Dumping Action Plan (Oct 2013) offers a range of strategies for addressing the barriers and/or reasons used by people who engage in littering and illegal dumping, rather than structural controls.

In wet-sump style gross pollutant traps (GPTs)—which are the most common type—organic litter decomposes and creates anaerobic conditions, which can lead to the leaching and desorption of bioavailable nutrients and metals. For example, Allison et al (1999) found increases in TP and TSS downstream of CDS™ units in dry weather conditions. Brisbane City Council's Stormwater Quality Improvement Device Monitoring Report (2000, unpublished) found similar results to the above reports, with increased concentrations of TN and TP downstream of a wet sump GPT following four monitored storm events.

Abood M. and Riley S.J. (1997) found that gross pollutants had a deleterious effect on water quality, and the decomposition of the gross pollutants increased with time whenever the gross pollutants were kept within a wet anaerobic environment. Significant increases in phosphorus, nitrogen, COD, and suspended solids, in non-aerated pools were observed during the first 100 days after collection. Cigarette butts were found to increase phosphorus, suspended sediment, and conductivity, and COD loads within the samples within about 10 days of being immersed.

Hunter (2001) reports that wet vaults should be cleaned out as soon as possible after a rainfall event and at intervals not exceeding 30 days. Inspection of the device, to determine the need for cleaning, should occur after 10 mm of rainfall or every 2 weeks, whichever comes first. Such maintenance regimes are unrealistic, with most GPTs subject to an annual cleanout at best.

On this basis, the use of wet sump GPTs should be avoided.

There are a range of trash racks and litter traps which hold collected material in a dry state which are worth considering in high-litter locations. Gully baskets are discussed separately in Section 9.2.1.

Melbourne Water used floating litter traps in the Yarra River to both collect buoyant litter and increase public awareness of litter issues.

9.2.4 Wetlands

Stormwater treatment wetlands are specifically designed to accept and treat stormwater. They are ideally densely vegetated water bodies that use enhanced sedimentation, fine filtration, adhesion, and biological uptake and transformation processes to remove pollutants from stormwater.

Wetlands are best located on flat land, and so have some potential in Townsville, although wetlands are also susceptible to aquatic weed infestations, and the high evaporation rates during the dry season poses challenges for establishing and sustaining plants.

Many constructed wetlands do not establish or sustain adequate plant coverage. Some potential causes of this include:

- Larger areas being too deep for healthy plant growth
- Damage to plants from waterfowl
- Prolonged inundation during rainfall events (due to the wetland being poorly sized for its catchment, outlet not having sufficient capacity, or outlet being prone to blockage).

The research on pollutant removal performance for constructed wetlands is limited and inconsistent, and whilst most studies have shown that both natural and constructed wetlands retain nutrients and sediments, others have shown that they have little effect, or even increase nutrient and sediment loads to receiving water bodies (Fisher and Acreman 2004, Coleman 2007 and Lucas et al 2015).

In Townsville, any new wetlands should be based on mimicking existing natural wetlands in the area as this is likely to result in the most resilient systems. Adapting natural wetlands to treat urban stormwater runoff is not acceptable to Council.

9.2.5 Bioretention (raingardens)

Bioretention systems, also known as raingardens) are vegetated soil filters that treat stormwater through vertical percolation through a prescribed filter media. Water quality is managed through a combination of evapotranspiration, exfiltration, filtration, sorption, transformation, and biological uptake. Short term studies in the lab and field indicate good pollutant reduction potential. However, there are few long term field trials. Success has been variable, with a 15-year-old system in SEQ having good vegetation growth and low maintenance requirements. There are also many more cases of very poor design and implementation. Some systems which appeared to perform well for several years have suffered from vegetation dieback.

One of the major benefits of bioretention systems is in slowing and minimising runoff. A summary of recent research on the hydrologic benefits of bioretention is provided in Table 9-2.

In Townsville, there is still insufficient evidence to be confident about the long term viability of bioretention systems. There are some prominent failures with very large bioretention systems. Smaller systems, tailored into the urban design at Jezzine Barracks, appear to be establishing well and will be interesting to observe over time.

The use of saturated zones underneath bioretention systems is likely to assist in helping plants survive extended dry periods.

To manage the risk of failure and promote better urban design integration, individual bioretention systems should be limited in size to less than 500 m² based on a 3.3 ha catchment size.

Table 9-2 Hydrologic benefits of bioretention systems (raingardens)

Study Authors	Year	Location	Study type	Bioretention type	Volumetric Losses	Peak Flow Attenuation
Lucke & Nichols	2015	Qld	Controlled dosing to simulate 30m 2r ARI event	3 x 10 yr old Streetscape pods, designed with impervious liner	61.6% (n=12)	79.5% - 93.6%
Parker	2010	Qld	Field monitoring, real storms	Newly installed, mid size, ~250 m²	42% (n=18)	94%
Mckenzie-McHarg et al	2008	Qld	Controlled dosing, reflecting a 4EY storm (3kL)	2 x streetscape bioretention pods	23% (n=5)	75%
Hunt	2006	USA	Field monitoring, real storms ~1 yr ARI	Mid size bioretention cells, constructed in 2001, on vey low permeability soils (0.0014-0.0042 mm/hr)	78% (n=48)	Not reported

9.2.6 Watersmart Street Trees

Simple designs allow runoff from kerb and channel to provide water into the root zone of street trees.

The use of passively irrigated street trees is increasingly being adopted by local governments such as Melbourne City Council (which has been trialling various designs for over 10 years), City of Sydney, Brisbane City Council, New York City, and in the UK.
Research shows that trees irrigated with stormwater grow about twice as fast as those irrigated with tap water. This was found to be the case across a range of tree species and soil types (refer Figure 9-5). Note that street trees often receive no irrigation at all, so this approach provides not only a source of water but one which is highly beneficial (Denman et al 2011).

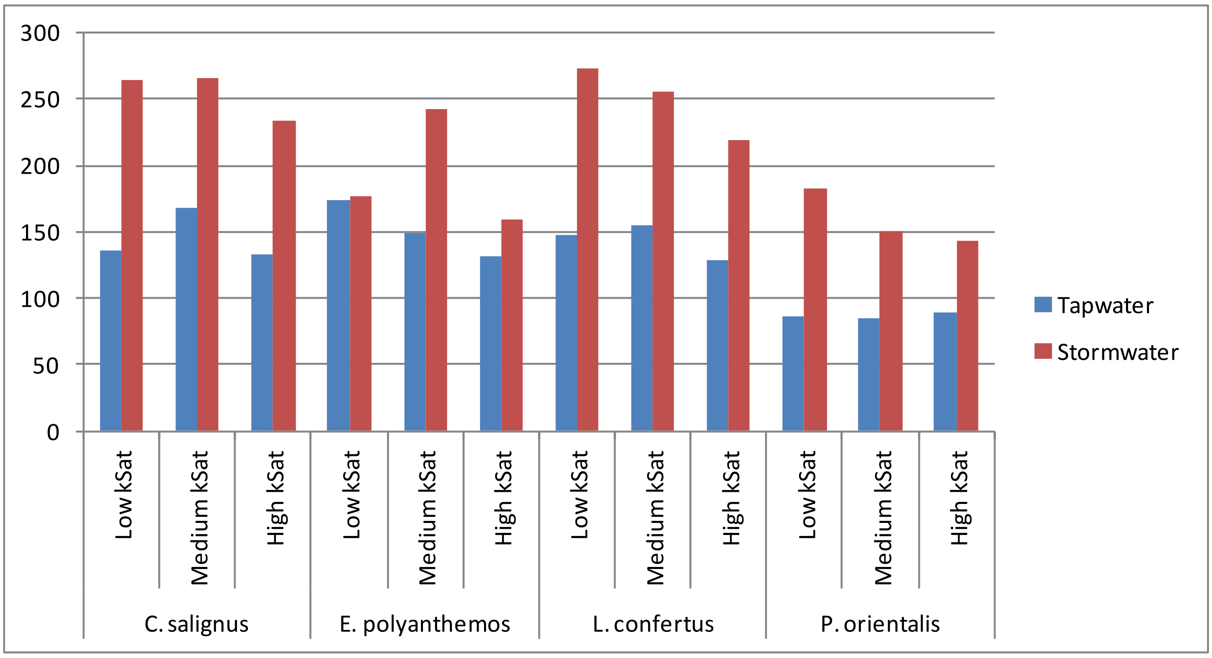

Figure 9-5 Comparison of tree growth with stormwater compared with tap water - height increase in cm over 10 months (Denman et al., 2011)

The stormwater quality benefits of each individual tree are modest, however there is potential for widespread application, with a large number of trees having a cumulative impact.

9.2.7 Proprietary Filtration Devices

A range of proprietary stormwater treatment products are available on the market, such as cartridge filtration devices. The performance claims of such products are often inflated, and a review by Bligh Tanner of cartridge filtration devices marketed by Stormwater360™ and SPEL™ found significant discrepancies between experimental results and claimed performance. Manufacturer's claims are almost always overstated and not based on credible science. The Humes Jellyfish™ and Rocla Enviss™ system, are probably the best credentialed proprietary systems currently available.

The performance of proprietary stormwater treatment devices is highly dependent on regular replacement of filters. Such devices do not provide the broader potential benefits of water sensitive urban design (amenity, hydrology, landscape, passive irrigation) as intended by the State Planning Policy (SPP), and instead have a single function of water quality improvement. The water quality performance of such devices is difficult to assess, and there are no universally accepted ways of doing so.

There are no Australian or state government mechanisms in place to ensure the maintenance of proprietary stormwater products. Most of the products being marketed in Australia originate from the United States (US), where the federal government has a framework and mechanism in place to ensure annual maintenance inspections and reports. However, in Australia, the absence of any such requirements by Australian or Queensland Governments means that the owners of such devices are, on the whole, simply not maintaining them. No local government in Queensland has yet developed an effective regime to ensure such devices are maintained.

Without maintenance, the claimed water quality benefits are not achieved once the initial filter is blocked – anywhere from several months to several years. Because the devices are generally in hidden underground chambers, and go into a bypass mode once blocked, there is no visual indicator as to when this has occurred.

The upfront cost of the devices are generally more expensive than most other ways of managing water quality, and so rarely represent good value for money and contribute to higher than necessary development costs, and the ongoing maintenance, if it were to occur, is an expensive ongoing cost. If Council were to administer a scheme of ensuring maintenance occurred, it would likely involve significant administrative resources in tracking the location, type, and history of assets on private property. Issuing of annual notices to the owners (or perhaps tenants) and requiring evidence of the required annual filter replacement would consume resources, and put council in potential conflict with its local businesses as the cost of filter replacement (in the vicinity of $5,000/ha/yr) would be seen as a council impost.

Approvals of proprietary stormwater quality devices is a technical minefield, as stormwater quality is complex and variable. Even in the US, there are no universally accepted approaches for how to test and validate the performance of such products. Many of the performance claims have been debated by industry experts. Council simply does not have the resources to assess such a complex set of literature. Recently the City of Gold Coast sought to implement a Proprietary Device Protocol and has been threatened with litigation and is incurring significant costs in legal and expert's fees.

Such measures have become seen to be a simple way of demonstrating compliance for development approval purposes, and most vendors will prepare stormwater management plans which specify their products free of charge. Developers are rarely provided comparative costs of various options.

The regional stormwater strategy should seek to minimise the use of such devices in favour of more cost effective and resilient water quality management options.

9.3 Offsets

The following measures could be undertaken in lieu of managing stormwater on individual developments. Some of the mitigation measures listed above could also be used in an off-setting context, such as large regional wetlands.

9.3.1 Lake Management

There are at least a few artificial urban lakes which have chronic infestations of *Salvinia molesta*, a class 2 declared weed, as well as several lakes that have experienced, or are at risk of experiencing, blue green algal outbreaks. Based on this experience, new urban waterbodies should not be created.

Harvesting of aquatic weeds from lakes directly reduces aquatic biomass and contributes to water quality improvements. In the context of the regional stormwater strategy, weed harvesting could be used to reduce stormwater pollutant loads if the pollutant composition of harvested weeds were known.

Offset schemes generally only allow credit for actions that are additional to existing obligations, and since management of Class 2 weeds is an existing obligation, it may be difficult to justify funding such activities through offset funds. This is worth exploring further.

9.3.2 Riparian Revegetation

Riparian revegetation is a good thing. It improves habitat, sequesters carbon, stabilises stream banks regulates hydrology and improves biodiversity. However, there is a broad body of literature pointing to the high level of variability and uncertainty in the water quality benefits of riparian vegetation. For example:

- Bartley et al (2015), in Stream bank management in the Great Barrier Reef catchments, reports:

  - there is considerable evidence that riparian zones will not significantly reduce nutrient loads to streams (Line et al., 2000; McKergow et al., 2003), and in many cases nutrient yields, particularly nitrogen, will actually increase following re-establishment of a riparian zone over time (Howard-Williams and Pickmere, 2010; Connor et al., 2013) (p 22).
  - Fencing off and revegetating riparian zones have been shown to be effective at <10 studies around the world, with improvements to sediment erosion, concentrations and/or yield in the order of 30-90%. However, there are almost as many studies suggesting that the remediation was not effective (p 27).

- Thompson and Parkinson (2011) compared open and forested reaches of waterways and found no change in algal biomass (an indicator of nutrient availability). They conclude that riparian plantings may have some positive effects on streams, even without broader catchment improvements in water quality and hydrology.

- Dosskey et al. (2010) writes:

  > Prolonged removal of riparian vegetation, such as what occurs after conversion to row cropping, reduces surface litter, soil organic matter stocks, and channel organic matter which may require many years to centuries to fully recover after the restoration of permanent vegetation (Matson et al., 1997; Hooker and Compton, 2003). Soil porosity and organic matter content can take many years or decades to redevelop (Seguin et al., 2006). Regrowth of mature forest and production of large woody debris can take decades or centuries (Beschta and Kauffman, 2000; Gregory et al., 2007). In some situations, disturbance may cause irreversible changes and effective components and processes never fully recover (Scheffer et al., 2001; Dupouey et al., 2002; Suding et al., 2004). For example, removal of riparian vegetation that coincides with runoff-enhancing climate change and agricultural and urban development in uplands may initiate channel incision that permanently lowers the riparian water table to below the root zone. Restoration of riparian vegetation, in this case, may not include the original vegetation types and may not reconnect groundwater with the root zone and root zone processes to the original degree. Furthermore, accelerated bank erosion may remove the restoration zone before slowly accruing vegetative components, such as soil organic matter and large wood, are restored to their original status. In these examples, stream chemistry will not be resilient and return to its original condition.

Based on the above, there is not a sufficient evidence base to justify investment in riparian revegetation as part of the regional stormwater strategy, while every effort should be made to protect any intact riparian vegetation.

9.3.3 Gully Erosion Management

Wilkinson et al. (2015) reviewed recent sediment source tracing, erosion mapping and catchment modelling studies, finding that gully erosion contributes approximately 40% of all fine sediment to the Great Barrier Reef (GBR) lagoon. This makes gully management a high priority for investments to reduce sediment loads.

The principles of gully management success are to increase the efficiency of sediment trapping within gullies, improve vegetation cover in gully features to improve stability, and to reduce surface runoff. The combination of techniques recommended for achieving these principles in GBR grazing lands are:

- Fence around gully features to heavily restrict the magnitude of livestock grazing pressure and control the timing of any occasional grazing to within the dry season.

- Revegetate the gully channel by trapping fine sediment and seed with small porous check dams with small catchment areas, or larger engineered structures where bed level control is required to prevent upstream gullying.
- Revegetate gully features with native perennial tussock grasses, where they will not return naturally.
- Manage grazing pressure and timing in surrounding catchment areas to maintain or restore perennial pasture biomass, and avoid vegetation clearing except weed species.

By comparing the gully management approach proposed for GBR catchments with international studies of gully remediation. It is estimated that the proposed approach can reduce gully sediment yields by 50% (Wilkinson et al., 2015).

Wilkinson et al (2015) estimated the cost of the above combined treatment at between $4,500 and $9,000 per km of gully. The cost-effectiveness of gully management is maximised by targeting catchment management units contributing the most sediment per km of gully. In the eight GBR management units with highest length-specific contributions, the cost-effectiveness of gully management in priority management units ranges between $81 and $217 per tonne of reduction in mean annual sediment load.

Due to the widespread steep and erodible terrain across Townsville, there is ample opportunity for gully erosion management. Specific areas for intervention should be prioritised in partnership with NQ Dry Tropics.

9.3.4 Agricultural Land Management

Townsville LGA contains large areas of rural and rural residential (peri urban) lands which are estimated to generate 45% of overall sediment loads (compared with 26% for urban areas and 28% for other open space). The Black Ross Water Quality Improvement Plan recommends the management actions outlined in Table 9-3 below.

These actions could potentially be funded through a water quality offsets scheme as more reliable data on the efficacy and cost effectiveness of such measures becomes available. However, some of the stakeholders consulted as part of this project were of the opinion that any money collected for stormwater quality offsets should be expended in urban areas to help contribute to the amenity of urban waterways.

Table 9-3 Agricultural Management Actions (Source: Black Ross WQIP).

MAT 4.1	Grazing best practice programs being implemented in the rural areas of Townsville
MAT 4.2	Intensive agriculture (horticulture and sugar cane cropping) best practice management actions being implemented within rural and peri-urban catchments across Townsville
MAT 4.3	Non-urban diffuse source pollutant loads reduced through cost effective approaches to erosion prevention and property management in priority sediment source catchments

9.4 Options Evaluation

The cost effectiveness in reducing TSS loads for the most viable management options listed above is shown in Figure 9-6 below. It highlights significant differences in cost effectiveness between management options, and that there are many options which are more cost effective than bioretention systems. Prima-facie, this demonstrates that there are cost savings which can be achieved by altering policy settings to encourage a broader suite of management actions. Full details of cost assumptions are provided in Appendix A.

A clear and simple evaluation of options is shown in Figure 9-7 which rates options in terms of their value, ease of implementation, applicability and ability to provide multiple benefits. The preferred suite of options are highlighted in the green region.

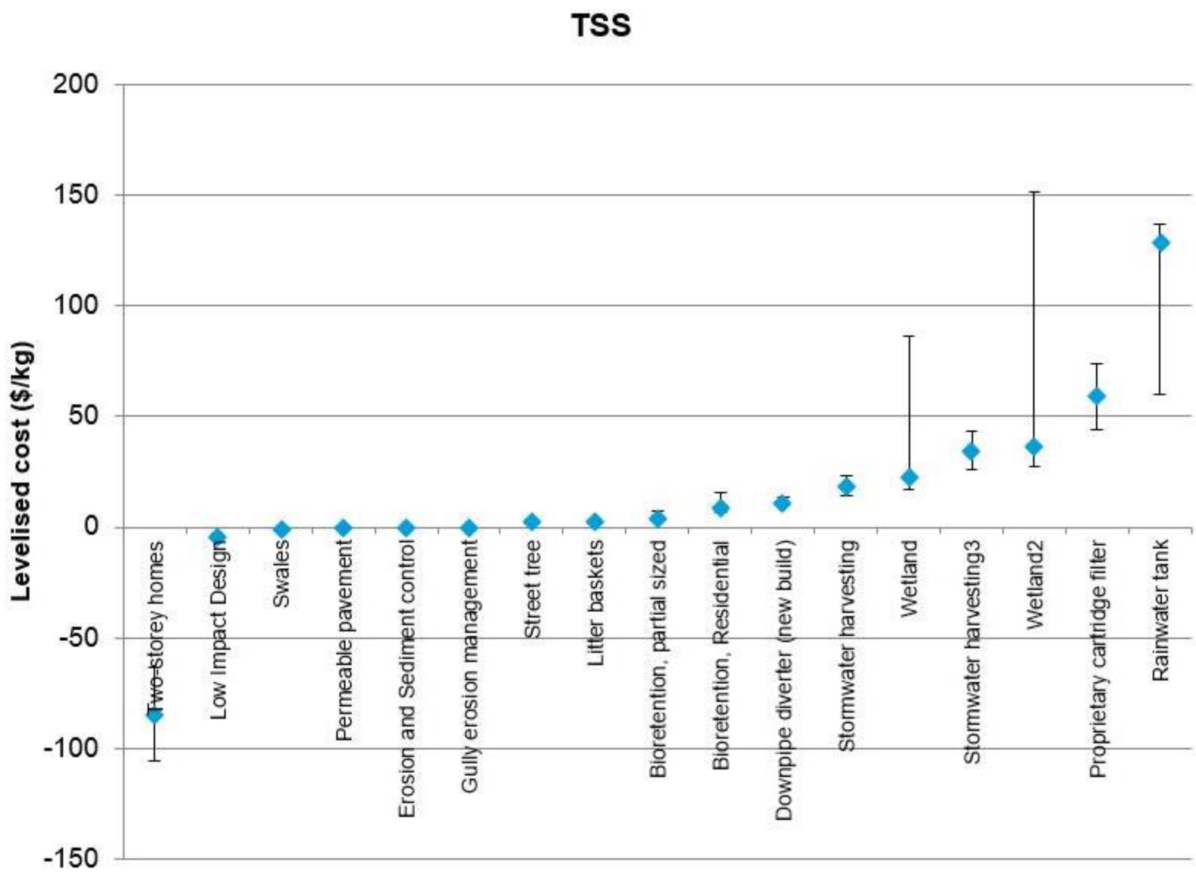

Figure 9-6 Cost effectiveness of various management options

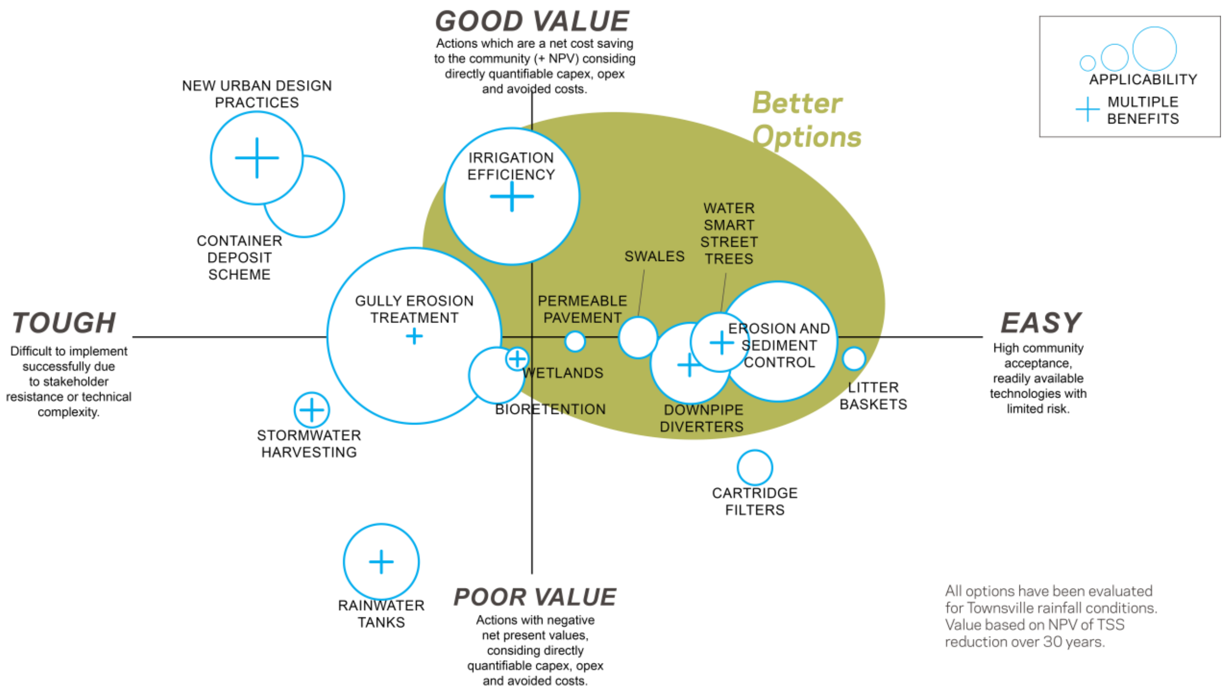

Figure 9-7 Evaluation of management options

9.5 Stormwater Management in the Stuart Creek Catchment

Stuart Creek is a special case within the regional stormwater strategy, because it has sufficiently intact environmental values to warrant full onsite management of stormwater. There is quite modest development within the catchment, and some of the future development is likely to be of a big enough scale that it can implement planned strategies that might not otherwise be practical on smaller developments.

The urbanisation of this catchment is not expected to result in significant direct deterioration in water quality, because the current land-use appears to generate relatively high sediment loads, and urbanising the catchment may in fact help stabilise some of the landscape. However, the increased runoff from impervious surfaces poses a real risk of severe waterway erosion, which can then cause downstream water quality issues in addition to the direct environmental and economic impacts.

Therefore, the focus within the Stuart Creek catchment should be on minimising hydrologic change. This can be achieved through a combination of measures including:

- Minimising impervious surfaces - by preserving areas of greenspace through zoning controls, prescribing minimum areas of greenspace within developments, and setting maximum plot ratios on allotments
- Minimising runoff from roofs - by using rainwater tanks and downpipe diverters
- Minimising runoff - by using permeable pavements, grass swales, raingardens and stormwater harvesting
- Slowing runoff – using swales, raingardens and detention systems.

For reasons described previously, large end of pipe bioretention systems are problematic and should be discouraged.

10 POTENTIAL OFFSETS SCHEME

Stormwater quality offsets is a complex and new area of practice. While offsets have been used effectively in the vegetation and carbon domains, internationally, there is only patchy experience applying offsets in a water quality context given the issues with multiple pollutants, and spatial and temporal equivalence.

10.1 Regulatory Basis for Offsets

Stormwater quality offsets are neither expressly provided for, nor expressly prohibited, under the existing regulatory framework.

The new Environmental Offsets Act (2014) is principally intended for major infrastructure and resource development projects, and currently has little relevance to stormwater quality offsets because water quality is not a prescribed environmental matter for the purposes of the Act, and hence the legislation is not relevant (DEHP pers. comm.).

Sustainable Planning Act (2009) (SPA) provides the head of power for the State Planning Policy, which establishes water quality as a state interest, and the SPP Code: Water Quality sets design objectives for stormwater quality management. State interests must be reflected in local government planning schemes.

The planning scheme is to appropriately integrate the state interest by a range of measures including [SPP p 30] (underlining added for emphasis):

> *(3) adopting the applicable stormwater management design objectives relevant to the climatic region, outlined in Tables A and B (Appendix 2), or demonstrate current best practice environmental management[13] for development that is for an urban purpose, and*
> *(4) facilitating <u>innovative and locally appropriate solutions</u> for urban stormwater management that achieve the relevant urban stormwater management design objectives, and*
> *(5) identifying land for urban or future urban purposes in areas which avoid or minimise the disturbance to natural drainage and acid sulfate soils, erosion risk, impact on groundwater and landscape features,*

In terms of water quality requirements, the SPP Code: Water Quality generally applies to development larger than 2500 m^2, and the Code has the following purpose:

> *to ensure development is planned, designed, constructed and operated to manage stormwater and wastewater in ways that support the protection of environmental values identified in the Environmental Protection (Water) Policy 2009.*

The SPA provides for environmental offsets under S346(A) Environmental Offset Conditions:

> *(2) An environmental offset condition may be imposed only if the concurrence agency or assessment manager is satisfied that <u>all cost-effective on-site mitigation</u> measures for the development have been, or will be, undertaken.*

Such conditions could potentially be used to allow a developer to contribute to regional stormwater quality infrastructure where on-site management is not cost effective. However, a stormwater offset

[13] The *best practice environmental management* of an activity is the management of the activity to achieve an ongoing minimisation of the activity's environmental harm through cost-effective measures assessed against the measures currently used nationally and internationally for the activity [EP Act s21(1)].

condition requiring monetary payment would potentially be unlawful because it is contrary to SPA s347(1)(b) and s626, which prohibit the imposition of a charges other than approved infrastructure charges.

The Environmental Offsets Bill was expected to amend SPA to remove this prohibition but has not done so. For this reason, Council may not impose a charge for stormwater quality offsets and instead any scheme must be voluntary.

10.2 Offset Principles

There is no absolute agreement on principles for offsets. However, in recent years there has been a significant convergence in the international literature on what the key principles for offsets should be. This is particularly the case for biodiversity, vegetation, and carbon. Less work has been done for water quality offsets. A proposed decision support tool for stormwater offsets is presented in Figure 10-1.

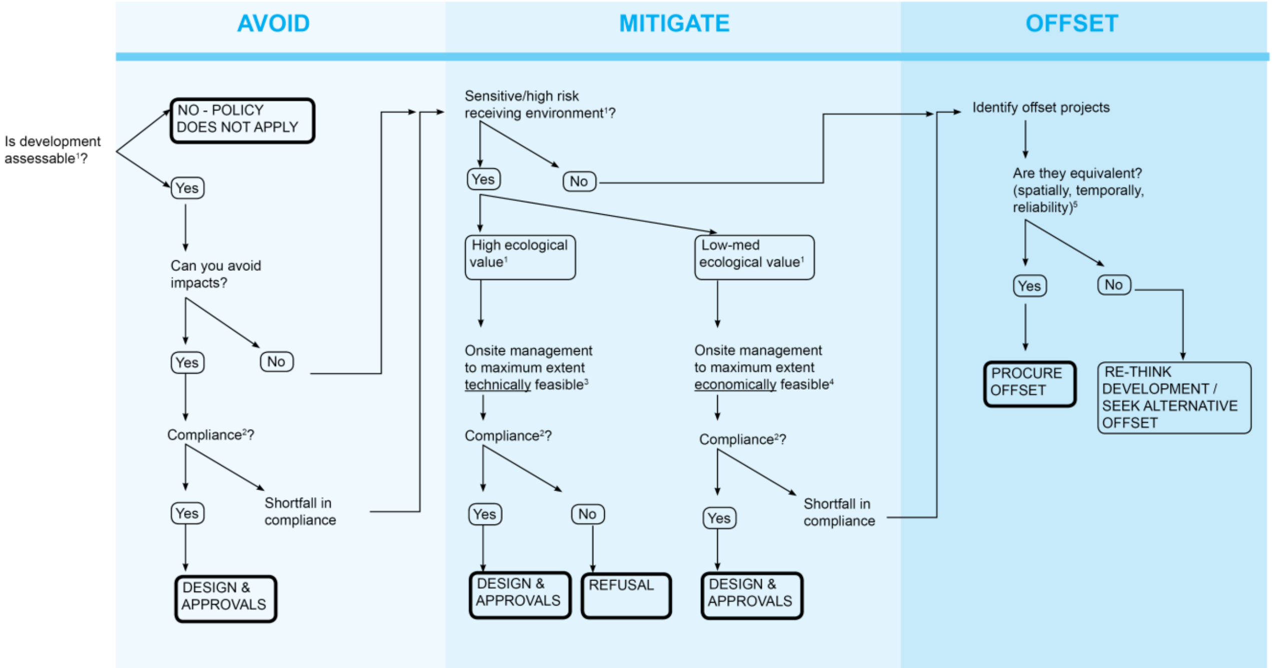

Figure 10-1 Recommend Offsets Decision Tree for Development Applications

The following offset principles, drawn from the international literature, have been used to guide the proposed stormwater offset policy decision support framework:

1. Offsets should not replace or undermine existing environmental standards or regulatory requirements. Rather, offsets should be part of a cohesive suite of measures to address water quality objectives.
2. Offsets should only be used once reasonable, technically feasible, and cost effective measures to avoid and mitigate on-site impacts of development have been exhausted.
3. Offsets must be expected to result in an equivalent or better regional water quality outcome, taking into account information uncertainties, management risks, and compliance and enforcement provisions.
4. Any approved offset project should demonstrate the offset actions are additional to any business as usual actions.
5. Offsets should be environmentally, temporally and spatially equivalent to the impacts from the development.
6. Time lags between the impacts of the development and benefits of the offset should be minimised.

7. Offsets should be independently and transparently monitored and their performance evaluated.

These principles are:

- consistent with other applications of offsets;
- provide an internally consistent suite of principles, and;
- can be practically incorporated and implemented within the existing development regime in Queensland.

10.3 Offset Metric

For a nascent stormwater quality offsets framework, TSS is likely to be a suitable water quality metric/currency. This is because:

- A simpler offsets scheme is likely to be better understood and easier to implement.
- There is better data on the efficacy of a range of management practices in abating TSS, and for diffuse sources.
- There are unresolved questions regarding the TP and TN composition of stormwater in Townsville (see Section 6).
- There is also a reasonable correlation between TSS and TP, and a fair correlation with TN. Only a few management practices have quite low TN or TP removal rates relative to their TSS reduction.
- TSS is often the limiting pollutant when determining the size of stormwater quality improvement measures.
- Nearly all aquatic ecosystems are sensitive to TSS, while sensitivity to TN and TP tends to vary depending on whether environments are N or P limited.

As offsets programs mature further, and more data is collected on the efficacy of various management practices in abating TP and TN, the relative merits of developing a more complex multi-parametric offset scheme will be better understood.

10.4 Spatial and Temporal Equivalence

Offset projects are most commonly in a different location, and implemented at a different time (typically later). This raises potential issues of spatial and temporal equivalence. One way of addressing concerns about equivalence is to introduce multiplication factors requiring a greater level of abatement for offset woks which are more remote in place and time.

A general overview of spatial factors is provided in Figure 10-2.

There is generally insufficient data to support the development of such factors at this point in time. A general guiding principle should be that offset works should be completed no more than two years from the time of impact.

In terms of spatial equivalence, the impacts will likely be small and dispersed, as will likely offset projects, so at this stage there does not appear to be a compelling reason to give significant regard to spatial equivalence.

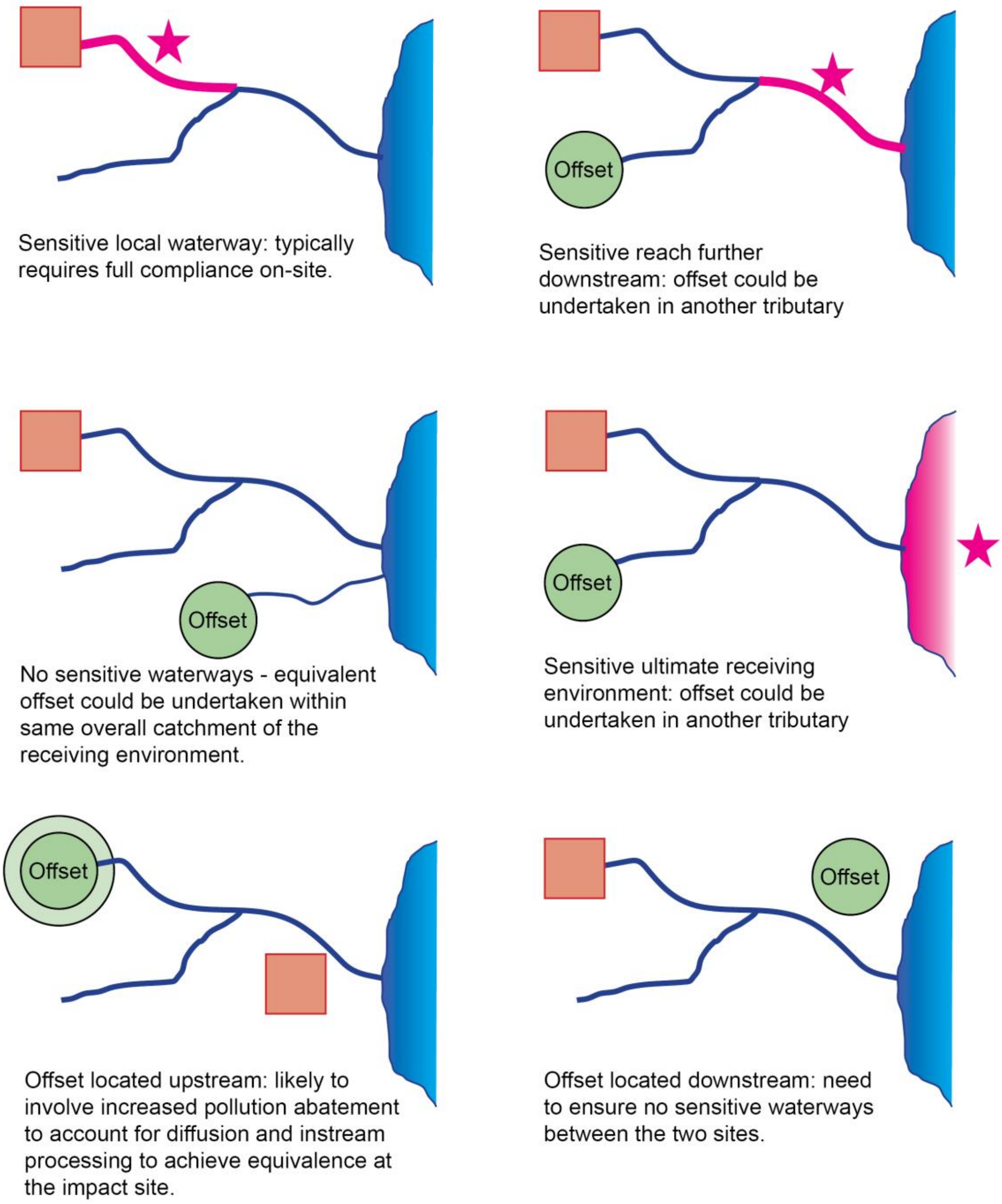

Figure 10-2 Spatial relationships between impact site, sensitive waterways, and offset sites. Red square denotes development site, pink star denotes sensitive receiving environment, green circle indicates offset location.

Key Risks

Lack of Equivalence

A fundamental principle underpinning the successful use of offsets is the concept of "equivalence". Effectively, an offset project should provide outcomes (in this case pollution abatement) that are environmentally equivalent to the impacts at the development site that is to be offset.

Where equivalence is not considered and achieved, the risks of poor policy and inefficient investment is increased significantly. This can have two impacts:

- Where the offset provides lower water quality outcomes because equivalence has not been properly assessed, water quality will decline further because the offset will be inadequate. Furthermore, the offset requirements have been under-priced, resulting in a windfall gain to the developer (lower development cost) at the expense of the community (water quality is worse than it would otherwise be).
- Conversely, where the offset provides higher water quality outcomes because equivalence has not been properly assessed, there is an overinvestment in the offset which could be considered a tax on development.

It is critical that equivalence considerations are embedded into offset policy design and implementation.

Poor Implementation
Poor water sensitive urban design outcomes stem, in part, from a lack of capacity in the design and on-ground implementation of (semi) natural assets. Depending on the offset project being considered, this lack of capacity is also likely to apply to offset projects. If the industry has trouble delivering small, localised wetlands, it may be unrealistic to think that it can deliver large regional ones.

In this regard, offsets should not be seen as a panacea to poor stormwater quality implementation without a significant investment in capacity building around offset projects.

Poor Long-Term Compliance
Catchment management practices, such as on farm management and riparian revegetation, are often seen as desirable offset projects. However, issues associated with land tenure and longer term reliability of the water quality benefit need to be resolved. For example, if offset funds are spent revegetating an eroding hill-slope, it would be possible for the vegetation to be lost to a bushfire, or cleared by a subsequent landowner. There should therefore be mechanisms in place to account for the reliability of the offset, and legal frameworks in place to secure that offset.

10.5 The Case for Partial Offsets

Partial offsets involve a developer delivering some water quality improvement on site, and purchasing an offset from Council to make up any shortfall in compliance. This approach is preferable to an all-or-nothing approach as implemented by some other local governments, where developers have the choice of full on-site compliance or purchasing a full offset.

Achieving full on-site compliance typically requires the use of a large bioretention system, as few other treatment practices are able to demonstrate full compliance.

The reason the partial offset approach is preferable is illustrated in Figure 10-3, which presents a bioretention performance curve for Townsville and highlights the non-linear relationship between size and performance.

Reducing the size of a bioretention system from 1.5% of catchment area—the deemed to comply' size under the State Planning Policy—to 1% of catchment area, which is a 33% reduction in size, results in only a 10% reduction in performance.

Reducing a bioretention system to 0.5% of catchment area, a 67% reduction in size, results in only a 30% reduction in performance. Smaller bioretention systems are cheaper to build and can be more easily integrated into developments with less impact on site design or development yield.

In addition to smaller, more efficient bioretention systems, a partial offset scheme would also allow for a broader suite of treatment measures such as swales, water-smart street trees, permeable paving, water harvesting, and some proprietary treatment products, which can contribute to water quality outcomes.

Ultimately, encouraging at least some treatment on site, though using treatment measures which are cost effective or sized in the most cost effective way, can contribute to least cost overall water quality outcomes.

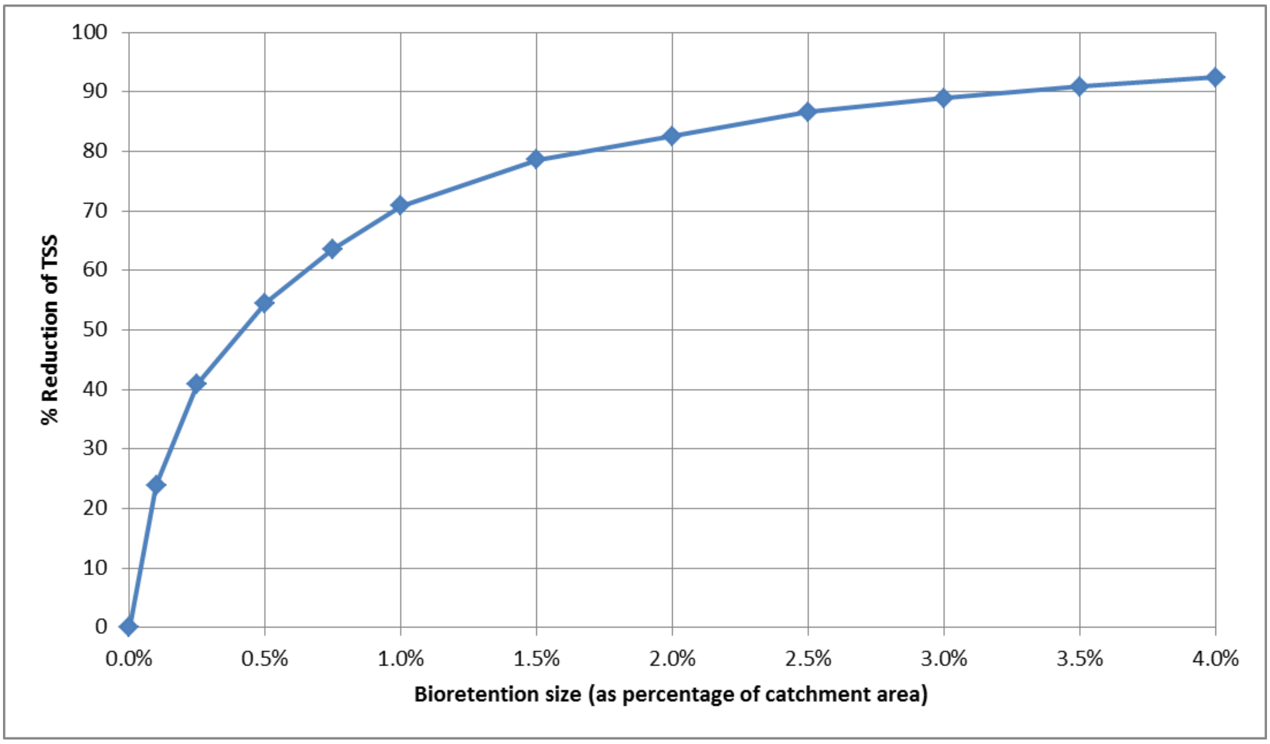

Figure 10-3 Bioretention performance curve for Townsville.

10.6 Supply and Demand

The following section estimates the likely demand for water quality offsets, and shows that the demand is significantly less than the likely supply of offsets available to Council. This is illustrated in Figure 10-4, with details provided in Table 10-1 and Table 10-2.

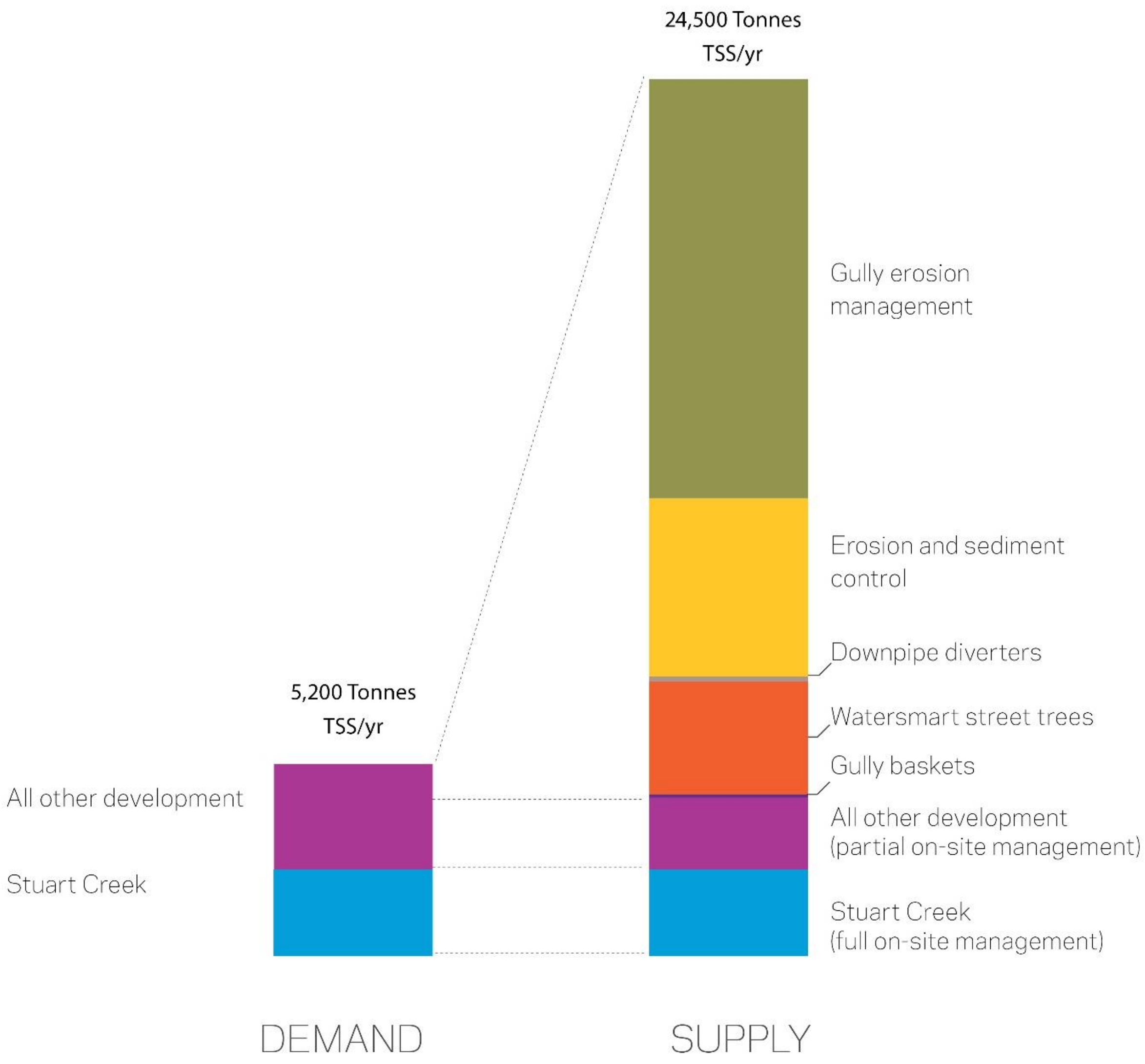

Figure 10-4 Estimated supply and demand of water quality abatement

Table 10-1 Potential demand for offsets

Management option	Potential supply	Potential sediment reduction (tonnes/yr)
Stuart Creek on site management	Using MUSIC to estimate pollutant loads for various land uses, the total sediment reduction across Stuart Creek development area was estimated based on achieving State Planning Policy load targets of 80% TSS reduction. On this basis, the resulting sediment reduction is estimated at 2,300 tonnes per year.	2,300
On site management (other development)	The same method was used as for Stuart Creek, this time using Council planning records to aggregate the sediment loads across all emerging community and infill development areas.	2,900
Overall Demand		**5,200**

Table 10-2 Potential supply of offsets/abatement

Management option	Potential supply	Potential sediment reduction (tonnes/yr)
Stuart Creek on site management	All development within Stuart Creek catchment is assumed to achieve 100% compliance with stormwater quality targets.	2,300
On site management (other development)	All other applicable development is assumed to achieve about 50% of its abatement target through on-site measures.	2,900
Gully baskets	Based on GIS data, there are approximately 334 gully pits within inner urban areas of Townsville (subcatchments #5 and #24). Additional commercial areas could also be considered.	41
Water smart street trees	If one tree could be planted per house, there is potential for 115,000 water smart street trees across Townsville14. This equates to a potential sediment reduction of 3,000 tonnes per year. As outlined below (Table 10-3), the strategy assumes just 10% of this potential is realised.	3,000
Downpipe diverters	Assumes 115,000 homes each have two diverters installed	142
Irrigation efficiency	Unable to be estimated with any confidence due to lack of data on base flow.	
Improved Erosion and Sediment Control	Based on the forecast development of about 3600 ha over 30 years, and sediment generation rate of 50 tonnes/ha, the construction phase sediment loads are estimated to be about 6000 tonnes/yr. Assuming best practices can reduce this load by about 80%, the potential abatement is 4800 tonnes/yr. Most of this abatement is the obligation of developers and sits outside an offsets scheme, however it is reasonable to apportion a small amount to Council for activities over and above routine compliance which contribute to improved water quality outcomes.	4800
Gully erosion management	Based on the current available gully erosion mapping for the Black Ross basin[15], there is limited ability to project the potential sediment reductions using gully erosion management for the Townsville region. In the absence of more detailed mapping, the low resolution mapping available from the Reef Trust for the greater GBR region has been used to calculate a preliminary estimate for the potential sediment reduction across rural Townsville[16] The gully density within the Black Ross basin appears to be similar to that of the Lower Burdekin, which is estimated to generate 0.18 t/ha/y of sediment (Table 3, Wilkinson et al,. 2015). Using this figure, and applying a factor of 0.5 to account for uncertainties around gully density and erosion, it is assumed that gully erosion	11,300

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[14] Calculated using forecast population of 300,000, and an average of occupancy of 2.6 people per household (ABS 2011 Census).

[15] After speaking with NQ Dry Tropics, it is understood that there is research underway at James Cook University (JCU) to use LiDAR data to locate and map gullies. It is expected that this will include more detailed mapping for the Black Ross region, which will assist in future planning for gully erosion management.

[16] https://www.environment.gov.au/marine/gbr/reef-trust/gully-erosion-control (Grant-Gully-toolbox)

	management can reduce sediment loads by 50%, resulting in potential sediment reduction of up to 11,300 tonnes per year. This number is indicative only, and calculated for the purpose of demonstrating the potential of this management approach for reaching abatement targets.		
Overall Supply			**24,500**

10.7 Recommended combination of options

There are multiple ways of combining the potential supply to meet the offset demand. The recommended combination of options in this strategy assumes uptake of options that are both cost effective and can be practically implemented.

Table 10-3 Recommended supply of offsets/abatement

Management option	Assumed uptake of potential supply of each option within the recommended strategy	Comment	Sediment reduction (tonnes/yr)
Stuart Creek on site management	100%	Assuming deemed-to-comply sized bioretention, which results in slightly reduced sediment reductions.	2,300
On site management partial compliance (other development)	20%	Assuming 20% of development sites (other than Stuart Creek) uptake partial sized bioretention[17]. The remaining development sites assume no on site management.	390
Gully baskets	100%	This assumes 334 gully baskets across the city.	41
Water smart street trees	10%	This translates to 1 street tree per 10 lots, on average across the city.	305
Improved Erosion and Sediment Control	10%	This is assumed to be a reasonable sediment reduction that can be apportioned to the impact that an Erosion and Sediment Control officer, funded through the offsets program, would be able to achieve.	480
Gully erosion management	15%	This is one of the most cost effective options but uptake has been kept low due to uncertainties in implementation but has significant up-size potential. Refer to Part 3 for more detail on gully erosion management recommendations.	1,700
Overall Supply			**5,200**

10.8 Offset Price

The offset price is very important to the effectiveness of the strategy. If set too low, there will be a very high demand and many cost-effective on site management practices will be overlooked. If set too high, there will be very little uptake, and Council may end up inheriting a very large number of expensive-to-maintain assets. Upper and lower bounds are defined as:

[17] Where partial sized bioretention is 0.5% of catchment area (i.e. 1/3rd the size requirement of deemed-to-comply sized bioretention systems).

Upper bound: 'Bypass price' – above this price, developers should prefer to meet requirements on-site.

Lower bound: 'Full offset cost recovery' - below this, the offset is under-priced and rate-payers fund the gap.

An offset price should at least include[18]:

- Design costs for offset action
- Capital costs
- Land costs (opportunity cost of site)
- Share of administrative cost of running offset scheme
- Environmental equivalence risk factor (% premium)
- Consideration of long term offset supply (not just priced for first offset opportunity).

Operating costs should not normally be included in the price because most water quality assets built as part of on-site compliance are contributed to Council, with it becoming responsible for their long term maintenance anyhow. Where assets would otherwise have been private assets (eg a raingarden or proprietary filter within commercial developments) and Council would not be responsible for maintenance, it would be reasonable for the offset price to account for that transfer of maintenance responsibility to Council.

From a developer's perspective, their willingness to pay could be higher than costs to Council, as it includes:

- Avoided design and construction costs
- Developer time and management costs
- Land take
- Flexibility in placement of POS
- Reduced transaction costs with planning approval
- Reduced delay in development
- Reduced ongoing maintenance costs (for private water quality assets).

The most efficient overall scheme is one where developers do at least some on-site management using cost effective measures, and potentially offset any shortfall in meeting the targets. Where a developer elects to offset their entire water quality obligation and do no on-site management, there is an additional benefit to them in avoiding any investment in design and approvals. So as to encourage at least some on-site management, there should be a premium charged where Council provides a 100% offset.

[18] Based on advice from Kym Whiteoak, RMCG.

10.9 Collecting and expending offset funds

An advantage of the recommended strategy is that the recommended offset activities are relatively small scale projects that are low cost and do need extensive planning. As a result, the offsets can be delivered in a 'just-in-time' approach.

This is quite different to large offset projects such as large regional wetlands which can take several years to plan and deliver.

This means that there is minimal lag between development impact occurring and the water quality offset being delivered, which has benefits for water quality outcomes.

It also means that there is reduced need to accrue offset funds across financial years, which simplifies accounting for Council.

In practice, the collection and expenditure of offset funds is expected to operate as follows:

1. DA teams, through the pre-lodgement process, have a forecast of expected offset demand and communicate this to Council's Technical Services team
2. When a DA is lodged, developers provide a formal notification of their intention to purchase water quality offset to supplement or replace on site management of stormwater
    a. This can be in the form of an infrastructure agreement, which specifies the timing and amount of payment

       or

    b. Council may issue development conditions requiring the applicant to either:
        i. Provide an amended plan of development demonstrating full on site compliance with the relevant stormwater quality targets; or
        ii. Enter into an infrastructure agreement for the purchase of offsets, coupled with amended plans which demonstrate the extent of on-site treatment

       or

    c. Council establishes stormwater quality offsets as a prescribed matter within its planning scheme and is able to directly charge applicants under the Environmental Offsets Act.

3. The Technical Services team maintains a schedule of future projects (e.g. sites for gully basket and street tree installation, and gully erosion remediation)
4. Developers pay offset funds to Council at the time of plan of survey for reconfiguration of a lot applications (RAL) and commencement of use for material change of use applications (MCU), with the latter triggered by the issuing of a plumbing and drainage certificate
5. The receipt of funds is recorded against the Development Application, along with the expected pollutant abatement. This discharges the developer's operational water quality responsibilities under the planning scheme and State Planning Policy
6. The funds are accounted for within a project within Council's existing enterprise management system, along with the expected pollutant abatement
7. Technical Services is notified when funds are received, and create work orders for the implementation of planned offset works
8. At the end of financial year any unspent funds are marked as 'tied funds' for use in the following financial year. As there is no likelihood of refunding offset funds, they are not recorded as a liability
9. Council's Annual Report records the amount of offset funds collected and expended, and projects implemented.

11 FUNDING

This chapter outlines possible funding sources to implement the strategy. It can be primarily delivered through developer created assets and voluntary offsets, however options like impervious area levies, and grants could be worthy of further consideration.

11.1 Developer-Created Assets

The default approach for new developments is for developers to create stormwater quality assets, and especially in the case of greenfield development, contribute those assets to Council. Under the recommended strategy, this is how the Stuart Creek catchment, and partial treatment in other development areas, will be delivered.

11.2 Voluntary Offsets

A voluntary offsets scheme is expected to be the primary way that Council will obtain funds to deliver improved erosion and sediment control, gully erosion management, water smart street trees, and gully baskets. It is also how Council will obtain funds to coordinate and implement the overall strategy, and invest in the necessary capacity building, research, development, monitoring and evaluation which underpins the strategy.

11.3 Impervious Area Levies

A growing number of cities have rates schemes which include a stormwater charge based on impervious areas. Such schemes are considered the most economically feasible way to reduce stormwater runoff because it essentially raises the price on impervious surfaces. These tend to be more common in areas with common effluent drainage, such as in the US and Europe, where the price signal is intended to help reduce sewer overflows. For example:

- The District of Colombia has a Clean Rivers Impervious Area Charge (CRIAC), which it says is a fair way to distribute the cost of maintaining storm sewers and protecting area waterways because it is based on a property's contribution of rainwater to the District's sewer system. Because charges are based on the amount of impervious area on a property, owners of large office buildings, shopping centers and parking lots will be charged more than owners of modest residential dwellings[19].

- The City of Philadelphia also has annual stormwater fees, and offers non-residential customers, including businesses, institutions, non-profits, and public agencies, ways they can reduce their stormwater rates and help clean up waterways by implementing green infrastructure projects. Such as rain gardens, green roofs, basins and ponds, wetlands, swales, underground infiltration projects, downspout planters, rainwater harvesting, porous pavement, and reducing impervious surfaces. Projects that reduce the amount of impervious surface on a site can result in a stormwater credit that will permanently reduce water bills[20].

Since large areas of Townsville are already developed without any stormwater quality infrastructure, an impervious area charge would have strong equity elements in its favour as it would share the burden for water quality improvement across all developments rather than focussing it on new developments.

This approach also avoids the potential phenomenon whereby, when the cost of new housing is increased as a result of a new regulation or stimulus, the value of the existing housing stock rises.

[19] https://www.dcwater.com/customercare/iab.cfmb accessed 4/11/2015
[20] http://www.phillywatersheds.org/whats_in_it_for_you/reduce-your-stormwater-fees accessed 4/11/2015

Satellite imagery and remote sensing can be used to streamline the assessment of impervious areas and reduce administrative costs.

11.4 Infrastructure Charges

Under the current capped charges regime in Queensland, it is probably not in Council's interest to include water quality infrastructure in the Local Government Infrastructure Plan (LGIP) given that:

- SPA only permits a voluntary offset contributions scheme
- There would be no additional funding made available to Council to deliver the additional water quality requirements.

Council could, however, incentivise good design by setting stormwater-related infrastructure charges on the basis of the amount of impervious surfaces.

11.5 Grants

11.5.1 Australian Government

In the first phase of the Caring for Our Country Reef Rescue program, the Australian Government committed $200 million over five years (2008-09 to 2012-13) to improve the quality of water entering the Great Barrier Reef lagoon. The Australian Government has committed to continue efforts to protect the Great Barrier Reef through existing contracted Reef Programme projects from 2013-2018. These projects are designed to improve the quality of water flowing into the Great Barrier Reef lagoon and will enhance the reef's resilience to the threats posed by climate change and nutrients, pesticides and sediment runoff through a number of complimentary approaches. Under this program most of the funding was directed through regional Natural Resource Management (NRM_ groups, and NQ Dry Tropics received $2.2m for on ground works to restoring Burdekin coastal ecosystems.

There are no open grant opportunities under this scheme.

There is an emerging grant opportunity for coastal infrastructure, which is expected to be advertised in mid 2016.

11.5.2 NQ Dry Tropics

At the time of preparing this report, NQ Dry Tropics had no publicly advertised grants.

11.5.3 Reef Trust

The Reef Trust will be a key mechanism for delivering on the Reef 2050 Long-Term Sustainability Plan and will focus on improving coastal habitat, water quality, and enhancing species protection.

The Australian Government has committed $140 million to the Reef Trust to provide innovative, targeted investment focused on improving water quality, restoring coastal ecosystem health, and enhancing species protection.

The Reef Trust will be jointly coordinated between the Australian Government Department of the Environment and Queensland Government Department of Environment and Heritage Protection with advice from the Great Barrier Reef Marine Park Authority (GBRMPA), the Australian Institute of Marine Science (AIMS), and other agencies. The Trust will complement investments made through other government initiatives such as the Green Army and the National Landcare Programme.

The Reef Trust has a Gully Erosion Control programme ($5 million of grant funding available, closing Nov 2015). However this funding is only available for 10 high risk catchments (or management units) which includes the Burdekin, but does not include the Black or Ross catchments.

Reef Trust Offsets

The Reef Trust is able to accept, after all reasonable efforts to avoid and mitigate impacts and where conditioned, financial contributions from environmental approval holders who are undertaking works which are expected to have a significant residual impact to the Great Barrier Reef World Heritage Area and the values within it.

Council could consider using the Reef Trust to serve as its offset broker, and could also potentially receive funds towards cost effective actions that contribute to water quality improvement. However within the broader context of the Great Barrier Reef, it is unlikely that significant funds would be available for Townsville as most actions would not be regarded to be additional to current requirements.

11.5.4 Queensland Government

There are no relevant Queensland Government grants advertised at the time of preparing this report.

12 DIAGNOSIS

This chapter draws together the key issues and analyses from the previous chapters, and lays out the basis for the strategy recommendations in the following chapter.

1. Waterway health appears to be most affected/threatened by:
    a. Erosion from altered hydrology
    b. Poor quality baseflows resulting from excessive irrigation and sodic subsoils
    c. Excessive sediment loads from construction sites
2. Urbanisation is not expected to result in a significant increase in stormwater pollutants due to the potentially high background levels being generated by yet-to-be-developed lands.
3. Local water quality may be significantly different to other regions. It is hypothesised that there are high concentrations of salts, nutrients, faecal, pathogens in base flows due to over irrigation, with these pollutants diminishing once it starts raining, then a TSS dominated discharge would occur.
4. There is strong support for water quality protection in the local development sector, although there are concerns about the efficacy and merits of current practices. Stakeholders support a regional approach which provides flexibility and certainty.
5. Smaller distributed stormwater systems appear to be more resilient than larger bioretention and wetland systems. In Townsville, nearly all the large systems had functionality problems, as is true in many other locations.
6. The natural drainage lines in lowland areas are wide, shallow and highly ephemeral, and this should be the preferred template for development areas rather than narrow, deeper channels which tend to encounter poorer soils and shallow groundwater.

13 CONCLUSIONS

1. Council has an obligation to ensure the impacts of new urban development on water quality are appropriately managed.

2. Vegetated stormwater management practices have largely been poorly implemented in Townsville to date. A dry and highly seasonal climate, poor soils, and invasive weeds have made it particularly difficult to achieve good water sensitive urban design outcomes in Townsville.

3. Local stormwater quality appears to have atypically low levels of phosphorus and, in particular, nitrogen. This has implications for the selection of treatment measures, and the emphasis should be on sediment management, which is a clear issue, while further investigations take place to determine how important nutrient management is locally.

4. The impacts of future urbanisation on water quality are estimated to be very small, with TSS, TP and TN loads likely to increase by less than 1% if no controls are implemented. Localised impacts may be more significant, however.

5. There is clear industry support for more flexible and locally appropriate solutions for stormwater quality management.

6. A voluntary offset scheme could operate across most of Townsville, with the exception of development in the Stuart Creek catchment which has sufficiently intact environmental values to warrant full onsite management of stormwater.

7. A partial offset scheme is recommended, which would allow developers to elect to top-up any shortfall in achieving water quality targets.

8. The price of offsets is critical to the overall functioning of the scheme. Further work is required to determine an appropriate offset price that incentivises the use of low-cost on site practices.

9. There is a large potential supply of stormwater quality offsets that are cheaper than the conventional bioretention solution, in terms of capital and ongoing maintenance costs. Many of these options have additional biodiversity or amenity benefits.

10. The Part 3 document outlines the recommended strategy.

Future work

1. Review opportunities for lower cost management of stormwater within the Stuart Creek catchment through low impact urban design practices.

2. Develop recommendations for an offset price, including a framework for its periodic review

3. Implement the recommended industry engagement strategy.

4. Establish systems and processes to clarify how developments that wish to use offsets are managed through the development assessment process.

5. Establish mechanisms to document the receipt and acquittal of offset funds.

6. Implement a local monitoring program to better characterise stormwater quality and baseflows in stormwater drains, and to verify the performance of local stormwater quality measures.

7. Undertake a proper economic assessment and risk assessment of rainwater tanks in Townsville.

8. Work with NQ Dry Tropics to identify focal areas for gully erosion management using a combination of local knowledge, alignment with other initiatives, and desktop prioritisation methods being developed through the Reef Trust.

14 BIBLIOGRAPHY

2015. Bring Your Bags: Say Goodbye to Plastic Shopping Bags [Online]. Tasmanian Government Department of Primary Industries, Parks, Water and Environment. Available: http://www.plasticbags.tas.gov.au/ [Accessed 22/07/2015 2015].

2015. Climate Change in Australia Map Explorer [Online]. CSIRO and Bureau of Meteorology. Available: http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/map-explorer/ 2015].

2015. Climate change projections [Online]. The State of Queensland (Department of Science, Information Technology and Innovation). Available: https://www.longpaddock.qld.gov.au/climateprojections/ [Accessed 2/07/2015 2015].

2015. Environmental Info: Container deposits [Online]. EPA South Australia. Available: http://www.epa.sa.gov.au/environmental_info/container_deposit [Accessed 22/07/2015 2015].

2015. Roof run-off diverted for greener gardens [Online]. City of Port Phillip Media Unit. Available: http://www.portphillip.vic.gov.au/june-2015-media_6087.htm [Accessed 12/08/2015 2015].

ABOOD, M. & RILEY, S. J. 1997. Impact on Water Quality of Gross Pollutants: Research Report No. 121. Urban Water Research Association of Australia.

ACTFR 2007. Event-Based Water Quality Monitoring of the Ross and Black River Basins During the 2006/07 Wet Season. Australian Centre for Tropical Freshwater Research.

AL-HAMDAN, A. Z., NNADI, F. N., et al. 2007. Performance reconnaissance of stormwater proprietary best management practices. Journal of Environmental Science and Health, Part A, 42, 427-437.

BARTLEY, R., HENDERSON, A., et al. 2015. Stream bank management in the Great Barrier Reef catchments: a handbook. CSIRO: CSIRO.

BEAN, E. Z., HUNT, W. F., et al. 2007. Field Survey of Permeable Pavement Surface Infiltration Rates. Journal of Irrigation and Drainage Engineering, 133, 249-255.

BOOGAARD, F., LUCKE, T., et al. 2014. Effect of Age of Permeable Pavements on Their Infiltration Function. CLEAN – Soil, Air, Water, 42, 146-152.

BUTLER, OCKLESTON, K. G., et al. 2004. Auckland City's field and laboratory testing of stormwater catchpit filters. New Zealand Water and Waste Association Conference.

COLEMAN, P. 2007. Do stormwater wetlands affect urban stream health? . Melbourne: Monash University.

DENMAN, E. C., MAY, P. B., et al. 2011. The use of trees in urban stormwater management. 12th National Street Tree Symposium.

DESIGNFLOW 2015. Independent Peer Review of Proprietary Device: A Report for City of Gold Coast. Designflow.

DOSSKEY, M., MICHAEL, G. D., et al. 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. Journal of the American Water Resources Association, 46, 261.

DUNCAN, H. P. 1999. Urban Stormwater Quality: A Statistical Overview. Melbourne: Cooperative Research Centre for Catchment Hydrology.

ENHEALTH 2004. Guidance on use of rainwater tanks, Commonwealth of Australia.

HALL, A. C. 2010. The life and death of the Australian backyard, Collingwood, Vic, CSIRO Publishing.

HOBAN, A. 2012 Doing things right or doing the right things? . Stormwater Industry Association of Queensland State Conference, 2012.

HOBAN, A., MILLS, K., et al. 2015. Climate change impacts on stormwater harvesting yields. Journal of the Australian Water Association, 42, 72-76.

HUNT, W., ET AL. (2006). "Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina." Journal of Irrigation and Drainage Engineering 132(6): 600-608.

HUNTER, G. 2001. Stormwater Quality Improvement Devices Issues for Consideration. IPWEA Conference.

KELLY, J & DONEGAN, P. 2015. City Limits: Why Australia's cities are broken and how we can fix them – MUP ISBN 9780522868005

LEWIS, S., BAINBRIDGE, Z., et al. 2008. Water quality monitoring of the Black Ross Basins: 2007/08 Wet Season. Australian Centre for Tropical Freshwater Research.

LUCAS, R., EARL, E. R., et al. 2014. Constructed wetlands for stormwater management in the UK: a concise review. Civil Engineering and Environmental Systems, 32, 251-268.

LUCKE, T. & BEECHAM, S. 2011. Field investigation of clogging in a permeable pavement system. Building Research & Information, 39, 603-615.

LUCKE, T. AND P. W. B. NICHOLS (2015). "The pollution removal and stormwater reduction performance of street-side bioretention basins after ten years in operation." Science of The Total Environment 536: 784-792.

MCGARRY & EADIE 2011. Water Sensitive Urban Design for the Coastal Dry Tropics (Townsville): Design Objectives for Stormwater Management. A Report for Townsville City Council. AECOM.

MCINTOSH, B. S., ARYAL, S., et al. 2013. Urbanisation and Stormwater Management in South East Queensland - Synthesis and Recommendations. Urban Water Security Research Alliance.

MCKENZIE-MCHARG, A., ET AL. (2008). Stormwater gardens to improve urban stormwater quality in Brisbane.

PARKER, N. (2010). Assessing the effectiveness of water sensitive urban design in South East Queensland. Faculty of Built Environment and Engineering, Queensland University of Technology. Master of Engineering: 235.

QUEENSLAND, S. O. 2005. Public Health Regulation 2005. Reprint 1 March 2014 ed.

QUU. 2015. Rates and charges 2015-16 [Online]. Queensland Urban Utilities. Available: http://www.urbanutilities.com.au/residential/accounts-and-billing/rates-and-charges-2015-16 [Accessed 18/08/2015 2015].

REEVE, A. & DESHA, C. 2014. 'Identifying opportunities for Brisbane City, based on international best practice in biophilic urbanism', Discussion paper prepared for Brisbane City Council (Natural Environment, Water and Sustainability Team). Brisbane: Queensland University of Technology with Bligh Tanner.

SANSALONE, J., KUANG, X., et al. 2012. Filtration and clogging of permeable pavement loaded by urban drainage. Water Research, 46, 6763-6774.

SEQWATER. 2015. Water security and consumption update - 14 August 2015 [Online]. Seqwater. Available: http://www.seqwater.com.au/latest-updates/news/2015/08/14/water-security-and-consumption-update-%E2%80%93-14-august-2015 [Accessed 18/08/2015 2015].

TCC. 2015. Resident Information: Water Billing [Online]. Townsville City Council. Available: http://www.townsville.qld.gov.au/resident/water/billing/pages/default.aspx [Accessed 18/08/2015 2015].

TERSTRIEP, M. L., BENDER, G. M., et al. 1982. EVALUATION OF THE EFFECTIVENESS OF MUNICIPAL STREET SWEEPING IN THE CONTROL OF URBAN STORM RUNOFF POLLUTION.

THOMPSON, R. & PARKINSON, S. 2011. Assessing the local effects of riparian restoration on urban streams. New Zealand Journal of Marine and Freshwater Research, 45, 625-636.

VAZE, J. & CHIEW, F. 2004. Nutrient Loads Associated with Different Sediment Sizes in Urban Stormwater and Surface Pollutants. Journal of Environmental Engineering, 130, 391-396.

WALKER, T., ALLISON, R., et al. 1999. Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap. CRC for Catchment Hydrology.

WILKINSON, S. N., BARTLEY, R., et al. 2015. Managing gully erosion as an efficient approach to improving water quality in the Great Barrier Reef lagoon. CSIRO.

Appendix A – Cost effectiveness of Management Options

APPENDIX A – COST EFFECTIVENESS OF MANAGEMENT OPTIONS

The cost effectiveness of management options was modelled using an adapted version of the life cycle costing methodology used in the Stormwater Offsets Discussion Paper (Water by Design 2015).

The methodology for life cycle cost estimates of stormwater quality best management practices is as follows:

- The life cycle costs are the net present value of:
  - Construction cost
  - Planning and design costs (typically 5% of construction costs)
  - Land costs (where specified)
  - Establishment costs (typically three times annual maintenance costs for the first two years)
  - Maintenance costs (which commence after the establishment period)
  - Renewal and adaption costs
  - Decommissioning costs
  - Revenue (negative cost, normally only applicable to water harvesting measures)
- A discount rate of 5% has been adopted, and lifecycle costs are estimated over a 30 year period because this is both the forecast lifespan of many best management practices, and ongoing maintenance costs beyond 30 years have a minor impact on lifecycle costs due to the effects of discounting.
- Where land costs are specified, they have been estimated as follows:
  - Bioretention: land valued at $300 /m^2, being typical opportunity cost of residential land based on a review of realestate.com.au, and assumed to be 200% of the filter media area.
  - Wetlands: land valued at $130 /m^2, being the typical value of low-lying land not suitable to residential development, and assumed to be 150% of the functional size of the wetland.
- Where rainwater tanks are specified, the costs are estimated as follows:
  - Supply and install of 3 kL tanks estimated at $2605 each, based on data from Rotational Moulders Association of Australia (assumed installation into new buildings rather than retrofitting).
  - Annual electricity costs estimated by multiplying the forecast average yield per tank by the typical energy intensity of domestic pumps (2 kWh/kL) by the average electricity tariff ($0.27 /kWh).
  - Annual avoided costs of supplied water are estimated by multiplying the forecast average yield by the marginal retail price of water ($2.71/kL). This simplistic approach could be expanded on in subsequent analyses.
- Data sources:
  - Capital costs are derived from the following data sources:
    - Melbourne Water (2014) Water Sensitive Urban Design Lifecycle costing data factsheet
    - Healthy Waterways (Jack Mullaly Pers. Comm.)
    - Bligh Tanner database of recent tender costs
  - Maintenance costs are derived from the following data sources:
    - Advice from Townsville City Council officers
    - Melbourne Water (2014) Water Sensitive Urban Design Lifecycle costing data factsheet
    - Healthy Waterways (Jack Mullaly Pers. Comm.)
    - Bligh Tanner database of recent tender costs
    - Eureka Landscapes (Pers. Comm.)
  - Gully erosion cost data are derived from Wilkinson et al. (2015) which summarises up to date research on gully erosion management in the Great Barrier Reef catchment. A nominal ongoing maintenance cost of 10% of capital expenditure has been applied for ongoing maintenance of fencing, vegetation management, and attending to minor erosion.

Following the calculating of lifecycle costs for each management option, the levelised cost per kilogram of pollutant for each management option has been calculated as a means of demonstrating the cost effectiveness of the options. The levelised cost was calculated as follows:

$$Levelised\ cost\ (\$/kg) = \frac{NPV\ (Lifecycle\ Costs)\ \ (\$/unit)}{NPV(Water\ Quality\ Benefits)\ \ (kg/unit)}$$

Water quality benefits

Water quality benefits were quantified in terms of the pollutant load reductions (kg/unit/yr) for TSS, TN and TP determined using MUSIC modelling.

Assumptions

- Discount rate of 5% is valid
- All input costs are valid, and where costs are uncertain, a conservative approach to estimating the cost effectiveness has been adopted.

Limitations

- Effectiveness of stormwater management technologies can vary over time, which is not reflected in MUSIC modelling;
- Formal sensitivity analysis of cost estimates has not been undertaken, and therefore the uncertainty of the results is not quantified with formal confidence intervals.

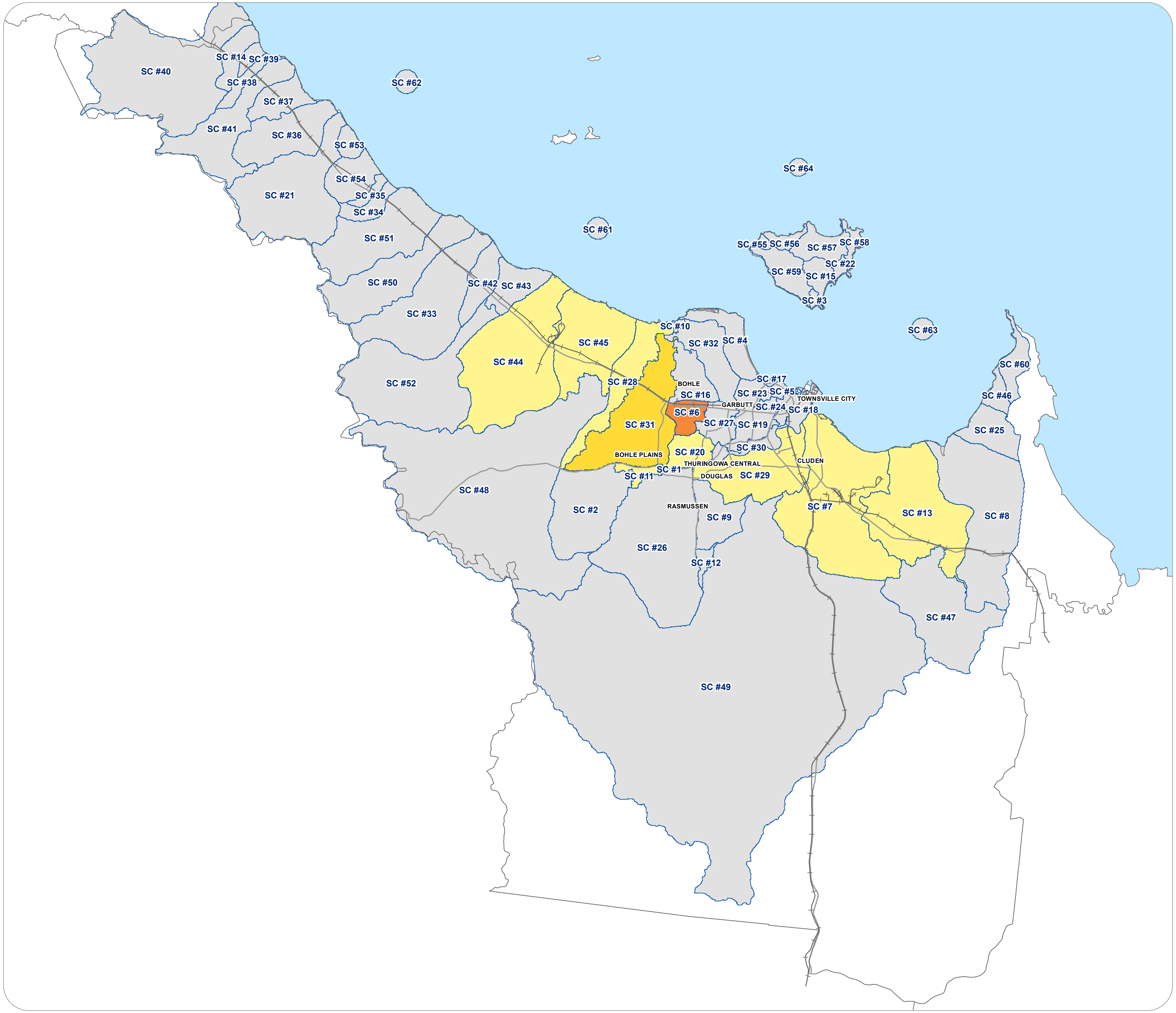
		Two-storey homes	Low Impact Design	Swales	Permeable pavement	Erosion and Sediment control
Description				2 - incl pipe cost saving		
Size		600	1	100	200	1
Unit		m^2	ha	m	m^2	ha
Land Cost/Avoided cost	$/unit	-$36,000.00	$0.00	-$270.00	-$77.20	$0.00
Planning & Design Cost	$/unit	$0.00	$50,000.00	$1.50	$2.80	$8,000.00
Construction Cost	$/unit	$10,000.00	-$220,000.00	$15.00	$56.00	$20,000.00
Establishment Cost	$/unit	$0.00	$0.00	$4.84	$0.00	$0.00
Maintenance Cost	$/unit	$0.00	$500.00	$1.61	$2.80	$0.00
Renewal / Adaption Cost	$/unit	$0.00	$0.00	$1.50	$1.12	$0.00
Decommissioning Cost	$/unit	$0.00	$0.00	$5.85	$0.00	$0.00
Revenue (negative cost)						
Annual ongoing costs		$0.00	$500.00	$3.11	$3.92	$0.00
Water Tank Yield (kL/yr)						
Water Price						
Lifespan	yrs	30	30	30	30	30
NPV Lifecycle costs	$/unit	-$26,000.00	-$161,813.77	-$191.86	$45.78	$28,000.00
TSS	kg/unit/yr	20.0	2370	11.2	69.1	20000
TP	kg/unit/yr	0.020	5.610	0.016	0.110	
TN	kg/unit/yr	0.200	46.420	0.018	0.340	
TSS	kg/unit	307.45	36432.71	171.56	1062.24	307449.02
TP	kg/unit	0.31	86.24	0.25	1.69	0.00
TN	kg/unit	3.07	713.59	0.28	5.23	0.00
TSS	$/kg	-$84.57	-$4.44	-$1.12	$0.04	$0.09
TP	$/kg	-$84,566.87	-$1,876.33	-$775.22	$27.07	
TN	$/kg	-$8,456.69	-$226.76	-$693.39	$8.76	
Lower range		-25%	-25%	-25%	-25%	-25%
TSS	$/kg	-$63.43	-$3.33	-$0.84	$0.03	$0.07
TP	$/kg	-$63,425.15	-$1,407.25	-$581.42	$20.30	
TN	$/kg	-$6,342.51	-$170.07	-$520.04	$6.57	
Upper range		+25%	+25%	+25%	+25%	+25%
TSS	$/kg	-$105.71	-$5.55	-$1.40	$0.05	$0.11
TP	$/kg	-$105,708.58	-$2,345.41	-$969.03	$33.84	
TN	$/kg	-$10,570.86	-$283.45	-$866.74	$10.95	

		Gully erosion management	Watersmart Street tree	Litter baskets	Downpipe diverter (new build)
Description					
Size			1	1	1
Unit			pits	baskets	1
Land Cost/Avoided cost	$/unit		$0.00	$0.00	$0.00
Planning & Design Cost	$/unit		$25.00	$50.00	$0.00
Construction Cost	$/unit		$500.00	$500.00	$140.00
Establishment Cost	$/unit		$15.00	$0.00	$0.00
Maintenance Cost	$/unit		$5.00	$196.00	$0.00
Renewal / Adaption Cost	$/unit		$10.00	$50.00	$0.00
Decommissioning Cost	$/unit		$195.00	$195.00	$0.00
Revenue (negative cost)					-$37.50
Annual ongoing costs			$15.00	$246.00	$0.00
Water Tank Yield (kL/yr)					
Water Price					
Lifespan	yrs		30	30	$30
NPV Lifecycle costs	$/unit		$980.59	$4,772.62	$102.50
TSS	kg/unit/yr		26.400	123.700	0.619
TP	kg/unit/yr		0.037	0.090	0.003
TN	kg/unit/yr		0.041	0.600	0.044
TSS	kg/unit		405.83	1901.57	9.51
TP	kg/unit		0.57	1.38	0.05
TN	kg/unit		0.63	9.22	0.68
TSS	$/kg	$0.20	$2.42	$2.51	$10.78
TP	$/kg		$1,724.02	$3,449.62	$1,947.40
TN	$/kg		$1,555.82	$517.44	$150.92
Lower range		**-25%**	**-25%**	**-25%**	**-25%**
TSS	$/kg	$0.06	$0.60	$0.63	
TP	$/kg		$431.00	$862.41	
TN	$/kg		$388.95	$129.36	
Upper range		**+25%**	**+25%**	**+25%**	**+25%**
TSS	$/kg	$0.05	$0.60	$0.63	$2.70
TP	$/kg		$431.00	$862.41	$486.85
TN	$/kg		$388.95	$129.36	$37.73

		Bioretention, Residential	Bioretention, partial sized	Wetland	Stormwater harvesting
Description		1.5% of catchment, inc. land costs	0.5% of catchment, inc. land costs	10.5% of catchment	Capex & Revenue
Size		1,000	1,000	8,500	55
Unit		m^2	m^2	m^2	ML
Land Cost/Avoided cost	$/unit	$310.00	$310.00	$50.00	$0.00
Planning & Design Cost	$/unit	$30.00	$30.00	$5.00	$2,244.78
Construction Cost	$/unit	$300.00	$300.00	$100.00	$44,895.67
Establishment Cost	$/unit	$7.00	$7.00	$12.00	$0.00
Maintenance Cost	$/unit	$5.00	$5.00	$6.00	$2,244.78
Renewal / Adaption Cost	$/unit	$6.00	$6.00	$0.52	$404.06
Decommissioning Cost	$/unit	$117.00	$117.00	$42.00	$17,509.31
Revenue (negative cost)					-$3,000.00
Annual ongoing costs		$11.00	$11.00	$6.52	-$351.16
Lifespan	yrs	30	30	30	30
NPV Lifecycle costs	$/unit	$944.10	$944.10	$315.75	$58,900.48
TSS	kg/unit /yr	7.160	15.880	0.906	202.530
TP	kg/unit /yr	0.013	0.027	0.002	1.410
TN	kg/unit /yr	0.035	0.078	0.006	1.860
TSS	kg/unit	110.07	244.11	13.92	3113.38
TP	kg/unit	0.19	0.42	0.02	21.68
TN	kg/unit	0.53	1.20	0.08	28.59
TSS	$/kg	$8.58	$3.87	$22.68	$18.92
TP	$/kg	$4,848.54	$2,257.90	$12,837.43	$2,717.42
TN	$/kg	$1,764.79	$787.37	$3,724.85	$2,059.98
Lower range		**-25%**	**-25%**	**-25%**	**-25%**
TSS	$/kg	$2.14	$0.97	$5.67	$4.73
TP	$/kg	$1,212.14	$564.47	$3,209.36	$679.35
TN	$/kg	$441.20	$196.84	$931.21	$514.99
Upper range		**Assuming reactive maintenance @ 10x the cost**	**Assuming reactive maintenance @ 10x the cost**	**Assuming reactive maintenance @ 10x the cost**	**+25%**
TSS	$/kg	$7.26	$3.27	$63.50	$4.73
TP	$/kg	$4,107.28	$1,912.70	$40,0336.46	$679.35
TN	$/kg	$1494.99	$666.99	$11703.84	$514.99

		Wetland (2)	Stormwater harvesting (3)	Proprietary cartridge filter	Rainwater tank
Description		21% catchment area	CAPEX, no revenue		
Size		8,500	55	1	1
Unit		m^2	ML	system	unit
Land Cost/Avoided cost	$/unit	$50.00	$0.00	$0.00	$0.00
Planning & Design Cost	$/unit	$5.00	$2,244.78	$2,950.00	$0.00
Construction Cost	$/unit	$100.00	$44,895.67	$59,000.00	$2,605.50
Establishment Cost	$/unit	$12.00	$0.00	$0.00	$0.00
Maintenance Cost	$/unit	$6.00	$2,244.78	$5,720.00	$100.00
Renewal / Adaption Cost	$/unit	$0.52	$404.06	$0.00	$0.00
Decommissioning Cost	$/unit	$42.00	$17,509.31	$10,000.00	$0.00
Revenue (negative cost)			$0.00		-$67.50
Annual ongoing costs		$6.52	$2,648.84	$5,720.00	-$32.50
Water Tank Yield (kL/yr)					50
Water Price					$1.35
Lifespan	yrs	30	30	1	30
NPV Lifecycle costs	$/unit	$315.75	$108,017.83	$83,117.62	$1,942.42
TSS	kg/unit/yr	0.561	202.530	1476.000	1.590
TP	kg/unit/yr	0.001	1.410	1.890	0.008
TN	kg/unit/yr	0.004	1.860	8.500	0.100
TSS	kg/unit	8.63	3113.38	1405.71	24.44
TP	kg/unit	0.02	21.68	1.80	0.12
TN	kg/unit	0.06	28.59	8.10	1.53
TSS	$/kg	$36.59	$34.69	$59.13	$128.37
TP	$/kg	$20,394.21	$4,983.49	$46,176.46	$25,229.38
TN	$/kg	$5,439.31	$3,777.80	$10,267.47	$2,047.20
Lower range		**-25%**	**-25%**	**-25%**	**Water price $3.40**
TSS	$/kg	$9.15	$8.67	$14.78	$68.66
TP	$/kg	$5,098.55	$1,245.87	$11,544.11	$13,494.16
TN	$/kg	$1,359.83	$944.45	$2,566.87	$1,094.96
Upper range		**Assuming reactive maintenance @ 10x the cost**	**+25%**	**+25%**	**Water price $1.09**
TSS	$/kg	$114.95	$8.67	$14.78	$8.71
TP	$/kg	$64,080.62	$1,245.87	$11,544.11	$1,711.46
TN	$/kg	$17,090.86	$944.45	$2,566.87	$138.87

Appendix B – Stormwater Loads by Subcatchment



L E G E N D

Townsville Regional Stormwater Strategy

Percentage change in TSS loads as a result of forecast urbanisation (excluding construction impacts)

Percentage Change in TSS Loads

- No change
- 0.1 - 5.0%
- 5.1 - 10.0%
- 10.1 - 20.0%
- 20.1 - 50.0%
- 50.1 - 100.0%
- 100.1 - 200.0%
- Above 200%
- Sub-Catchment Boundary

City of Townsville

Buckley Vann

BLIGH TANNER

Author: ELM

Date: 7/10/2015

Data Source: TRC and QGIS 2015

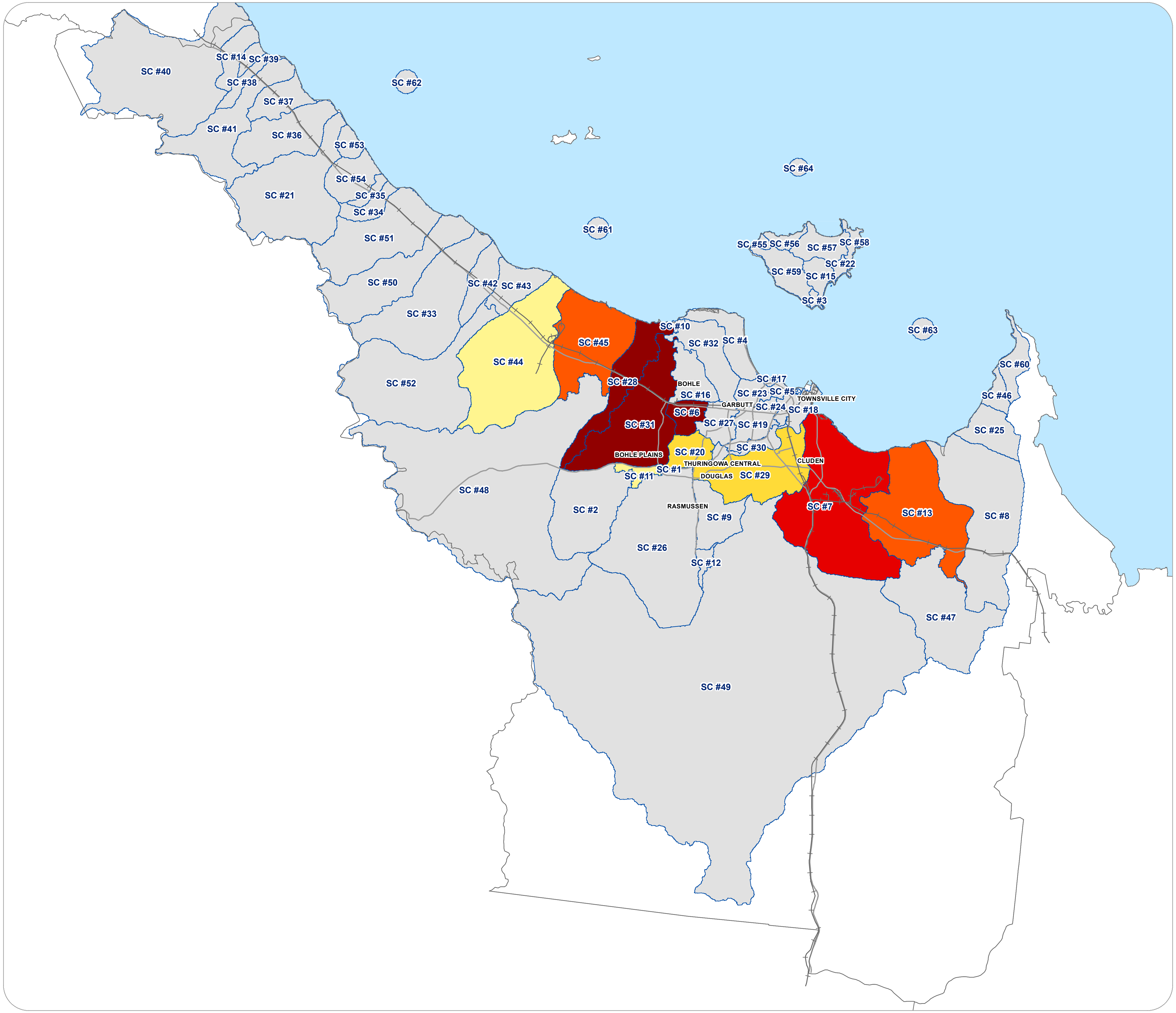
Projection: GDA 94 Zone 55

N

0 5 10 km

1:350,000

Disclaimer



L E G E N D

Townsville Regional Stormwater Strategy

Percentage change in TSS loads as a result of forecast urbanisation (including constructing impacts)

Percentage Change in TSS Loads

- No change
- 0.1 - 5.0%
- 5.1 - 10.0%
- 10.1 - 20.0%
- 20.1 - 50.0%
- 50.1 - 100.0%
- 100.1 - 200.0%
- 200.1 - 434.2%
- Sub-Catchment Boundary

Author: ELM

Date: 7/10/2015

Data Source: TRC and QGIS 2015

Projection: GDA 94 Zone 55

0 5 10 km

1:350,000

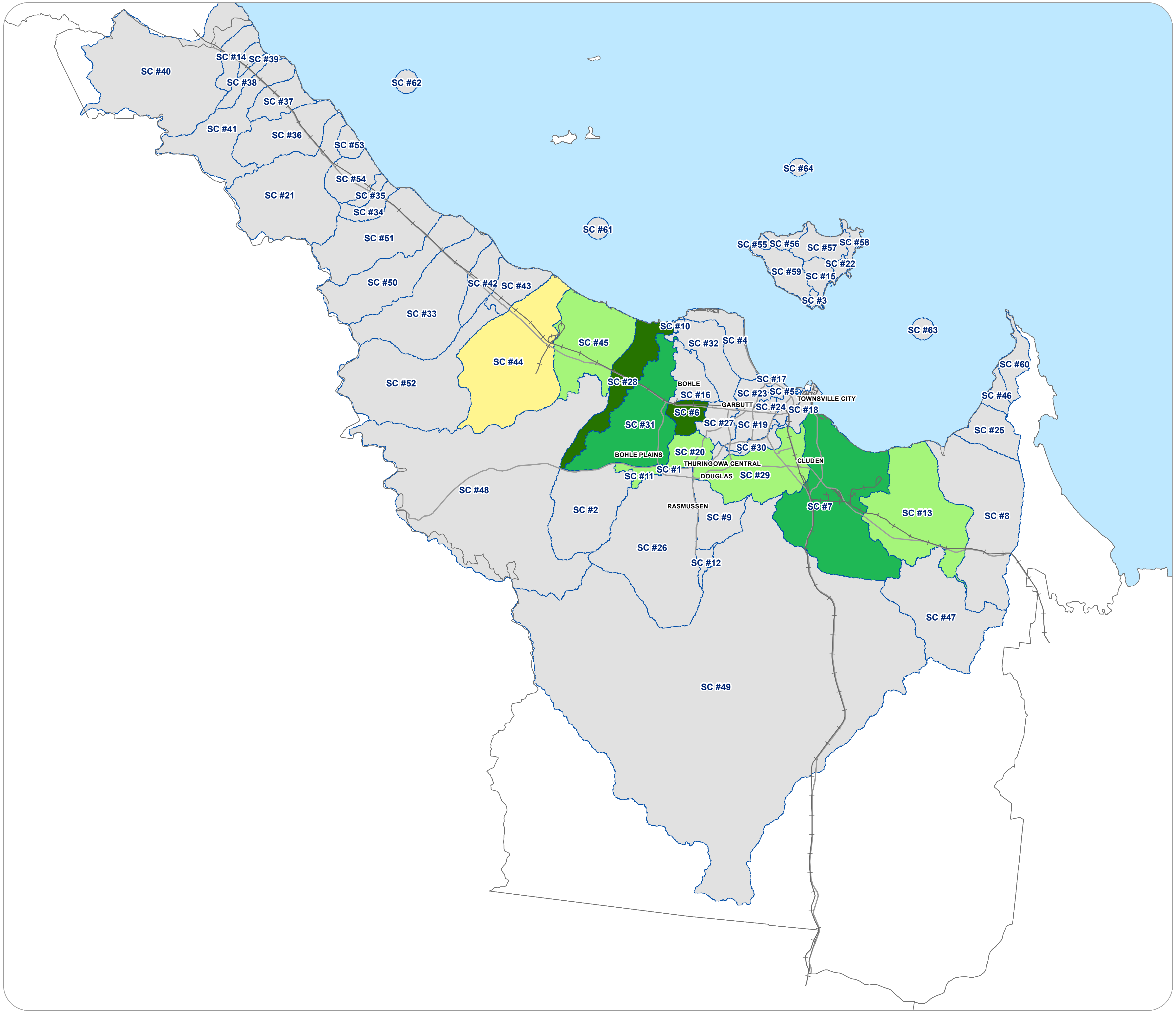
Disclaimer

This product is for informational purposes and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. The map layers displayed are compiled from various sources. Therefore, Buckley Vann gives no warranty in relation to the data displayed on this map (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data.

L E G E N D

Townsville Regional Stormwater Strategy

Percentage Change in TSS loads with State Planning Policy targets applied (excluding construction impacts)



- Sub-Catchment Boundary

Percentage Change in TSS Loads

- Below -15.0%
- -14.9 - -5.0%
- -4.9 - -0.1%
- No change
- 0 - 5.0 %

City of Townsville

Buckley Vann TOWN PLANNING CONSULTANTS

BLIGH TANNER

Author: ELM

Date: 7/10/2015

Data Source: TRC and QGIS 2015

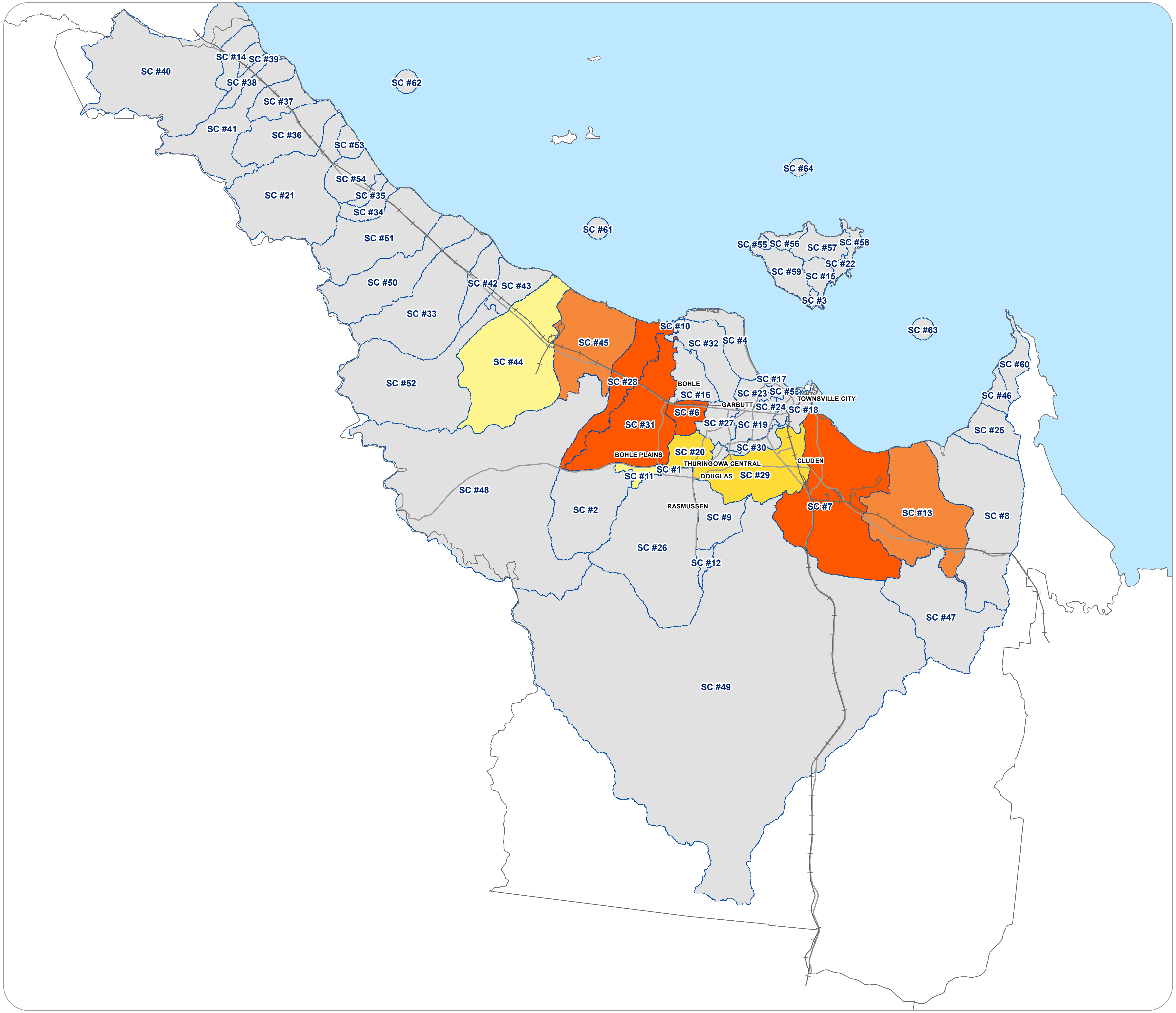
Projection: GDA 94 Zone 55

N

0 5 10 km

1:350,000

Disclaimer



L E G E N D

Townsville Regional Stormwater Strategy

Percentage Change in TSS loads with State Planning Policy targets applied (including construction impacts)

Sub-Catchment Boundary

Percentage Change of TSS Loads

- No change
- 0.1 - 5.0%
- 5.1 - 10.0%
- 10.1 - 20.0%
- 20.1 - 50.0%
- 50.1 - 100.0%
- 100.1 - 200.0%
- 200.1 - 434.2%

Author: ELM

Date: 7/10/2015

Data Source: TRC and QGIS 2015

Projection: GDA 94 Zone 55

N

0 5 10 km

1:350,000

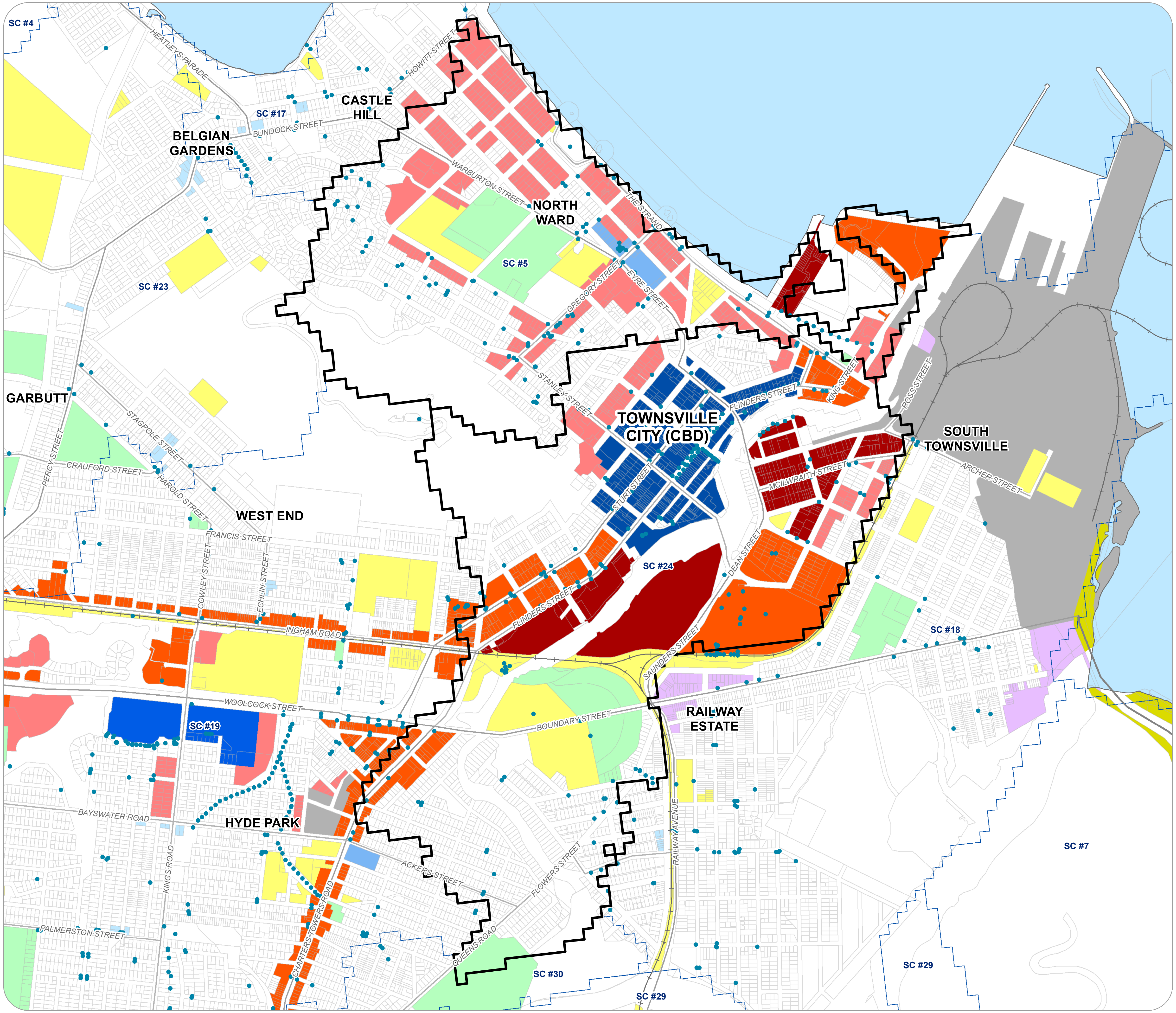
Disclaimer

Appendix C – Priority Locations for Gully Baskets

L E G E N D

Townsville Regional Stormwater Strategy

Priority Areas for Litter Baskets CBD INNER URBAN AREA



- Gully Pit
- Priority Sub-Catchment for Gully Baskets
- Boundary

Zoning

- Medium Density Residential
- High Density Residential
- Neighbourhood Centre
- Local Centre
- District Centre
- Major Centre
- Principal Centre
- Specialised Centre
- Mixed Use
- Sport and Recreation
- Community Facilities
- Low Impact Industry
- Medium Impact Industry
- High Impact Industry
- Special Purpose

City of Townsville

Buckley Vann

BLIGH TANNER

Author: ELM

Date: 9/10/2015

Data Source: TRC and QGIS 2015

Projection: GDA 94 Zone 55

0 0.25 0.5 km

1:18,000

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