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Site Based Stormwater Management Plan

Oonoonba Urban Development, Townsville

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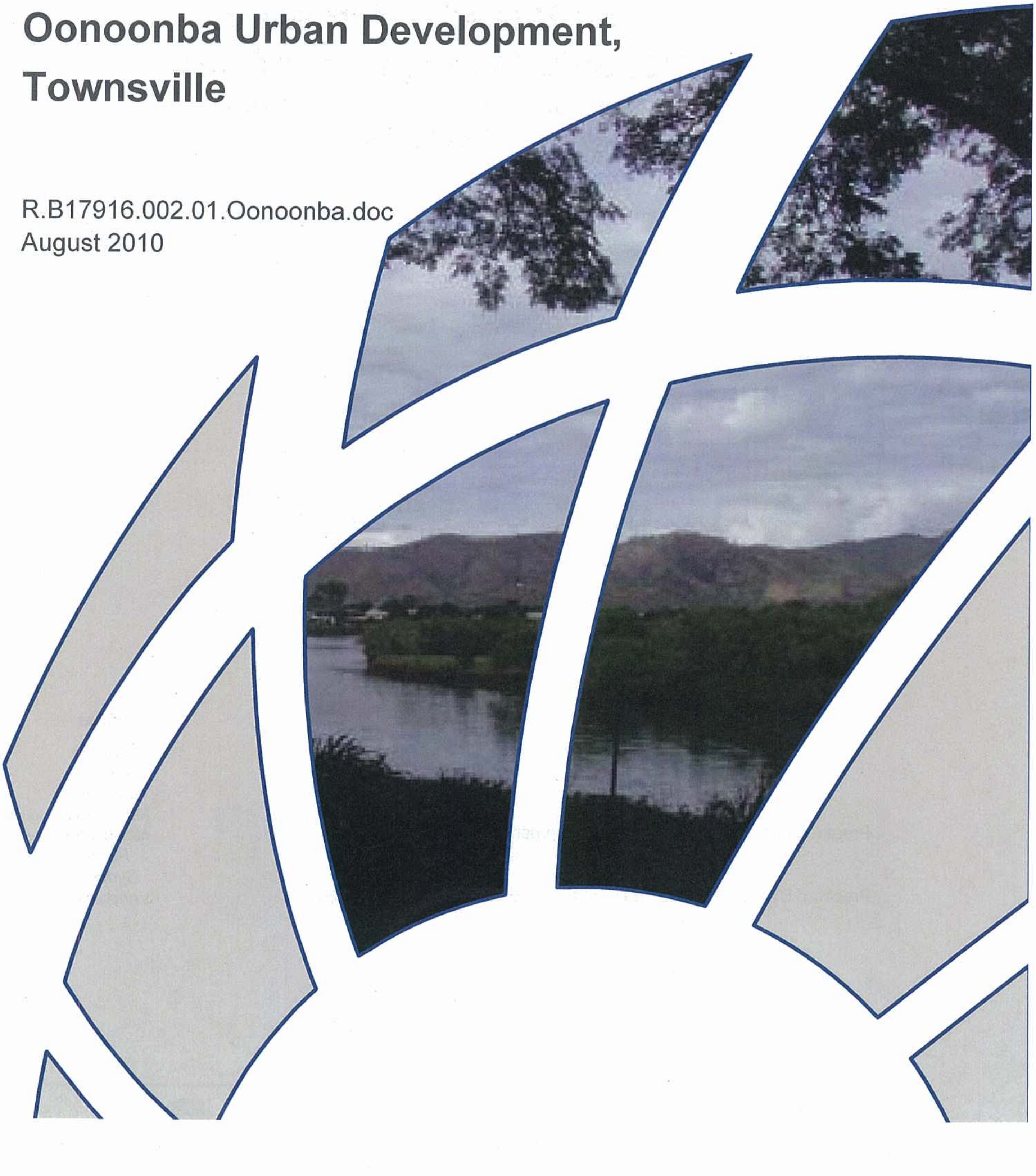

Site Based Stormwater Quality Management Plan

Oonoonba Urban Development, Townsville

Prepared For: Urban Land Development Authority

Prepared By: BMT WBM Pty Ltd (Member of the BMT group of companies)

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Title :	Site Based Stormwater Quality Management Plan- Oonoonba Urban Development, Townsville
Author :	Sarah Glasson
Synopsis :	Provides a preliminary assessment of options for stormwater quality management for the proposed urban development at Oonoonba, Townsville.

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1 INTRODUCTION

The Urban Land Development Authority is proposing the development of a parcel of state owned land at Oonoonba, Townsville to deliver housing outcomes in accordance with the ULDA objectives in providing affordable housing.

Presented within this document is the Site Based Stormwater Quality Management Plan (SBSQMP) for the proposed development. The SBSQMP provides a Stormwater Management Strategy broadly outlining the planning, management and maintenance issues for stormwater treatment measures, both structural and non-structural.

Stormwater from the site will drain to receiving waterways including the adjacent Ross River. Consequently, there is a need to manage stormwater to ensure that there are no unacceptable environmental impacts resulting from the proposed development.

This SBSQMP addresses the important issue of stormwater management at the site and considers the following key issues:

- Characteristics of the site and any natural opportunities and/or constraints it provides in managing stormwater quality and/or quantity;
- Definition of acceptable Water Quality Objectives (WQO's) for stormwater discharges from the site;
- Identification of ULDA development requirements relevant to water quality issues;
- Integration/selection of Water Sensitive Urban Design (WSUD) principles and Stormwater Quality Best Management Practices (SQBMPs) into the proposed development to achieve the required WQOs; and
- Identification of any further requirements that may be required with future approvals and applications.

The SBSQMP included in this report provides a conceptual water quality assessment of the proposed development site as a whole, however it is noted that the current Development Application is for Stage 1 only, which covers a small area at the southern extent of the site (adjacent to the neighbouring 'Fairfield Waters' development). This management plan has been prepared entirely on a conceptual level of detail, however it explains how the development will satisfy targets related to stormwater quality.

2 SITE CHARACTERISTICS

2.1 Location

The subject site is located at 180-202 River Boulevard, Oonoonba, approximately 3 kilometres south of the Townsville CBD. The site is bound by the Ross River to the north and west, a rail corridor and Abbott Road to the east, and the master planned development 'Fairfield Waters' to the south, which consists of detached houses on individual lots. The location of the subject site is illustrated in Figure 2-1. The Stage 1 development area for which the current development application applies to is shown in Figure 2-2.

The site is described as Lot 51 on K 103 928 however also includes the land extending to the water level to the west and north.

2.2 Topography & Site Drainage

The site is low lying and relatively flat throughout. Areas of saltwater intrusion and surface ponding are evident. The ground surface level across Stage 1 is undulating, with the majority of the area at gentle slopes with level varying between RL 4m and RL 5m. However, there is a prominent ephemeral channel/gully running approximately north south and bisecting Stage 1 where water appears permanently ponded in areas and ground surface level drops from approximately RL 4m down to less than RL 2m. There is also another less prominent channel/gully, on the east side of the north-south gully, which runs south-east to north- west from the southeast corner of the parcel of land. Here ground level drops from RL 4m down to approximately RL 3m (AECOM, 2010). A moderate scale of earthworks is proposed to build up low lying areas for flood immunity and to accommodate drainage needs. Refer to Appendix A for detailed survey information of the site.

2.3 Soils and Groundwater

Geotechnical investigations undertaken by AECOM (2010) indicate ground conditions are variable across the site. Sediments are mostly comprised of weak alluvial sediments generally underlain by very stiff to hard clays. The upper alluvial deposits are interlayered sands, silty sands, clayey sands and some sandy clays/clayey sands.

In most locations, there are significant depths (i.e. > 1 m thick) of very loose to loose sandy soils, which are sometimes evident at surface and elsewhere are below surface. In a few locations, significant thickness of soft clay was recorded (AECOM, 2010). Groundwater levels recorded in test pits were highly variable across the site, ranging from very high (RL 3.2 - 4m adjacent to the main gully running through the site) to no detection at all in pits excavated as low as RL 1m. The potential for encountering a high groundwater table, particularly around low lying open space areas (that will have no/minimal fill) may restrict the adoption of end of pipe treatment devices such as bioretention systems. At-surface management of stormwater through the use of streetscape bioretention will be less constrained by potentially high groundwater levels on the site.

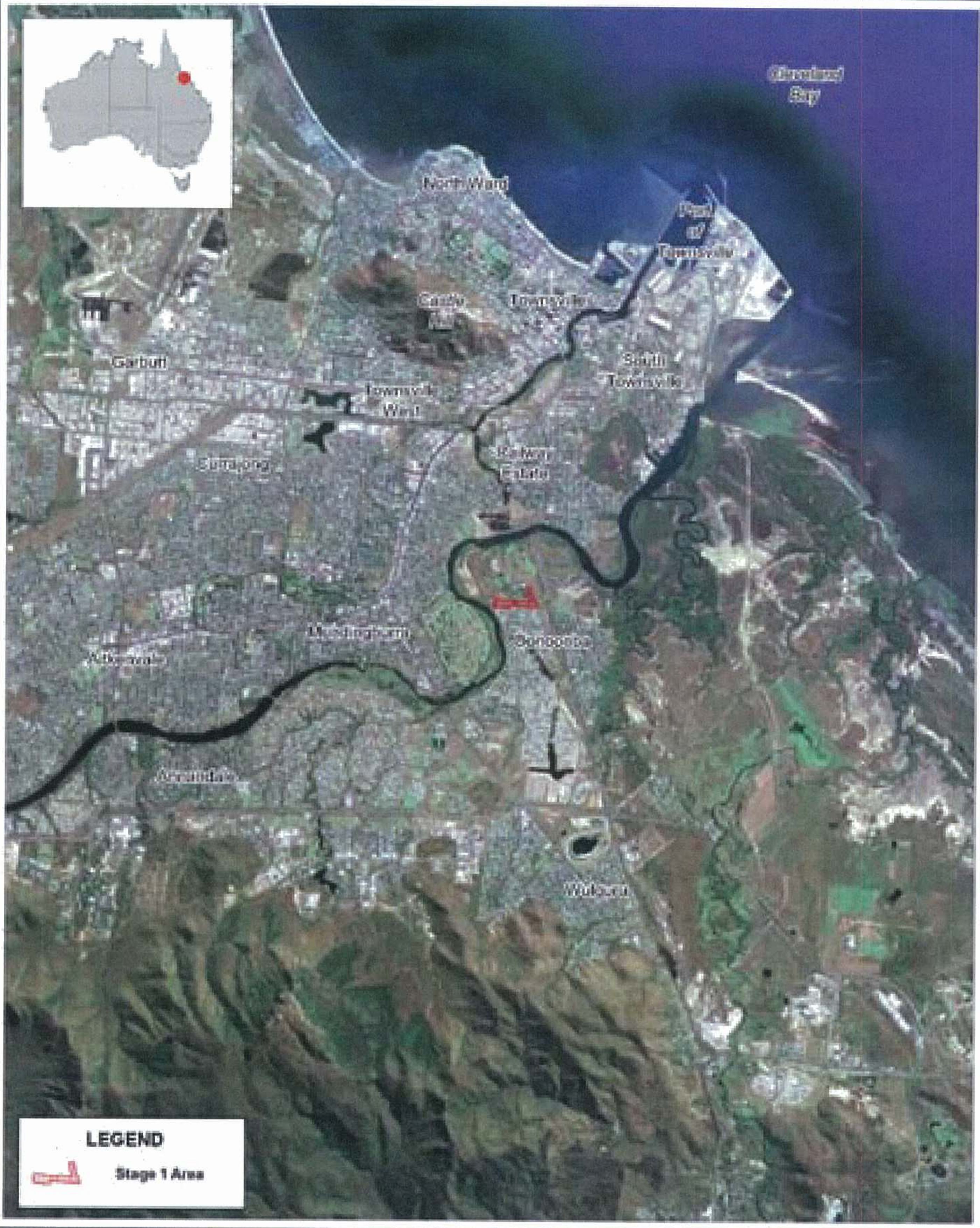
As the majority of the site is located below RL 5 m AHD, and will require >500m^3 of fill placed at an average depth >0.5m, an Acid Sulfate Soil (ASS) investigation has been undertaken to fulfil the *State Planning Policy 2/02 Guideline for Acid Sulfate Soils* (SPP 2/02). The investigation identified the presence of ASS across the site, and as such a detailed ASS management plan will be developed to mitigate potential impacts associated with the disturbance of ASS for the construction phase. Please refer to AECOM's *Oonoonba Site Geotechnical Assessment of Land Suitability for Residential Development* (2010) and Acid Sulfate Soil investigation (AECOM, 2010b) for further details.

2.4 Existing & Proposed Land Usage

The site is currently occupied by the Department of Primary Industries and houses a quarantine facility and research centre for animals. An aerial photo showing the location of the existing site is provided in Figure 2-1.

A residential development is proposed at 180-202 River Boulevard, Oonoonba (Townsville City). The site is approximately 80 ha in area, and will ultimately be developed into approximately 900 lots (primarily residential) with a lot size range from nominally 200m^2. The proposed development site layout is shown in Figure 2-2.

It is noted that water quality modelling undertaken for the current investigation has been based on a previous lot layout, as shown in Appendix B. However the new lot layout (Figure 2-2) includes only minor alterations for Stage 1 (the subject of the current Development Application), and the superseded lot layout (Appendix B) is consistent with the overall development intention and suitable for the purpose of this report, which has been to demonstrate how water quality objectives can be achieved on the proposed development site. Furthermore, the key difference in the updated lot configuration is the maintenance of the existing overland flow channel through the site, which is expected to increase the overall area of open space on site, and thus actually improve water quality discharged from site.



Title:
Location of Site

Figure: 2-1

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Title: Proposed Development Layout	Figure: Figure 2-2	Rev: A

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3 WATER QUALITY

3.1 Opportunities & Constraints for Water Quality Management

3.1.1 Site Opportunities

There are a number of opportunities presented by the site for the application of stormwater quality and quantity controls, as described below:

- **Layout** – The proposed site layout offers areas where Stormwater Management Measures (SMMs) could be incorporated, without detracting from the usability of the site.
- **On Site Water Demand** – The site will require a large amount of water for several non-potable household usages (eg. irrigation, laundry and toilet flushing), as well as parkland irrigation. Opportunities exist for the use of alternate water supply sources such as rainwater and stormwater to meet these demands and assist in conserving potable water supplies. The reuse of rainwater and stormwater would also reduce stormwater runoff volumes and pollutant loads generated from the site. Although these opportunities have been investigated, it is noted that harvesting rainwater/stormwater runoff within the urban development may not be feasible given Townsville's rainfall patterns (long dry season). Sewer mining or greywater reuse may provide viable alternative options for satisfying a significant portion of irrigation demands (due to consistent supply throughout the year), however these options have not been investigated as part of this study. These options will reduce the demand on potable water supply, however it is noted that they will not improve the quality of stormwater discharged from site.
- **Education** – The nature of the project makes it an ideal candidate for implementation of a targeted information and educational program including such practices as interpretive signage and information handouts for visitors to the site in relation to stormwater quality management. This can have a significant effect on reducing pollutant loads in stormwater (eg, litter, nutrients).

3.1.2 Site Constraints

The major constraints identified for the site with respect to the application of stormwater quality controls are as follows:

- **Topography** – The site has very small gradients, which are generally unsuitable for stormwater treatment devices that convey flows, such as vegetated swales. In addition, the water table and outlet heights will be a constraint in the depth of the stormwater treatment systems, and locating devices to be able to drain off site.
- **Lot Access** – Residential lots are typically located on both sides of proposed road reserves. Each lot will obviously require its own access (ie. driveway). The integration of longitudinal SMMs (eg. vegetated swales, bioretention swales) would be likely to be difficult due to the need for 'driveway cross-overs' (over or through the SMMs), which cause several operational problems (eg. high cost, potential reduction in conveyance, postal access difficulties, safety issues).

3.2 Pollutants of Concern

3.2.1 Construction Phase

During the construction phase of a development, the pollutants listed in

Table 3-1 have been identified (Brisbane City Council, 2000) as being typically generated.

Table 3-1 Typical Pollutants Generated During the Construction Phase

Pollutant	Source	Priority
Litter	Paper, construction packaging, food packaging, cement bags, off-cuts	High
Sediment	Unprotected exposed soils and stockpiles during earthworks and building works	High
Hydrocarbons	Fuel and oil spills, leaks from construction equipment	High
Toxic materials	Cement slurry, asphalt prime, solvents, cleaning agents, wash waters (eg. from tile works)	Medium
Acid or Alkaline substances or producing substances	Acid sulfate soils, cement slurry and wash waters	High

3.2.2 Operational Phase

Pollutants typically generated by low and high-density residential development types are listed in Table 3-2 (Brisbane City Council, 2000). Highlighted cells in Table 3-2 represent the key pollutants to be targeted for treatment.

Table 3-2 Typical Pollutants Generated During the Operational Phase

Pollutant	Low Density Residential Landuse	High Density Residential Landuse
Litter	Yes	Yes
Sediment	Yes	Yes
Oxygen Demanding Substances	Yes	Yes
Nutrients (Nitrogen & Phosphorus)	Yes	Yes
Pathogens	Yes	No
Hydrocarbons	No	Yes
Heavy Metals	Yes	Yes
Surfactants	Yes	Yes
Organochlorines and organophosphates	No	No
Thermal Pollution	No	No
pH altering substances	No	No

3.3 Water Quality Objectives

3.3.1 Construction Phase

Performance criteria for the construction phase of the development have been taken directly from DERM's (2009) "*Draft Urban Stormwater – Queensland Best Practice Environmental Management Guidelines 2009*". These criteria are given in Table 3-3.

Table 3-3 Construction Phase Performance Criteria

Pollutant/ Issue	Stormwater Design Objective
Coarse sediment	Retain coarse sediment on site
Fine sediment (Total Suspended Solids)	Take all reasonable and practicable measures to collect all run-off from disturbed areas and drain to a sediment basin — up to the design storm event. Site discharge during sediment basin dewatering complies with a TSS concentration less than 50 mg/L up to the design event — flocculation as required. In storms greater than the design event take all other reasonable and practicable measures to minimise erosion and sediment export.
Turbidity	Released waters from the approved discharge point(s) have turbidity (NTU) less than 10% above receiving waters turbidity—measured immediately upstream of the site.
Nutrients (N and P)	Manage through sediment control
pH	Prevent litter/waste entering the site or the stormwater system or internal watercourses that discharge from the site—minimise on-site production, contain on-site and regularly clear bins.
Litter or other waste	As recommended by Acid Sulphate Soil Management Plan.
Hydrocarbons and other contaminants	Prevent from entering the stormwater system or internal watercourses that discharge from the site—control storage, limit application and contain contaminants at source. Waste containing contaminants must be disposed of at authorised facilities.
Wash down water	Prevent from entering the stormwater system or internal watercourses that discharge from the site.
Cations and anions	As required under an approved Acid Sulfate Soil Management Plan, including aluminium, iron and sulfate.
Stormwater drainage/ flow management	Take all reasonable and practicable measures to minimise changes to the natural waterway hydraulics and hydrology from: • peak flow for the 1–year and 100–year ARI event (respectively for aquatic habitat and flood protection) • run-off frequency and volumes entering receiving waters • uncontrolled release of contaminated stormwater.

For more information, see DERM (2009)

Detailed construction phase plans will be submitted as part of the 'operational works application' for each stage of the development.

A construction checklist for Bioretention systems from Townsville City Council's WSUD Technical Design Guidelines for the Coastal Dry Tropics is contained in Appendix C.

3.3.2 Operational Phase

Performance criteria for the operational phase of the development have been taken directly from Townsville's Water Sensitive Urban Design Guidelines (2009). These criteria are given in Table 3-4 below and specify the design objectives for Coastal Dry Tropics in mean annual pollutant load leaving a development site, compared to traditional urban design where stormwater is not treated.

Table 3-4 Townsville Pollutant Load Reduction Targets (TCC, 2009)

Pollutant	Criteria
Total Suspended Sediment	65% reduction
Total Phosphorus	55 % reduction
Total Nitrogen	35% reduction
Gross Pollutants	90 % reduction

The draft Black Ross (Townsville) Water Quality Improvement Plan (WQIP) (Gunn and Manning 2009) also identifies draft Environmental Values and Water Quality Objectives for the Ross River, that stormwater from the site will discharge to. The receiving waterways and aquatic ecosystems downstream of the site (in the Ross River) have been characterised as slightly to moderately disturbed in this WQIP. Concentration based estuarine ambient Water Quality Objectives and Targets documented in the WQIP for the Ross River are detailed in Table 3-5. It is noted that these are ambient concentrations rather than stormflow concentrations, which will be naturally elevated. Hence the load-based pollutant removal targets in Table 3-4 are adopted as best practice water quality objective targets for the proposed urban development.

Table 3-5 Ambient Water Quality Objectives and Targets (Gunn and Manning, 2009)

Pollutant	Criteria
Total Suspended Sediment	20 mg/L
Total Phosphorus	0.025 mg/L
Total Nitrogen	0.3 mg/L

3.4 Modelling Approach

The performance of possible stormwater treatment strategies in managing stormwater pollutants (during the operational phase) has been assessed using the MUSIC software package (Version 3) developed by the CRC for Catchment Hydrology and now supported by the eWater CRC. MUSIC is well suited to the assessments required for the proposed development, i.e. prediction of annual discharge loads of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). The software has been specifically designed to allow comparisons to be made between different stormwater management systems and thereby function as a decision support tool.

The site was separated into four sub-catchments, and the extent of these locations is illustrated in Figure 3-1. Source nodes and treatment nodes were specified within each sub-catchment and land use categories were selected to represent as accurately as possible how each sub-catchment will generate and treat stormwater.

Stormwater management systems are simulated in MUSIC by the construction of treatment trains comprising various sources, treatment and receiving nodes. A brief overview of the nodes that have been used in the model can be found in the sections below.

3.4.1 Source Nodes

Within MUSIC, the user is required to specify source nodes. The source nodes represent the pollutant generating areas of the site.

MUSIC has generic source nodes, which represent different land-uses. The default parameters for soil properties and storm and base flow pollutant concentrations differ for each land use. The option exists within MUSIC for the user to alter the default parameters as required to best represent the land use being modelled, particularly when the land-use which requires modelling does not correspond with the urban, forest or agricultural defaults supplied in MUSIC.

Source nodes were specified within each sub-catchment to represent as far as practicable how each sub-catchment will generate stormwater. To allow for an accurate pollutant generation and hydrologic assessment of the site, each sub-catchment was assigned source nodes representing the various sized areas.

Townsville City Council is developing MUSIC modelling guidelines specific to the Townsville region. These guidelines are due to be released in 2011. In the current absence of MUSIC Modelling Guidelines specific for Townsville City Council, Water By Design's (2009) "*Draft MUSIC Modelling Guidelines for South East Queensland*" (SEQ MUSIC modelling guidelines) have been applied in the development of the MUSIC models.

As outlined previously, four sub-catchments within the site were identified for modelling purposes.

For this assessment, the existing land use has been assumed to consist of 'Agriculture' and 'Rural Residential' land uses. This classification was based on the existing land use (DPI quarantine facility and research centre for animals), inspection of aerial photography and a site investigation undertaken on 30 June 2010.

As recommended by SEQ MUSIC modelling guidelines, the proposed development areas were discretised into roof, road reserve and other impervious (ground level) areas.

The extent of the residential lot, road reserve and open space areas was measured from plans made available from ULDA. The MUSIC modelling has assumed that the lots have an average size of $410m^2$, with an average roof area of $250m^2$. In the rainwater tank modelling scenario, 50% of the roof area was assumed to be connected to the rainwater tank (in accordance with SEQ MUSIC modelling guidelines).

The applied land usage proportions are summarised in Table 3-6.

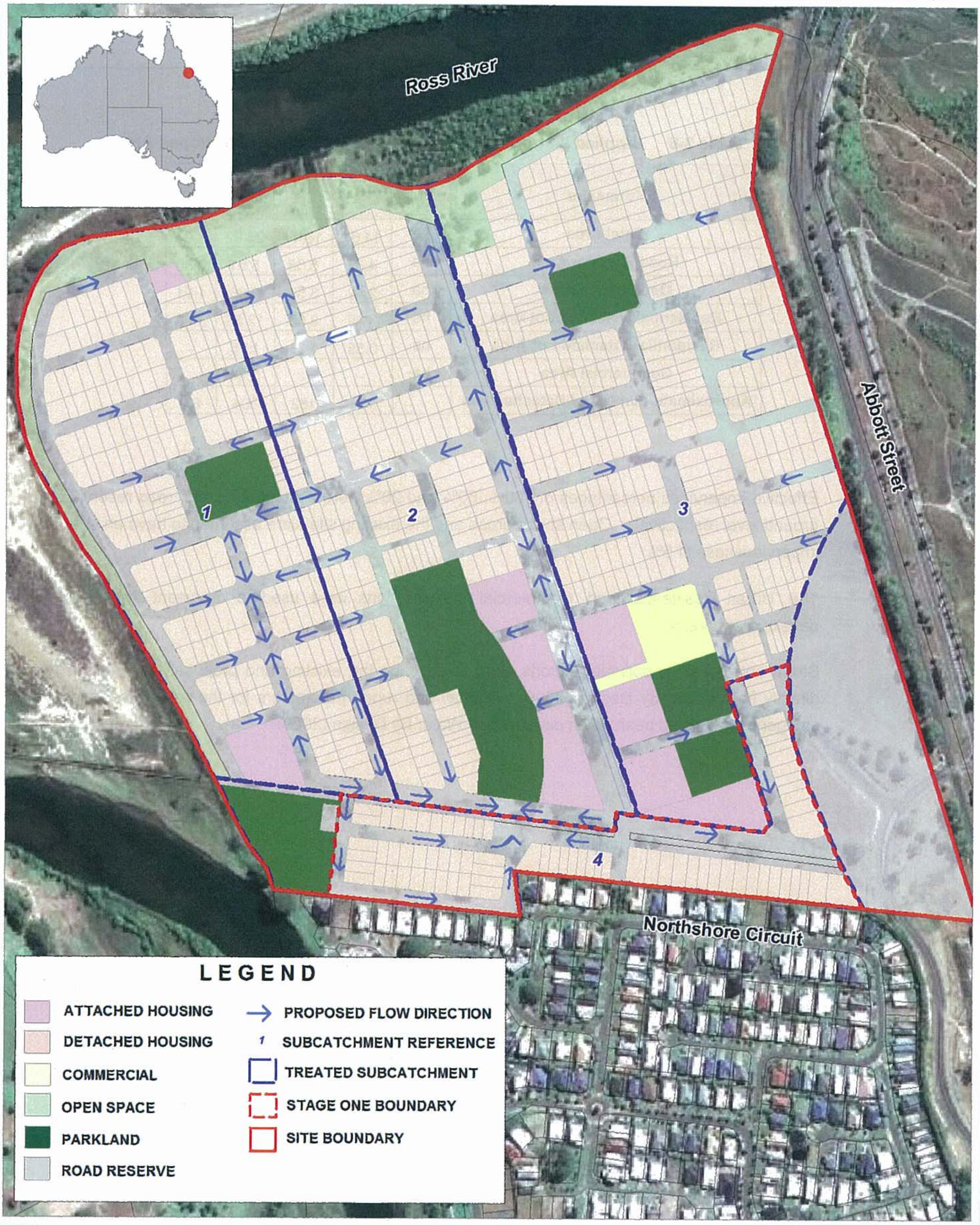
Table 3-6 Applied Land Usage Proportions for Proposed Developed Areas

Parameter	Units	Subcatchment Reference			
		1	2	3	4
Total Area	ha	14.61	18.41	23.92	7.03
Road Reserve Area	ha	4.35	5.66	5.61	3.50
Open Space Area	ha	2.42	3.50	2.96	1.01
Residential Detached Lot Area	ha	7.29	8.00	12.86	2.53
Residential Attached Lot Area	ha	0.55	1.25	1.75	-
Commercial Area	ha	-	-	0.74	-
Approximate number of Detached lots		194	182	304	62

Effective impervious percentages of 100%, 60% and 20% were assumed for roof, road reserve, and ground level respectively. Open space areas and the existing site were assumed to have an effective imperviousness of 5%.

The 'Urban Residential' and 'Commercial' classifications were used to represent the proposed development areas.

Storm and baseflow pollutant exports used to describe the existing and proposed site were taken directly from Water By Design (2009). Rainfall and runoff parameters for the respective land use categories have also been taken directly from Water By Design (2009).



Title: Subcatchment Layout	Figure: 3-1	Rev: A

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3.4.2 Treatment Nodes

MUSIC requires the user to specify stormwater treatment nodes. These nodes essentially represent the stormwater treatment train.

MUSIC has a number of generic treatment nodes including gross pollutant traps, ponds, wetlands, swales, bio-retention systems, sedimentation ponds and buffer strips. Each treatment node has several default parameters that can be altered by the user to allow the treatment device to be 'customised' to better represent the treatment device that would ultimately be installed on site. A treatment train consisting of education, gross pollutant traps and streetscape bioretention has been proposed for the site of the proposed development. Options have also been investigated to capture and reuse rainwater and stormwater to reduce demands on potable water supplies. The treatment train is illustrated in Figure 4-2. Details of the types of treatment devices proposed for use on the site and how they will be configured are presented in the following sections.

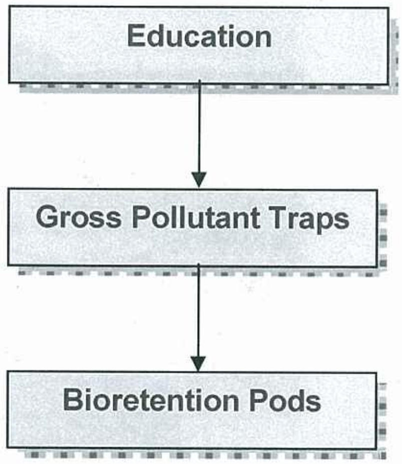


Figure 3-2 Recommended Stormwater Quality Best Management Practice Treatment Train for the proposed development

3.4.2.1 Education

Education has significant potential to decrease pollutant loads at the source and increase peoples' understanding and acceptance of water quality issues and stormwater treatment devices. It is proposed that signage be installed at appropriate locations (eg. adjacent to proposed SMMs).

An example of educational signage to improve understanding of water quality issues is given in Figure 3-3. While the potential for pollutant load reduction due to education is noted, it has not been assumed within the MUSIC model.

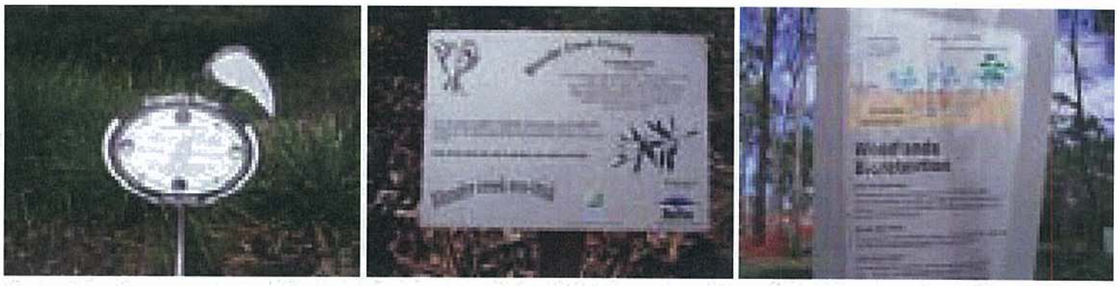


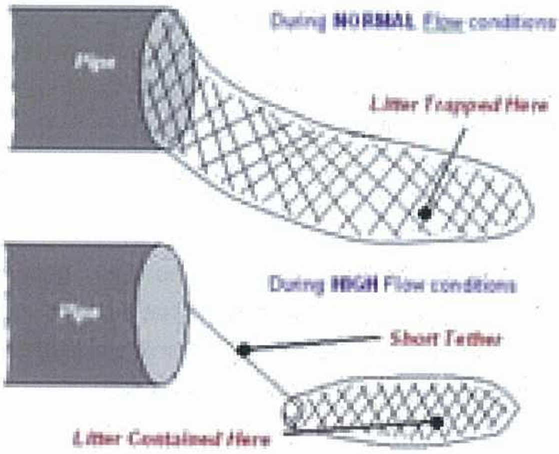
Figure 3-3 Examples of Signage to Improve Understanding of Water Quality Issues

3.4.2.2 End-of-Pipe GPTs

Gross Pollutant Traps (GPTs) are devices for the removal of solids conveyed by stormwater that are typically greater than 5mm. There are a variety of gross pollutant traps currently suitable for use in urban catchments including in-ground gross pollutant traps, trash racks and pipe nets. Illustrated examples of these devices are provided below.

(Source: CDS, 2005)

Figure 3-4 Example of an In-Ground Gross Pollutant Trap (image of a CDS Unit)



(Source: Melbourne Water)

Figure 3-5 Example of a Release Net

Figure 3-6 Example of a Trash Rack

In-ground gross pollutant traps such as a CDS Unit create centripetal forces to draw pollutants into the centre of the unit, which then gravitate to an offline sump. Pipe nets are simply netting attached over the outlet of a pipe. If the design flow is exceeded or the netting is full the net can detach from the drain, with the net being choked by a short tether. Trash racks consist of a series of metal bars located across a channel or pipe, which act to trap large litter and debris such as plastic bottles, cans, leaves and branches.

These devices could be applied at the 'end-of-pipe' (at the downstream end of a stormwater drainage system), providing pre-treatment (removal of gross pollutants) to SMMs (eg. bioretention basin). located downstream. It is noted that the best practice guidelines (Water by Design, 2009) also state that end of pipe GPTs with wet sumps are not a suitable treatment option for low to medium density residential developments due to low gross pollutant generation in these types of catchments high maintenance demands associated with these GPTS. If not regularly maintained, these types of GPTs can in fact worsen pollutant export rates through nutrient leaching. Therefore the adoption of this type of GPT would only be suitable for use surrounding commercial or high density residential areas.

As an alternative measure, we would suggest the use of gully baskets if required in residential areas to capture litter/gross pollutants. These don't have a wet sump (so reduces potential for leaching pollutants). Note that where bioretention systems are located these may not be required (as litter would be captured on bioretention surface for removal).

3.4.2.3 Gully Baskets

Gully baskets could be inserted on selected gully inlets within the road reserves of the catchment, and are the preferred treatment for residential situations as they require less maintenance and are less likely to export pollutants than GPTs with wet sumps (ie CDS). Gully baskets are a type of GPT, and gully baskets (like any GPT) are principally aimed at the removal of solids conveyed by stormwater that are typically greater than 5mm.

Most GPTs are installed at the 'end-of-pipe' (ie. downstream of a relatively large catchment, often as a single pre-treatment device for other stormwater treatment devices like sedimentation basins, wetlands and bioretention basins). Gully baskets, however, are installed as a component of the gully pit design (not within the pipeline) and screen the pollutants out of the runoff as it enters the pit. Subsequently, numerous gully baskets are required within a given catchment area to provide treatment to all stormwater flows.

Figure 3-7 Pictures of Gully Baskets and Filter Mesh Installation

Gully baskets have several significant benefits (relative to other GPTs), including (Greg Kennedy, Stormwater360: 2007: *Pers.Comm.*):

- Installed below ground (usually under a grate and are relatively safe to leave unattended);
- Pollutants are captured before entering the drainage system;
- Pollutants are drained dry and stored that way (not in a wet vault);
- Significantly reduced potential for anaerobic breakdown of captured pollutants compared to wet vault systems.

- Maintenance can be performed manually by lifting out the bag insert or mechanical by suction truck;
- The capital cost and decommissioning costs are quite low in comparison;
- They can be retrofitted at any time;
- Inspections for maintenance can be visually assessed; and
- Typically there is no need for confined spaces entry during cleaning and maintenance.

As they are installed within the gully pits (within the road reserve), temporary traffic control measures would, however, be required in order to install and maintain these devices.

Stormwater360 are the suppliers of the 'Enviropod' gully basket and they claim that laboratory and field tests carried out on the Enviropod concluded that they removed "*97% of particles down to 100μm with a 200m screening bag insert*" and (because of nutrient loads are often associated with particulates and organics removed by the gully basket) some level of nutrient removal is also possible (Greg Kennedy, Stormwater360: 2007: *Pers.Comm.*). The removal efficiencies reported by manufacturers would be highly dependent on a number of factors (eg. catchment characteristics, rainfall intensity, maintenance activities), but we would anticipate that gully baskets would achieve a significant reduction of gross pollutant loads entering the wetlands (and possibly some removal of suspended solids and nutrients).

Stormwater 360 advise that their gully baskets cost approximately $484/ basket (plus GST) to purchase and install, and that typical cost for cleaning (including tipping and down time) would be approximately $30/ basket (plus GST) (Michael Wicks, Stormwater 360, 2009: *Pers.Comm.*).

3.4.2.4 Bioretention 'Pods'

A bioretention system is a soil and plant-based SQBMP. A typical system consists of a porous medium sandy loam with vegetation established to promote evapotranspiration, maintain soil porosity, encourage biological activity, and promote uptake of pollutants. Run-off is directed into the bioretention system and infiltrates through the plant/mulch/soil environment.

Bioretention systems can be integrated into a site at a variety of scales and locations, including within the road reserve as streetscape bioretention 'pods'. As illustrated in **Error! Reference source not found.** a number of configurations are available for streetscape bioretention 'pods'.

It is recommended that any bioretention systems proposed at the development have 'submerged zones'. These zones comprise of a mix of medium-to-coarse sand and a carbon source or gravel and a carbon source. The submerged zones also contain a permanent pool of water to support the plants and microbial community during extended dry spells, as well as to enhance nitrogen removal (because it promotes denitrification).

MUSIC modelling has been undertaken to assess the size of bioretention area required to achieve the stormwater management objectives (given in 3.3.2). For the MUSIC modelling, all streetscape bioretention has been assumed to have the properties as given in Table 3-7.

Figure 3-8 Examples of Streetscape Bioretention

Table 3-7 Assumed Properties for Bioretention Systems

Parameter	Value
Extended Detention Depth	0.10 m
Is Base Lined?	Yes
Saturated Hydraulic Conductivity	180 mm/hr
Filter Depth (includes saturated zone)	0.90 m

An indicative cross section of the modelled bioretention system design for the proposed development is shown in Figure 3-9.

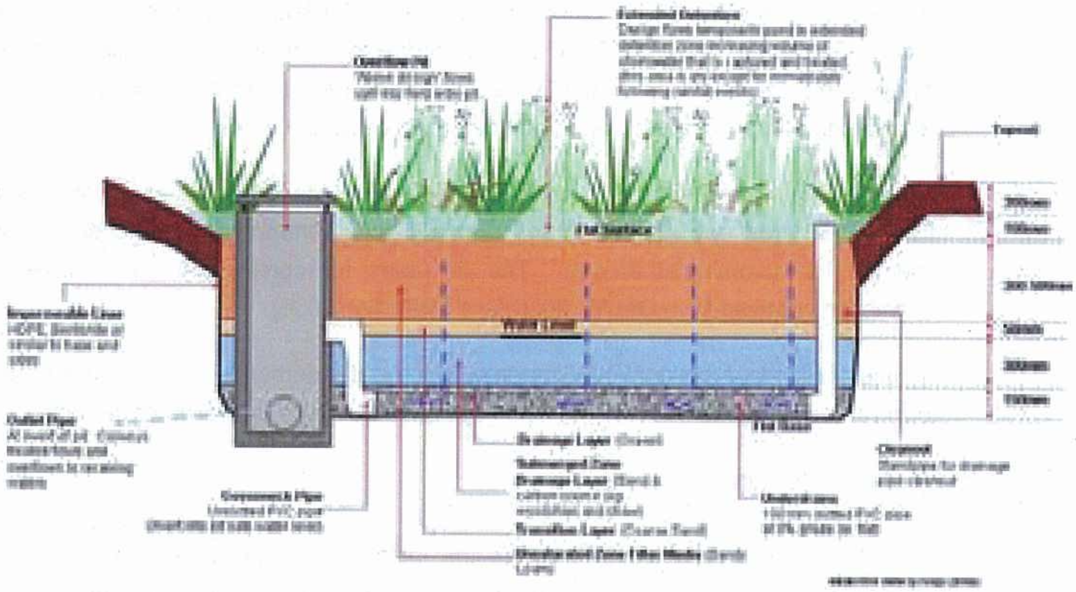


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Figure 3-9 Indicative Cross Section of Proposed Bioretention System Design

For the purposes of this report, we have provided an estimate of the approximate bioretention filter area (and, of less importance in terms of overall treatment effectiveness, bioretention surface area) required for streetscape bioretention systems within each of the catchment areas of the proposed development. The configuration, size and number of the individual bioretention systems required to satisfy the given WQOs will be determined during subsequent design stages. Native, drought tolerant vegetation will be selected for use to minimise watering needs and ensure a climate responsive solution to managing water quality on site.

3.4.2.5 Option - Rainwater Tanks

Townsville is exempt from the statutory requirement for all new residential developments to install rainwater tanks: Queensland Development Codes 4.2 and 4.3 (eg. detached residential dwellings are required to install a tank of at least 5000 litres). The reason for this is the reduced efficiency of rainwater tanks in the climatic scenario of the yearly distribution of rainfall typical of Townsville, where a continuous supply of water is not available.

In addition, Townsville is currently exempt from the mandatory water savings targets in MP4-2 and 4-3 of the Queensland Development Code, which apply to new residential and commercial developments.

Rainwater tanks were therefore modelled as a best practice water savings option, rather than as a statutory requirement. In addition, further treatment would be achieved by the use of rainwater tanks, thereby potentially reducing the area required for streetscape bioretention.

For the purposes of the MUSIC modelling, the rainwater tanks have been represented in the MUSIC model as a single 'Rainwater Tank' in each of the sub catchments. Dwellings have been modelled assuming the use of 5kL rainwater tanks. It has been assumed that each tank will be approximately 1.8m in diameter and have a permanent detention depth of 0.2m.

A non-potable water demand (potentially supplied by alternative water sources, such as rainwater tanks) of 167 litres/ day/ household and 2.25 kL/day for commercial area (toilet flushing only has been assumed for commercial areas). The demands for commercial areas have been based on assumptions derived from DECC (2010) and DNRMW (2006).

The use of rainwater tanks to supplement potable water demands would reduce peak and volumetric stormwater discharges from the site and substantially reduce mains water demand.

3.4.2.6 Option - Stormwater Harvesting

Stormwater harvesting typically involves the installation of either open water bodies (eg. ponds, wetlands, lakes) or enclosed structures (eg. storage tanks) at locations where runoff from upstream catchment areas can be collected for subsequent reuse. Pre-treatment of flows is typically recommended to protect the water body or structure from excessive pollutant loads accumulating within the device (and reducing the quality of the harvested stormwater). Treatment of the harvested stormwater is also often required, depending on how the harvested stormwater is to be utilised (and the associated potential risks, eg. to human health). For the current option it has been assumed that runoff from the entire development could potentially be harvested to meet irrigation demands for the five key parkland areas shown in Figure 2-2 (excludes the existing ephemeral channel area).

(Source: Humes, 2007)

Figure 3-10 Installation of an Underground Stormwater Harvesting Tank

Stormwater harvesting would have the following benefits:

- Provide an alternative water supply to supplement mains-water demands (within and/ or external to the site) and improve the 'security of supply' (particularly for open space areas); and
- Improve the health of downstream waterways by reducing the amount of pollutant loads from diffuse (catchment based) sources entering the waterways and returning the existing catchment hydrology to a more 'natural' condition (by retaining the frequent stormwater flows that would be unlikely to be discharged into downstream waterways in a 'natural' catchment').

The most suitable use of harvested stormwater would likely be to supplement irrigation demands for selected open space areas.

For the purposes of this assessment, we have assumed that the parklands have an average irrigation demand of 548mm/year, and irrigation application rates are scaled (in MUSIC) by daily potential evapotranspiration minus rainfall (ie. so irrigation rates are typically higher in warmer months, but no irrigation occurs during periods of rainfall).

3.4.3 Receiving Node

One node is used to represent the final destination of runoff from the site, which would ultimately discharge to the Ross River.

3.4.4 Meteorological Data

Six minute time step meteorological data for Townsville was used in MUSIC. Modelling of the site was performed for a period of ten years (from 1st January 1966 to 31st December 1976). This modelling period was selected as it provides a good match to the long term Mean Average Rainfall (MAR) for Townsville. Average potential evapo-transpiration data has been used from Townsville (as given in MUSIC).

4 SELECTION OF STORMWATER MANAGEMENT OPTIONS

4.1 Construction Phase

The pollutants of concern during the construction phase are not readily modelled due to the site-specific nature of typical construction pollutant sources. Pollutant export would be largely dependent on site management practices and would vary throughout the construction phase depending on the particular activities being undertaken. A Best Management Practice (BMP) approach should be adopted in selecting management options for the construction phase.

During the construction phase of the development, an Erosion and Sediment Control Program (E&SCP) will be implemented to minimise water quality impacts. A detailed E&SCP will be submitted during the detailed design phase of the development. The following information is provided to identify the controls and procedures that would be incorporated into the detailed E&SCP. These measures are considered sufficient to ensure the guidelines will be met given the site characteristics and the details of the proposed development.

4.1.1 Sedimentation Basin Requirements

Sedimentation basins are usually required where:

- The disturbed area is greater than 1 hectare; and/or
- The disturbed soils are dispersive; and/or
- Where there is a need to control runoff turbidity.

Since the proposed development is over 1 hectare in area, sedimentation basins will be required during construction.

4.1.2 Pre-Construction Requirements

Before construction activities begin, the following measures need to be implemented to ensure minimal disturbance and adverse water quality impacts. These measures may be adopted in a staged approach and may be implemented prior to construction beginning in one section of the proposal.

- Designating and delineating, where possible, buffer strips (approximately 10 m wide) adjacent to roadways. These buffer strips will remain vegetated and will filter sediment from construction site runoff and encourage sheet flow from the site. No construction activities will occur within this buffer zone.
- Constructing sediment fences on the upstream edges of the designated buffer areas and at the base of fill embankments.
- Designating areas for machinery and construction material storage (if required). These areas should be somewhat removed from drainage paths and runoff from these areas is directed to a holding pond in case of spillages.

- Catch drains at the downstream boundary of construction activities should also be created (wherever possible) to ensure any sediment-laden runoff is contained and directed toward treatment areas and not permitted to flow onto downstream, undisturbed areas or off-site. Diversion banks should be constructed approximately along contours to minimise scour along the drains.
- Silt fences and sand bags can be placed along catch drains to slow flow, reduce scour and capture some sediment from runoff.
- Designation and marking of transport routes across undisturbed portions of the site to ensure minimal unnecessary vegetation disturbance.
- Education of site personnel to the sediment and erosion control measures implemented on site.

4.1.3 During Construction Requirements

Prior to construction, detailed designs for the proposal will have been completed. Runoff should be directed through water quality controls before discharging off-site. Measures to mitigate water quality impacts during construction will include:

- Progressive re-vegetation of filled areas and fill batters.
- Confining construction activities within the necessary construction area(s).
- Mulching and detention of vegetation and topsoil for final site rehabilitation and landscaping works.
- Installation of silt fences downstream of disturbed areas. Silt fences should be located continuously along contours and should treat areas less than 0.6 ha per 100 m of silt fence. A maximum slope length of 60 m will also ensure optimal performance.
- Regular inspection and maintenance of silt fences, sedimentation basins and other erosion control measures. Following rainfall events greater than 20 mm inspection of erosion control measures and removal of collected material should be undertaken. Replacement of any damaged equipment should be performed immediately.
- The functional elements (eg. underdrain pipes, gravel surround, transition layer and filter media) of the streetscape bioretention systems can be constructed/ installed during road and lot-scale construction activities. However, they will need to be protected (eg. from excessive sediment loads, vehicle damage) by over-laying a temporary filter cloth (bidum or similar) over all the media, followed by a 25mm layer of topsoil and turf. This protection can be applied to all of the filter media or a section (with stormwater flows prevented from entering the remainder of the bioretention system by a plywood barrier or similar barrier). Figure 4-1 provides an example of streetscape bioretention with temporary protection (during lot-scale works). Once at least 90% of lots are completed, the turf, topsoil and filter cloth could be removed and vegetation planted throughout the bioretention systems. This has the advantages of constructing the bioretention systems as part of bulk earthworks and improving the aesthetic appearance of the bioretention basin areas during the lot-scale works. Further information in relation to the construction and establishment of bioretention systems is available in Water By Design's (2009a) "*Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands*".

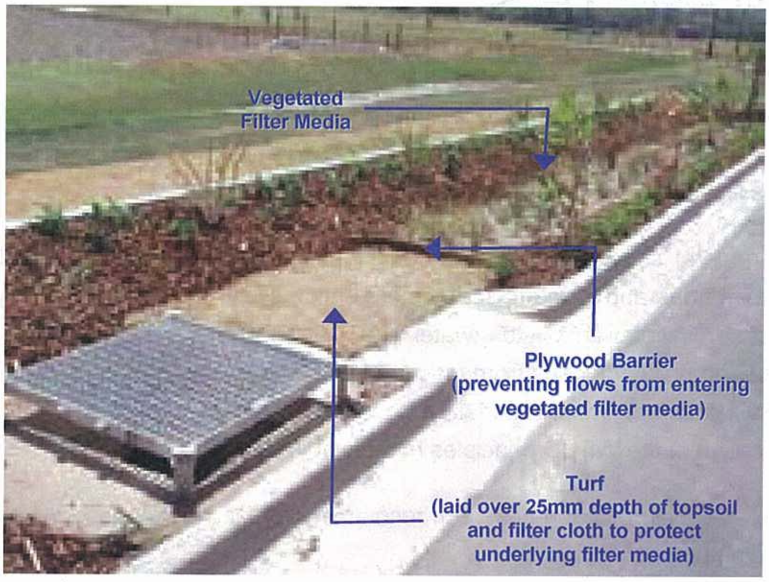

Figure 4-1 Example of Streetscape Bioretention System with Temporary Protection (During Lot-Scale Works)

4.1.4 Post Construction Requirements

Following the completion of construction works in a section of the development, the following activities will be performed:

- Re-vegetation and landscaping of remaining exposed areas using the topsoil and mulched vegetation retained from initial site clearing. Vegetation should be watered and maintained until it is suitably established.
- Maintenance of mitigation measures retained during the operational phases.

4.1.5 Monitoring

The E&SCP will specify monitoring requirements for different stages of site construction activities. The general requirement of the monitoring will be to ensure that:

- Work activities are maintained within the dedicated construction areas;
- Site clearing, and cut/fill activities occur in accordance with the requirements of the E&SCP;
- E&SC structures are installed in accordance with the requirements of the E&SCP;
- E&SC structures are checked for integrity and functionality on a regular weekly basis, as well as after (*and/or during*) heavy rain events;
- Stormwater discharges from the site are not causing any damage to downstream waterways or water bodies (*i.e. site gullies, Ross River*); and
- Appropriate water quality levels are set on stormwater discharges from sedimentation ponds and these are maintained during the construction period (refer Table 3-3).

4.2 Operational Phase

A wide range of Stormwater Quality Best Management Practices (SQBMP's) were assessed for applicability to the site. From the available SQBMP's, treatment trains have been proposed for the site to target each of the pollutants of concern identified. The proposed treatment train for the subject site is illustrated in Figure 3-2.

The general concept of the treatment train is to direct the majority of stormwater through gross pollutant traps and /or streetscape bioretention systems prior to discharge from the site. The option of using rainwater tanks/stormwater harvesting to reduce potable water demands and reduce peak flows and pollutant loads from the site has also been investigated. Water quality modelling using the MUSIC software was undertaken to assess the effectiveness of the treatment trains and the application of the WSUD principles to the whole site.

Streetscape bioretention has been recommended for the proposed development for several reasons, including (but not limited to):

- Reduced risk of operational problems (eg. scour/ erosion)
- Improved integration into the landscape (particularly relative to 'end-of-pipe' solutions, which necessitate large depths/ batters).
- Less likely to encounter groundwater table compared to the use of bioretention systems as end of pipe solutions.
- Reduced risk to public safety.
- Reduced area requirements for stormwater treatment.
- Considered best practice stormwater management for sites with constraints similar to the proposed development.

This is discussed further below.

It should be noted that this report has been prepared entirely at a conceptual level of detail. Streetscape bioretention is likely to be a preferred method for stormwater management given several reasons (including those described below). Nevertheless, opportunities for 'end-of-pipe' bioretention systems may be explored where considered potentially feasible and a possibly better method of stormwater management. The filter area requirements for 'end-of-pipe' bioretention systems are identical to 'streetscape' bioretention systems.

Reduced Risk of Operational Problems

BMT WBM recently undertook a review of Council-owned constructed wetlands and bioretention systems (used for stormwater treatment) within South East Queensland. This assessment demonstrated that 'end-of-line' stormwater treatment devices had a greater risk of operational problems (relative to 'at source' devices), including (but not limited to) erosion/ scour, poor drainage and vegetation loss.

Where 'end-of-pipe' devices have been applied, the health of downstream environments is often heavily dependent on these 'end-of-pipe' devices due to the small numbers of these devices present (relative to 'at source'/ distributed treatment devices). If these 'end-of-pipe' devices have operational problems, there is obviously greater consequences to the health of downstream environments relative to problems potentially experienced by isolated 'at source'/ distributed stormwater treatment devices (given the increased number of these devices).

The use of swales on flat sites can also present poor drainage issues along the invert, due to the low longitudinal grade generally required of the swale. Another operational risk of roadside swales is the adjacent resident filling or planting within the swale, which would change the conveyance characteristics of the swale. Swales also typically require more ongoing maintenance than streetscape bioretention systems.

Improved Integration into the Landscape

As shown by the examples of streetscape bioretention provided in Figure 3-8 streetscape bioretention systems can be easily integrated into the landscape/ streetscape. 'End-of-pipe' wetlands and bioretention systems are significantly more difficult to integrate into the landscape. This is often due to the invert depths necessary for upstream stormwater infrastructure that necessitates large invert depths of the treatment devices. Given these large depths, 'end-of-pipe' wetlands and bioretention systems often need large batter areas (if gradually sloping) or steep batters with fencing. Figure 4-2 provides an example of a poorly integrated 'end-of-pipe' bioretention basin.

Figure 4-2 Example of a Poorly Integrated 'End-of-Pipe' Bioretention Basin

The need for driveway crossovers when using swales also makes them significantly more difficult to integrate into the landscape than streetscape bioretention, and make them a less aesthetically appealing option.

Typical road sections for the development that show how bioretention systems can be incorporated into the road reserve are included in Appendix D. Some standard drawings showing how these systems have been incorporated in another ULDA development are also included.

The typical road sections in Appendix D include the following principles to incorporate bioretention into the road reserve:

- One way crossfalls promoting flows to bioretention systems ;
- Footpath on one side of the road only in access streets to allow for bioretention on the other side;
- Incorporating bioretention as feature landscaping treatments;

- Locating the footpath closer to the property alignment in some areas along north south spine road to incorporate bioretention as wider landscaping features.

To maximize the available width for treatment measures in road reserves the following treatments are proposed where possible:

- Narrowing the width of footpaths around bioretention systems (from 2m to 1.5m)
- Locating the footpath over the water service adjacent to bioretention systems
- Locating the water service beneath bioretention systems.

Less Likely to Encounter Groundwater Table

The results of the geotechnical investigation indicated a highly variable groundwater levels across the site. The potential for encountering a high groundwater table, particularly around low lying open space areas (that will have no/minimal fill) may restrict the adoption of end of pipe treatment devices such as bioretention systems. Therefore at surface management of stormwater through the use of streetscape bioretention will be less likely to encounter high groundwater levels on the site.

Reduced Risk to Public Safety

Streetscape bioretention would not necessitate the use of driveway crossovers required by swales, reducing the risk to public safety from these types of treatments. Bioretention systems also do not contain any permanent water. As result, the risk of drowning is significantly lower than wetlands.

Reduced Area Requirements

Streetscape bioretention areas are anticipated to require less area relative to 'end-of-line' treatment devices (particularly wetlands). Although the total filter areas required for 'end-of-line' bioretention basins would be the same as for streetscape bioretention, increased invert depths and hence batters would likely increase the total surface area required. Furthermore, as previously discussed streetscape bioretention system can provide far greater opportunity for integration into landscaped areas.

Best Practice Stormwater Management

In addition to the aforementioned benefits, streetscape bioretention also is highly effective at reducing pollutant loads, retaining stormwater flows and treats stormwater 'at the source'. As a result, streetscape bioretention is typically considered best practice stormwater management (particularly for flat sites such as the proposed development).

Water By Design's (2009) "*Conceptual Design Guidelines for Water Sensitive Urban Design*" also support the above statement. Section '*Best Planning Practice 2 – Flat Sites*' describes the advantages of streetscape bioretention in great detail and cites the existing Stockland's "*Bellvista Estate*" (and its use as streetscape bioretention) as follows:

"*After considering several approaches, an at-source and at-surface approach was adopted using bioretention pods in residential streets. This strategy is the best outcome for the site given the constraints of low-lying, flat topography and sensitive receiving waters. By using an approach that finds the synergies between stormwater quality, road drainage, traffic calming, and landscape design,* *Bellvista Estate delivers innovative streetscapes that provide at-source treatment of stormwater integrated into the urban landscape*

The solution represents best practice in stormwater management by protecting natural systems, integrating stormwater treatment into the landscape, protecting water quality, reducing runoff and peak flows, and adding value... "

Water by Design is a capacity building program that was established by the South East Queensland Healthy Waterways Partnership (SEQHWP) as an "*integral part of the South East Queensland Healthy Waterway Strategy*" (Water By Design, 2010). Although the project site is outside of SEQ, the Water by Design program reflects current best practice and research findings for Water Sensitive Urban Design.

We subsequently believe that our proposed stormwater management strategy (consisting of education, gross pollutant traps and streetscape bioretention) represents best practice stormwater management for the proposed development (and associated site conditions).

Streetscape bioretention is likely to be a preferred method for stormwater management given several reasons (including those described above). Streetscape bioretention may also be located in parkland areas to receive surface runoff from adjacent impervious areas. As previously discussed, however, this report has been prepared at a conceptual level of detail.

Opportunities for 'end-of-pipe' bioretention systems may be explored where considered potentially feasible and a possibly better method of stormwater management (relative to streetscape bioretention systems).

4.2.1 Water Quality Modelling

4.2.1.1 Model Scenarios

Modelling of stormwater discharge quality was performed using the MUSIC software, as described in Section 3.4 for TN, TP and TSS. Other parameters such as faecal coliform contamination of stormwater cannot be readily modelled at this time. The following three scenarios were considered as part of the modelling exercise:

1. *The Base Case - Undeveloped Site*. The base case is an assessment of the undeveloped site. The areas of agricultural activity associated with the DPI site were modelled as 'agricultural', while the remainder of the site was modelled as 'Rural Residential'.
2. *Developed Case - Unmitigated Site*. The developed case without mitigation is essentially an assessment of what would occur if the site were developed without any integration of stormwater treatment devices or pollution control measures. For consistency, the unmitigated site has been modelled using identical source node parameters as that of the scenario for modelling the developed site incorporating Water Sensitive Urban Design (WSUD) features.
3. *Developed Case with WSUD*. This case is an assessment of the fully developed site with all WSUD features installed and working at their "design" capacities. Treatment nodes have been incorporated into the model in the form of gross pollutant traps and streetscape bioretention systems.

4. *Developed Case Option 1 - WSUD with Rainwater Tanks.* This scenario was identical to the case above, though included Rainwater Tanks treating roof areas. As the model above achieved targets from a water quality perspective, this scenario was modelled primarily to investigate best practice reuse options.
5. *Developed Case Option 2 - WSUD with Stormwater Harvesting.* This scenario was modelled to include stormwater harvesting from the water treated by bioretention devices. This scenario was modelled to investigate the feasibilty of best practice reuse options only, although it is noted that it would include substantial water quality benefits.

The scenarios were modelled for a ten-year period from 1966 to 1976 at six-minute time-steps.

4.2.1.2 Model Results

Water Quality

Total annual flow and pollutant loads from the site for each scenario are included in Table 4-1. These values represent the flow and loads that are predicted to enter the Ross River.

Table 4-1 Predicted Annual Pollutant Loads (1966-1976)

Parameter	Base Case	Unmitigated Development	Developed Site with WSUD	Developed Site Option1 (Rainwater Tanks)	% Removal		Townsville Load Reduction Targets
					Developed Site with WSUD	Developed Site Option1 (Rainwater Tanks)	
Flow (ML/yr)	364	457	457	416	0%	9%	-
TSS (kg/yr)	124000	77900	13400.00	11800	83%	85%	65%
TP (kg/yr)	121	197	60.6	64	69%	67.7%	55%
TN (kg/yr)	964	951	581	559	39%	41.2%	35%
Gross Pollutants (kg/yr)	3420	8100	0	0	100%	100%	90%

As shown in the results given in Table 4-1, the proposed SQBMP's for the development will result in a significant decrease in total suspended solids and gross pollutants from the base case (existing) scenario. Furthermore, the Townsville load reduction targets (see Table 3-4) for solids, phosphorus, nitrogen and gross pollutants are satisfied.

Rainwater Tank Reuse

Rainwater tank reuse for residential and commercial non-potable uses was modelled as a water savings option. It is noted that adoption of this option would also reduce the overall area required for bioretention. If this option is likely to be adopted, further modelling could be undertaken to determine the reduced area of bioretention required to meet water quality objectives.

As shown in Table 4-2, approximately 38% of the onsite non-potable water demands (i.e. toilet flushing, laundry and outdoor use) may be satisfied with this modelled scenario.

Table 4-2 Rainwater Tank Scenario results

Subcatchment	In (ML)	Out (ML)	Yield (kL)	Daily demand (kL)	% of Demand Satisfied
Detached 1	24.00	15.00	24.66	57.99	43%
Attached 1	1.33	0.59	2.02	6.53	31%
Detached 2	22.50	13.40	24.93	66.65	37%
Attached 2	3.11	1.40	4.68	14.97	31%
Detached 3	37.60	22.70	40.82	106.05	38%
Attached 3	4.30	1.92	6.52	20.85	31%
Commercial 3	1.82	1.34	1.32	2.25	58%
Detached 4	7.66	4.68	8.16	20.61	40%
Total	*102.32*	*61.034*	*113.11*	*296*	*38%*

Stormwater Reuse

Stormwater reuse for irrigation of the 5 dedicated parkland areas (shown in Figure 3-1) was also modelled as a water savings option, and will also result in an overall reduction in pollutant loads and improved water quality discharging from site. However it is noted that it may not reduce the area required for bioretention systems as stormwater will require treatment prior to reuse (that has been facilitated using bioretention systems).

The table and figure below indicate that as the size of the storage increases, the volume of water available generally also increases, however so will the cost. A larger tank is able to store more of the volume however diminishing returns means that beyond a certain size, large increases in size may provide relatively small increases in reuse.

The optimal tank size would most likely be approximately 400m^3, meeting 42% of the irrigation demands of selected parklands, as shown in the flattening of the curve in Figure 4-3 from 250 m^3 to 500m^3. However this is a very large volume for a storage tank (with an area of approximately 330 m^2 assuming a depth of 1.5 m) that will also require potable water supply to meet irrigation demands for the majority of the time. Additionally this assumes that runoff from the entire catchment can be captured.

This option was initially considered not to be cost effective due to the large tank size required to meet a reasonable demand reliability. However the cost effectiveness of this option may be improved through investigation of alternative options that consider smaller designated irrigation areas (hence improving the demand reliability) and the use of a more affordable storage system (than conventional proprietary tank systems).

This option will be further investigated as more information becomes available through the detailed planning and design process for the current and subsequent development stages.

Stormwater harvesting and reuse can have significant benefits in terms of reducing the demand on potable water supplies while also reducing pollutant loads to receiving environments, thereby protecting the environmental values of the Ross River.

An opportunity may also exist to gain federal funding under a stormwater harvesting and reuse grant that the Labour government has pledged (if elected) to assist in securing and diversifying water supplies for a sustainable Australia (ABC News, 2010).

Table 4-3 Stormwater Harvesting Model Results

Stormwater Harvesting Tank Size (m^3)	In (ML)	Out (ML)	Yield (kL)	Annual Irrigation Demand (kL)	% of Demand Satisfied	Stormwater Harvesting Tank Size (m^3)
10	331	328	3000	21482	14%	10
50	331	328	3000	21482	14%	50
100	331	327	4000	21482	19%	100
250	331	324	7000	21482	33%	250
500	331	321	10000	21482	47%	500
1000	331	318	13000	21482	61%	1000
1500	331	316	15000	21482	70%	1500
2000	331	314	17000	21482	79%	2000

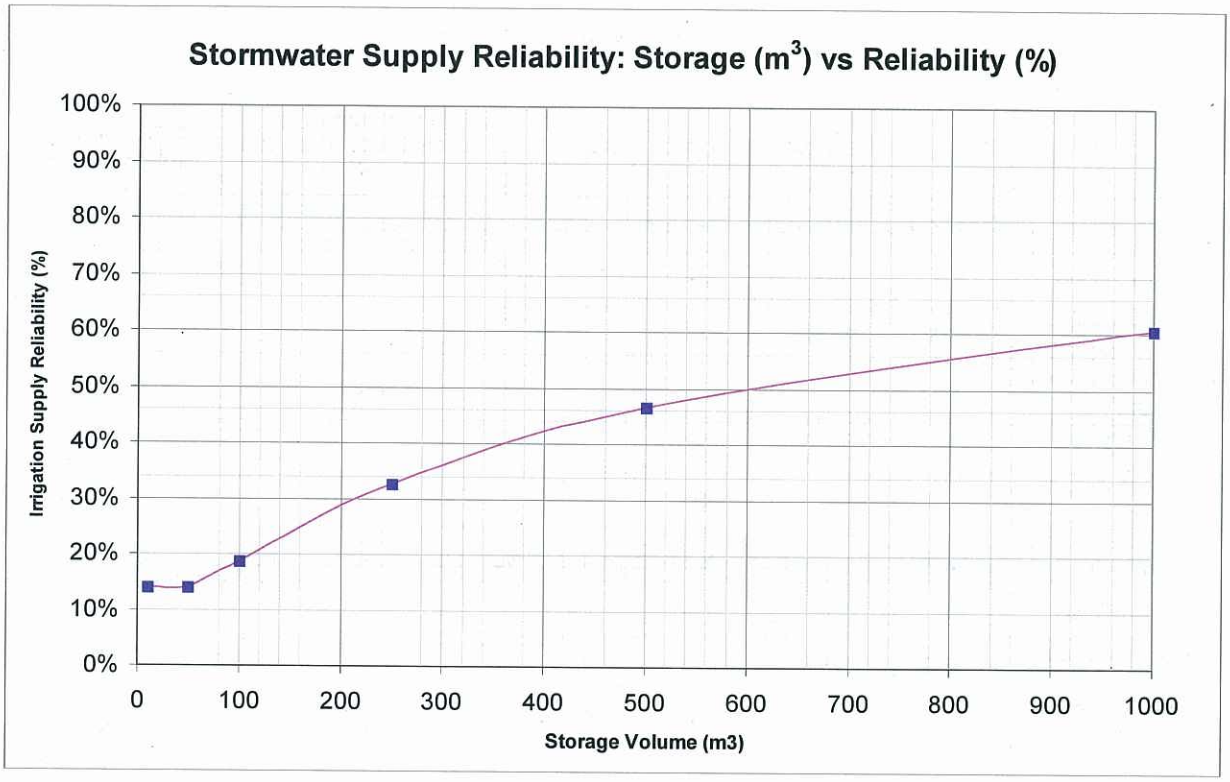

Figure 4-3 Stormwater Harvesting Supply

4.2.1.3 Model Conclusions

From the conceptual modelling results of the MUSIC model, it can be concluded for the site of the proposed development that with the integration of Water Sensitive Urban Design principles and Stormwater Quality Improvement Devices, the pollutant export loads from the site can be significantly reduced compared to the base case and unmitigated scenario for pollutants of concern. Furthermore, the Townsville City Council load reduction targets (see Table 3-4) for solids, phosphorus, nitrogen and gross pollutants will be achieved with the proposed treatment train.

Further simulations at a more detailed level of design may be required to verify the model outcomes only if the final development layout differs significantly from the conceptual layout and prevented the implementation of the proposed treatment measures.

Details of these systems, assumed for the purposes of the conceptual modelling approach, are provided in Section 3.4 of this report. Table 4-4 also provides the approximate sizing of bioretention filter areas required for each subcatchment to meet Townsville City Council's Load Based Reduction Targets. ***From the modelling undertaken it is evident that the bioretention filter area required for treatment will be approximately 1.6% of the catchment area.*** Typical road sections for the development that show how bioretention systems can be incorporated into the road reserve and some examples of drawings for streetscape bioretention systems are included in Appendix D.

Table 4-4 Sizing of Bioretention Areas

	Sources	Residual	Reduction	Objective	Bioretention Top Surface Area Required (m^2)	Bioretention Filter Area Required (m^2)
Subcatchment 1: Approximate Bioretention Filter Area as a % of Subcatchment Area = 1.6%						
Flow (ML/yr)	101	101	0	-	**2785**	**2359**
Total Suspended Solids (kg/yr)	17100	2720	84%	65%		
Total Phosphorus (kg/yr)	35	11	68%	55%		
Total Nitrogen (kg/yr)	211	127	40%	35%		
Gross Pollutants (kg/yr)	1910	0	100%	90%		
Subcatchment 2: Approximate Bioretention Filter Area as a % of Subcatchment Area = 1.6%						
Flow (ML/yr)	132	132	0%	-	**3030**	**2961**
Total Suspended Solids (kg/yr)	23900	4560	81%	65%		
Total Phosphorus (kg/yr)	48	17	65%	55%		
Total Nitrogen (kg/yr)	271	172	36%	35%		
Gross Pollutants (kg/yr)	2240	0	100%	90%		
Subcatchment 3: Approximate Bioretention Filter Area as a % of Subcatchment Area = 1.6%						
Flow (ML/yr)	173	173	0%	-	**3926**	**3847**
Total Suspended Solids (kg/yr)	25400	4250	83%	65%		
Total Phosphorus (kg/yr)	93	26	72%	55%		
Total Nitrogen (kg/yr)	361	218	40%	35%		
Gross Pollutants (kg/yr)	3040	0	100%	90%		
Subcatchment 4: Approximate Bioretention Filter Area as a % of Subcatchment Area = 1.6%						
Flow (ML/yr)	51	51	0%	-	**1250**	**1161**
Total Suspended Solids (kg/yr)	11600	1860	84%	65%		
Total Phosphorus (kg/yr)	22	7	69%	55%		
Total Nitrogen (kg/yr)	104	63	39%	35%		
Gross Pollutants (kg/yr)	910	0	100%	90%		
Total					***10991***	***10328***

5 MAINTENANCE PLANS

Maintenance plans may be required for the following Stormwater Quality Best Management Practice (SQBMPs) proposed for the development:

- Gross pollutant traps;
- Bioretention systems.

Maintenance inspection forms and plans would be developed for these SQID's during the detailed design phase of the development and would include the following information:

- Inspection frequency;
- Maintenance frequency;
- Data collection/storage requirements (eg. information collected during inspections);
- Detailed clean-out procedures (main element of the Plans). These procedures cover aspects such as:
  - Equipment needs;
  - Maintenance techniques;
  - Occupational health and safety;
  - Public safety;
  - Environmental management considerations;
  - Disposal requirements (polluted water and solid waste);
  - Access issues;
  - Stakeholder notification requirements;
  - Data collection requirements (if any);
- SQID design details and supplier contacts (in case modifications to the design need to be made in future).

Indicative maintenance requirements for bioretention systems are provided in Appendix E.

In addition, the asset transfer checklist will need to be completed and approved by Townsville City Council prior to asset handover to Council for maintenance after the conclusion of the off-maintenance period. This checklist is contained in Appendix F.