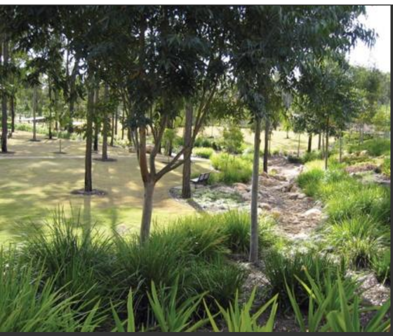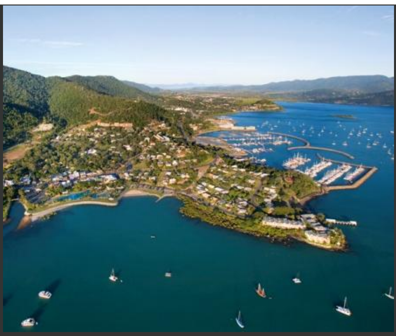

Stormwater Management Plan
Lee Point Road, Darwin
September 2009

engineering | planning |environmental planning and management | urban design | project management

Document / Report Control Form

Project Name: **Lee Point Road, Darwin – Stormwater Management Plan**

Report for: **Defence Housing Australia**

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
Draft 1	30/07/09	Eoghain O'Hanlon	Jake Franklin	
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Contents

Executive Summary

This document presents the conceptual Stormwater Management infrastructure requirements to be provided for the development proposal of Lot 9793 Lee Point Rd, Darwin.

Lot 9793 is located approximately 16kms northeast of Darwin's Central Business District (CBD) and in close proximity to Buffalo Creek. (Refer to Figure 1.)

The site is above the Darwin Storm Surge Zone as shown by Figure 5.

The proposed development will comprise over 1084 residential lots and will involve the construction of approximately 20 km of roads, 18.8 km of piped drainage, and three (3) stormwater attenuation basins. Figure 3 shows the proposed development layout.

Site specific objectives and criteria for water quality and stormwater management are presented in detail in the following sections of this report and are shown summarised in Table 1 below.

Table 1: Stormwater Management Plan Summary (adopted from the Principal objectives for managing storm water in Darwin, Water Sensitive Urban Design Planning Guide, 2009)

Objective	Proposed Measures
Water quality – *to maintain or improve the surface and groundwater quality within the development areas relative to pre development conditions*	• Gross pollutant traps will be provided throughout the piped drainage network to trap litter and sediments close to source. • Public Open Space and Drainage Reserve fronting Buffalo Creek will be landscaped, including deep rooted native trees indigenous to the area, for nutrient removal. • The Public Open Space for the outflow that crosses Lee Point Road will be landscaped, including deep rooted native trees indigenous to the area, for nutrient removal.
Water quantity - *to maintain the total water cycle balance within development areas relative to pre development conditions.*	• Post development peak discharge flows will be attenuated within detention basinsto approximate pre-development flows for specific design storm events.
Water conservation - *to maximise the reuse of stormwater / rainfall*	• Rain water harvesting – residents will be encouraged to capture and store rainwater to supplement mains water supply. This could also assist in mitigating the impact of the sub-division development on flow regimes, thus reducing potential stormwater runoff into receiving environments. • Grey water re-use systems – residents will be encouraged to install grey water re-use systems (e.g. for toilet flushing) to decrease water supply demand. • Provision of a non potable water reticulation network for irrigation purposes.
Ecosystem health - *to retain natural drainage*	• The proposed discharge points for stormwater coincide with the existing natural discharge locations on site.
Economic Viability – *to implement stormwater management systems that are economically viable in the long term*	• The stormwater management methods proposed for the site have reasonably low maintenance requirements.
Public Health – *to minimise public risk, including the risk of injury or loss of life to the community*	• All drainage, including basins are designed to drain completely to avoid public health and safety issues relating to standing water. • All drainage areas where detained water depths exceed 750mm will be fenced to restrict public access.

Protection of Property – *to protect the built environment from flooding and water logging*	• Piped drainage and culvert crossings to convey runoff from minor storm events of 2 years Average Recurrence Interval (ARI) minimum. • Overland flow paths, including roads, public open spaces and drainage reserves to convey runoff from major storm events of 100 years ARI.
Social Values – *to ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater*	• The ecological value of Buffalo Creek and its foreshore area have been considered. A green buffer is proposed along the creek frontage to provide protection from potential negative effects of land development. • The attenuation basins will be designed to be visually aesthetic and to blend in with the surrounding environment.
Development – *to ensure the delivery of best practise stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.*	• The cost effective and practical stormwater management controls proposed for this development are consistent with best practice stormwater management principles.

Through the use of attenuation basins and culvert sizing the developed conditions flows match the existing pre-developed flows for the design event storms. With the inclusion of bio-retention basins, sediment basins, swales and gross pollutant traps the developed pollutant loads meet the Darwin City Council (DCC) guideline reduction targets. In order for these targets to be achieved, considerations have been made for the operation and maintenance of the treatment devices. A monitoring program has been set out taking into consideration the requirements of the DCC that there be no ponding of water due to biting insects. The measures that have been set out in this document are conceptual and will be confirmed with detailed designs at the next stage of the development proposal.

Introduction

Background

SMEC Urban has been commissioned by Defence Housing Australia (DHA) to develop a Stormwater Management Plan (SMP) of which includes a Erosion and Sediment Control Plan (ESCP) and a Hydraulic Impact Assessment (HIA) to accompany a Development Application to be made to Darwin City Council in regards to a development proposal of Lot 9793 Lee Point Rd, Darwin. The HIA is to be submitted separately to this document.The development site boundary is shown in Figure 1.

Figure 1. Locality Plan

Objectives

The purpose of this document is to present the onsite Stormwater Management (during and post construction) and Flood Management infrastructure requirements proposed for the development of Lot 9793 Lee Point Rd, Darwin to achieve best practice stormwater management in accordance with sustainability principles.

The general objectives and criteria for water quality and stormwater management have been developed with consideration of the following guidelines, standards, codes, and / or policies:

- Australian Guidelines for Urban Stormwater Management, ANZECC (2000)
- Australian Rainfall and Runoff (AR&R) - A Guide to Flood Estimation (2001)
- Subdivision and Development Guidelines, Darwin City Council (2005)
- Managing Urban Stormwater: Soils and Construction, NSW Department of Housing (1998)
- Resources Management for the NT – Erosion and Sediment Control, Nat. Res. DLPE.
- Queensland Urban Drainage Manual (QUDM)(2007)

The principal objectives for managing urban stormwater are to:

- maintain or improve the quality of surface and groundwater relative to pre-development conditions;
- protect people, property and built environment from stormwater and flooding; and
- maintain the total water cycle balance relative to pre-development conditions to all reasonable extents.

These objectives will be achieved through the implementation of the following management measures where appropriate and relevant:

- Flood Protection Measures: the provision of major and minor drainage systems with appropriate levels of protection to people, property and the built environment from stormwater runoff and flooding.
- Retention and Detention Measures: retaining and restoring existing valuable elements of a stormwater system, such as natural channels and riparian vegetation, through the implementation of appropriate Policy, Planning and Urban Design.
- Non Structural Source Controls – methods that aim to change community behaviour to reduce the amount of pollutants that enter the stormwater drainage system, through community education, local government enforcement, operations and management activities. This does not involve fixed or permanent facilities or structures.
- Structural Source Controls – permanent, engineered devices implemented to control, treat or prevent stormwater pollution and/or reduce the volume of stormwater requiring management.

Non structural controls should be used in combination with structural controls to achieve a balanced mix of stormwater management measures.

Site Description and Key Characteristics

Topography

The site is slightly undulating, with levels ranging from approximately 7m above Australian Height Datum (AHD) to 28m AHD. The site's topography is dominated by a saddle running in an arc from the south west corner of the site through a point west of centre of the site and then heads towards the northwest corner of the site.

The area to the east of the saddle is transected by a central spur running east west. The northern portion of the site falls towards the northeast corner of the site (Catchment "A") at a grade of approximately 1.5%. The southern portion of the site falls towards the south east corner of the site (Catchment "B") at a grade of approximately 2%. The area west of the saddle (Catchment "C") grades at approximately 2% towards a low point located almost centrally along the Lee Point Road frontage, which drains into the existing drainage reserve within the Lyons Development. Figure 2 shows contour levels and sub-catchment boundaries for Lot 9793

Figure 2. Site Topography

Overview of Proposed Development

The proposed development will comprise of 1084 residential lots and will involve the construction of approximately 20 km of roads, 18.8 km of piped drainage, and three (3) stormwater attenuation basins. Figure 3 shows the proposed development layout.

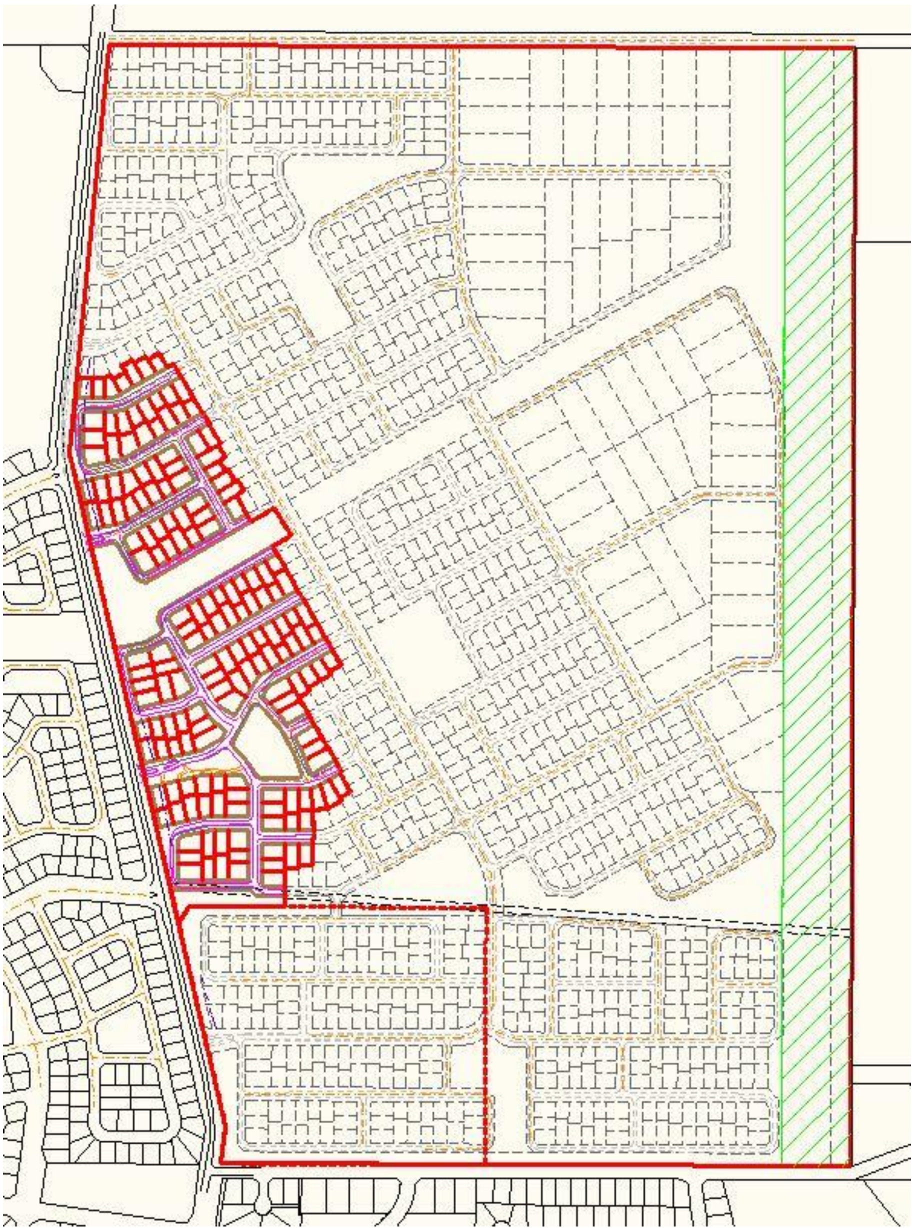

Figure 3. Proposed Development Layout

Existing and Surrounding Landuse

This site is adjacent to the Casuarina Coastal Reserve and Leanyer Sewerage Treatment Plant to the north east and east respectively. Fitzmaurice Drive and Lee Point Road border the site to the south and west respectively and an unnamed unformed road reserve forms the northern boundary. Land immediately to the north and east appears to be largely undeveloped though there is a waste water treatment plant located approximately 500m east of the southern half of the site.

The site is north of the existing suburbs of Leanyer, Woodleigh Gardens and Wanguri. The Defence Housing Australia (DHA) Lyons Development is adjacent to the west.

The Royal Darwin Hospital is approximately 500 m west of the site, Casuarina Shopping Centre approximately 1.2 km southwest and Charles Darwin University is approximately 2.5 km southwest.

The Darwin CBD is located approximately 16 km southwest of the site and the Darwin International Airport is approximately 6 km south.

The site is undeveloped with the exception of a temporary construction compound used by BMD, the contractors for the Lyons Development.

Climate

The region's climate is classified as Equatorial and experiences two distinct seasons annually: "the wet" (October to April) and "the dry" (May to September).

During the wet season, the weather is largely determined by the position of the monsoon trough. If located close to, or over land, widespread heavy rainfall can result. When the monsoon trough temporarily weakens or retreats north of Australia, the climate is characterised by light winds, isolated showers and thunderstorm activity, sometimes with gusty squalls.

During the dry season, the prevailing south-easterlies bring predominantly fine conditions and rainfall is low to non-existent.

Mean annual rainfall for Darwin (Bureau of meteorology – BOM - Darwin Airport site 14015): 1710.7 mm.

Vegetation

The northern section of the site has been largely cleared though the southern portion retains native vegetation.

As shown in Table 2, the Northern Territory Flora Atlas database lists five near threatened and one vulnerable species under the *Territory Parks and Wildlife Conservation Act 2000* (NT) (TPWC Act).

Table 2: Listed flora recorded in the NT Flora Atlas Database within 10km of the development site

Family	Species Name	*TPWC Act 2000*	*EPBC* 1999*
Cycadaceae	*Cycas armstrongii*	Vulnerable	Not Listed
Avicenniaceae	*Avicennia integra*	Near Threatened	Not Listed
Byblidaceae	*Byblis aquatica*	Near Threatened	Not Listed
Fabaceae	*Crotalaria quinquefolia*	Near Threatened	Not Listed
Pittosporaceae	*Pittosporum moluccanum*	Near Threatened	Not Listed
Scrophulariaceae	*Peplidium maritimum*	Near Threatened	Not Listed

*EPBC - Environmental Protection and Biodiversity Conservation Act

Table 3: Threatened and near threatened flora (TPWC Act) and likelihood of occurrence

Species Name	Status (TPWC Act)	Preferred Habitat and Known Distribution	Likelihood of Occurrence
Cycas armstrongii	Vulnerable	Eucalypt woodland in the Darwin area	Present
Avicennia integra	Near Threatened	Soft mud banks in intertidal estuaries	Highly Unlikely
Byblis aquatica	Near Threatened	Near freshwater lagoons, also occurs in both grassland and sedgeland	Possible
Crotalaria quinquefolia	Near Threatened	Recorded at Holmes jungle in the Darwin area on areas of grassland, sedgeland and floodplain.	Possible
Pittosporum moluccanum	Near Threatened	Coastal dunes and coastal monsoon vine thickets in the Lee Point area.	Unlikely
Peplidium maritimum	Near Threatened	Brackish to freshwater swamps and claypans. Found in Leanyer swamp	Unlikely

The EcOZ (2008) report notes:

'Despite these species being specifically targeted during the survey only one species (Cycas armstrongii) was located on the site. Two of the remaining five near threatened species (Byblis aquatica and Crotalaria quinquefolia) can be found in habitats that are present within the Muirhead Development site but given the rarity of these species and the quality of potential habitat (seasonally inundated grasslands and sedgelands) it is thought possible but not likely that these species occur on the site.

*The vulnerable cycad species **Cycas armstrongii** was located on the Muirhead Development site. This species is locally abundant but is vulnerable to land clearing in the Darwin area (Holmes et al. 2007).*

*The Mangrove species **Avicennia integra** inhabits soft mud banks in intertidal estuaries along the Northern Territory coastline (Duke and Kleine 2006). This habitat is not found inside the Muirhead Development site.*

***Byblis aquatica** is a delicate annual herb growing in shallow water in seasonally inundated grasslands and sedgelands (Holmes et al. 2007). This habitat is found within the Muirhead Development site and this species has the potential to occur on the site.*

*The annual herb **Crotalaria quinquefolia** is found in moist grasslands, sedgelands and floodplains. It has been previously recorded in Holmes Jungle in the Darwin region (Holmes et al. 2007). This habitat is found within the Muirhead Development site and this species has the potential to occur on the site.*

***Pittosporum moluccanum** is not likely to inhabit the site as it is restricted to areas of coastal monsoon vine thicket (Holmes et al. 2007). This habitat is not represented within the Muirhead Development site.*

*The annual herb **Peplidium maritimum** inhabits areas of swamps and seasonally inundated claypans often near mangroves (Holmes et al. 2007). This habitat does not occur within the Muirhead Development boundary.'*

Geology and Soils

Douglas Partners were commissioned by Connell Wagner in late 2008 to undertake a geotechnical assessment of Lots 9737 (DHA land) and 9370 (NTG land).

The investigation comprised a review of existing terrain unit information and aerial photographs followed by a site walkover survey, excavation of test pits and laboratory testing of soil samples. The investigation occurred between 11 and 18 November 2008 with 28 test pits being excavated.

The report notes that *'the site is underlain by tertiary aged soils comprising unconsolidated sand, ferrinous, clayey, sandy and gravelly soil commonly containing limonite pisolites or pisolitic and mottled laterite. In the lower lying areas, Quaternary age colluvial sediments comprising sand, silt and clay deposited by unconcentrated surface runoff predominate. These soils are underlain by Proterozoic age meta-sediments of the South Alligator Group which consist of steeply dipping metamorphosed siltstone, shale and phylite, commonly carbonaceous pyritic with bands of quartzite'*

Acid Sulfate Soils

Acid Sulfate Soils (ASS) are soils that contain iron sulfides which, when drained or exposed to oxygen, produce sulfuric acid and result in the release of soluble iron, sulfate, aluminium and other toxic metals. This acid has the potential to leach through soil and contaminate ground water and watercourses and can have serious environmental impacts on aquatic organisms including fish and vegetation. Moreover acid sulphate soils can corrode concrete, iron and steel and damage water and sewage pipes.

The Geotechnical assessment undertaken by Douglas Partners revealed that acid sulphate soils were not present on the DHA site.

Groundwater

Two groundwater bores RN002839 and RN002840 are located within the site. Only RN002839 has a bore data sheet available. The bore was drilled in 1961 with groundwater encountered at a depth of 35.5 m. The soil strata was described as sandy clay with ferruginous soils at the top of the casing and alternatively hard and soft light coloured silty slate at the bottom of the casing. No further water quality analysis was recorded

Regional Catchment Flooding and Ocean Tidal Storm Surge

Peak tropical cyclone storm surge tide levels have been determined by the NT Department of Planning and Infrastructure for various sites in the Greater Darwin Region. The predictions at Lee Point are shown in shown in Table 4.

Table 4: Peak storm surge levels at Lee Point

Annual Excedence Probability (AEP)	Peak Strom Surge Level (m AHD)
1% (1 in 100 years)	**4.5m**
0.1% (1 in 1000 years)	**5.5m**
0.01% (1 in 10000 years)	**6.5m**

Buffalo Creek is tidal in the vicinity of Lot 9793 and subject to storm surge. However, the site itself is sufficiently elevated to be above the Secondary Storm Surge Level of 6.5m AHD as recorded in the Darwin Storm Surge Maps. Figure 6 shows the extent of the storm surge from Buffalo Creek.

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Figure 6. Extent of Storm Surge

Existing Surface Water Quality

There is no existing water quality monitoring data available for the receiving water bodies nor specific water quality objectives (WQO's) for Buffalo Creek. The trigger values for the protection of aquatic ecosystems from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZEC, 2000) are shown in Table 5 as a basis for comparison. The default trigger values are applicable for slightly disturbed ecosystems for a lowland river.

Table 5: Existing water quality parameters for freshwater and estuarine rivers for tropical Australia

Water Quality Parameter	Trigger Value Tropical Australia Freshwater (ANZECC guidelines)	Trigger Value Tropical Australia Estuarine (ANZECC guidelines)
Mean Chlorophyll a - Chl a (mg/L)	0.005	0.002
Mean Total Phosphorus (mg/L)	0.01	0.02
Mean Filterable Reactive Phosphate FRP (mg/L)	0.004	0.005
Mean Total Nitrogen TN (mg/L)	0.2 – 0.3	0.25
Mean Oxides of Nitrogen NO_x (mg/L)	0.01	0.03
Mean Ammonium NH_4^+ (mg/L)	0.01	0.015
Mean DO (% saturation)	85 – 120	80 – 120
Mean PH	6 – 8	7 – 8.5
Mean Salinity ($uscm^{-1}$)	20 - 250	
Mean Turbidity (NTU)	2-15	1 - 20

Site Data

Collection

Table 6 below contains a list of data and information collected during the course of this report that has been used to produce the site development SMP and where applicable, hydrologic and/or hydraulic investigations and assessments.

Table 6: Data Collected

Data Information Title	Source	Date	Format
Report on Geotechnical Assessment - Proposed residential subdivision of Lots 9737 and 9370 Lee Point Rd, Muirhead	Douglas Partners through Connell Wagner Pty Ltd	January 2009	Pdf report
IFD	AUS-IFD/AR&R		software
Climate data for Darwin	Bureau of Meteorology	August 2009	Csv file
Flora and Fauna Assessment	EcOZ	January 2009	Pdf repot

Review

At the time of undertaking this study to the best of SMEC Urban's knowledge no previous studies pertaining to stormwater and/or flood management have been produced for the site or adjacent watercourses/catchments.

Site Inspections

A site inspection was conducted by SMEC Urban on the 19th of June 2009. The site was seen to be extensively cleared as shown in Figures 7 and 8. Part of the southern portion of the site contains a dense regrowth forest shown in Figure 9. Figure 10 shows two stormwater pipes that leads from the proposed site to the Lyons stormwater drainage system, but they don't link up with the concreted channel and are directed at the back of a house lot. Figures 11, 12 and 13 show the Lyons development stormwater drainage structures and some of the erosion that is occurring around them. Figure 11 shows an additional stormwater pipe leading to the Lyons drainage system. Figure 14 and 15 show the Fitzmaurice Terrace stormwater drain. These drainage structures are the proposed discharge points for catchments B and C respectively.

Figure 7 Western side of site looking from Lyons Development across Lee Point Road

Figure 8 Looking north east from across Lee Point Road at the proposed site

Figure 9 Looking south along Lee Point Road, proposed development on the left and Lyons Development on the right

Figure 10 Stormwater pipes leading from proposed site to the Lyons Stormwater drainage system.

Figure 11 Lyons stormwater drain drop structure looking back towards site

Figure 12 Lyons Stormwater drain looking downstream from drop structure

Figure 13 Erosion below drop structure in Lyons stormwater drain

Figure 14 Head wall of Fitzmaurice Terrace stormwater drain

Figure 15 Fitzmaurice Terrace stormwater drain looking east towards the sewage treatment plant

Water Conservation Measures

Rain Water Harvesting

The main water supply for the development will come from mains water supply however the collection and use of rainwater by residents will be encouraged.

In a lot-scale rainwater supply system, the quality of runoff from the roof depends on roofing materials, materials deposited on the roof and roof maintenance regime. There are many treatment and maintenance techniques that can be adopted to ensure a high rain water quality supply but as a minimum it is recommended residents be encouraged to fit a first flush device or filter sock to limit the transfer of contaminants that have built up between storm events from entering their rainwater tanks

Water Reuse

It is recommended that residents also be encouraged to install grey water re-use systems (eg. for toilet flushing) to decrease demand on mains water supply.

It is proposed to include a non potable water reticulation network for (POS) irrigation purposes.

Wastewater Management

The site is proposed to be fully sewered.

Stormwater Management

Stormwater Drainage System Criteria

Consistent with Darwin City Council (DCC) guidelines, the stormwater drainage system is proposed to be a minor/major system. The minor drainage component is defined as the network of kerb and channel, gully pits, piped drainage and culverts designed to convey runoff generated by low intensity storms. It is proposed that the minor drainage components be designed to accommodate runoff from storm events of up to a 2 year Average Recurrence Interval (ARI) storm event. The major drainage component is defined as the network of overland flow paths (including roads, public open space and drainage reserves) designed to convey stormwater runoff in excess of the capacity of the minor drainage system during less frequent storm events up to a 100 year ARI.

Flow widths, depths and velocities over roads, public open spaces and drainage reserves eventually shall comply with the DCC guidelines for public safety.

The design of the minor (sub-surface) stormwater drainage system is not included in this SMP, but rather is provided in the site civil works design. The major system conceptual design has been provided in this SMP as where appropriate in the form of open channels like swales.

Water Quantity Management

DCC and QDUM require a “no-worsening” of stormwater runoff flow rates discharging from the site, and hence as such water quantity management must ensure the post-development peak runoff flow rates mimic pre-development peak runoff flow rates for the critical design storm event duration for ARI’s from 1 to 100 years.

In order to satisfy water quantity management objectives detention basin(s) are proposed to control site stormwater runoff outflows. Hydrological estimation is required to estimate design storm flows pre and post development, and subsequent basin sizing to control outflows.

Hydrological Estimation

<u>Site Catchment Delineation</u>

Site stormwater drainage catchments have been delineated based on intended development earthworks and design surface information provided from the project Civil Designers and are shown in Figure 16. Figure 17 shows these three main catchments, further divided into sub-catchments to aid in hydrological analysis.

DCC Subdivision and Development Guidelines state that C for developed subdivisions is to be 1 which equates to 100% impervious fraction within the WBNM model. Initial Loss (IL) and Continuing Loss Rate (CLR) were taken from Australian Rainfall and Runoff Volume 1. CLR was adjusted to obtain peak flows more closely resemble the peak flows calculated by the Rational Method (Appendix 1)

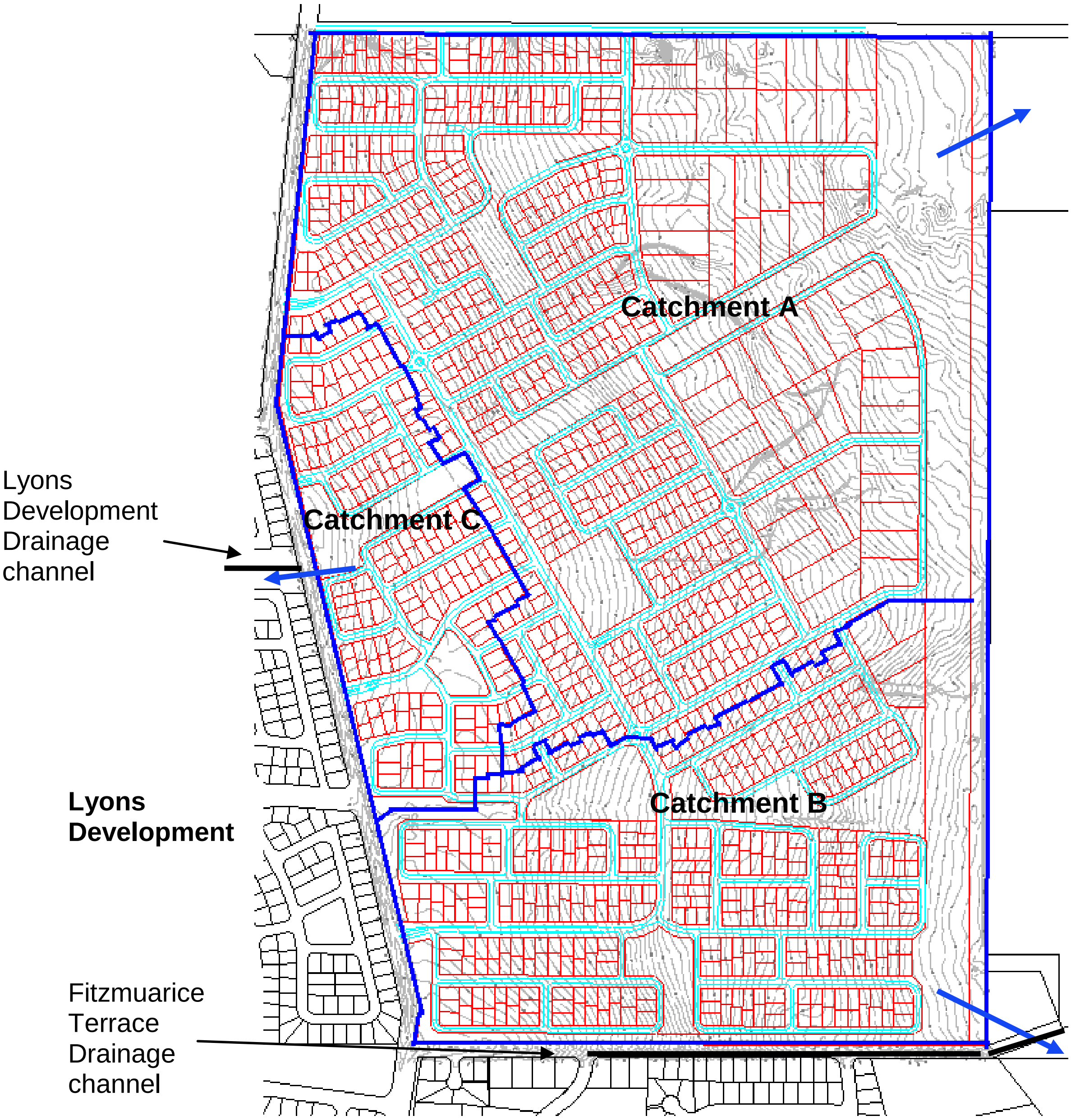

Figure 16 Main stormwater drainage catchments for the Muirhead site

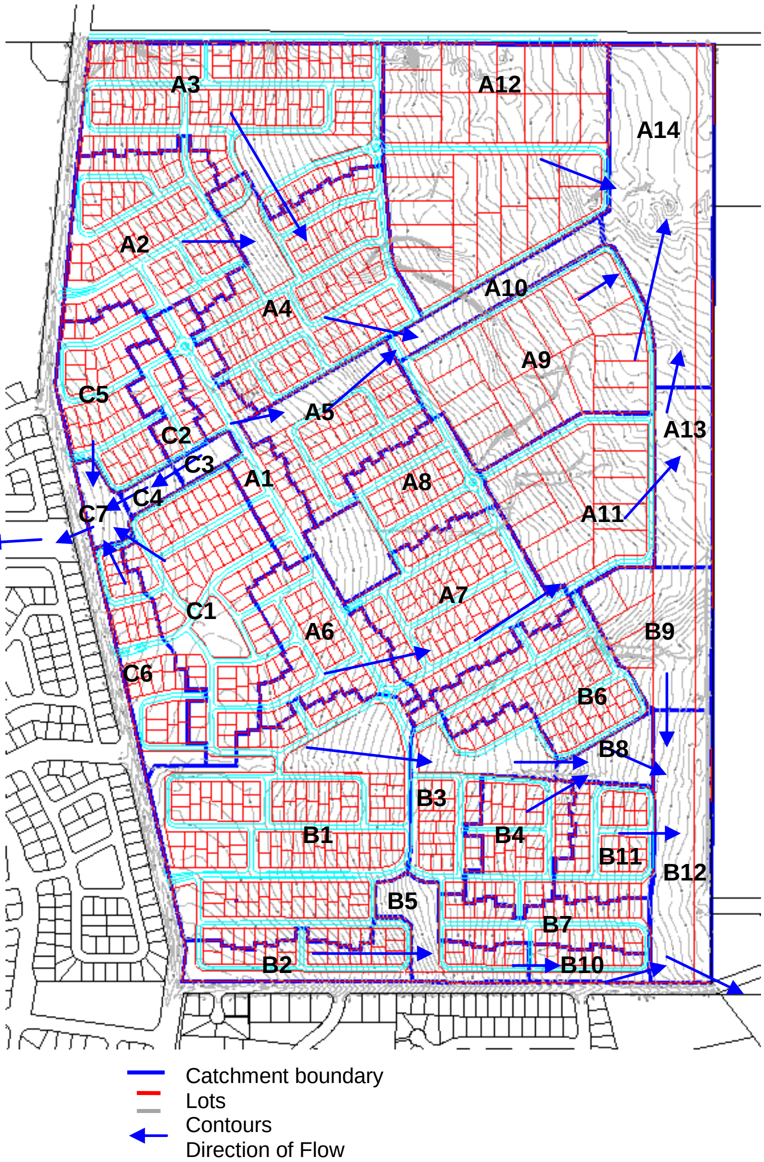

Figure 17 Sub-catchment of the Muirhead development site

<u>Selection of Modelling Approach</u>

Peak design storm discharges across the site were derived using the runoff routing model WBNM in accordance with AR&R and QUDM and involved:

- Derivation of design rainfall data (IFD) for Darwin Airport in accordance with ARR; and
- Calculation of design flows through the site for Q_{100}, Q_{50}, Q_{20}, Q_{10}, Q_5, Q_2 and Q_1.

WBNM is a software package designed for modelling stormwater, sanitary and river systems and enables the modelling of the attenuation.

The results obtained from WBNM were validated through the use of the Rational Method to determine pre and post development design flows.

<u>Pre Development Design Stormwater Flow</u>

Table 7 outlines the parameters used for the pre-developed scenario. Critical storm durations were derived by running the model with numerous durations for each ARI and selection the maximum flow for the catchment. The critical storm duration was found to be

60min for the catchments A and B and 25 min for the catchments C , Fitzmaurice Terrace and Lyons the for all ARI’s in the respective catchments.

Table 7: WBNM parameters for the pre-developed scenario

Catchment	Drainage	Area	Imp Fraction	Lag Parameters		Rainfall Loss parameters		
		(Ha)	(%)	C	Imp Lag	IL (mm)	CLR (mm/hr)	Imp IL (mm)
SubA-1	SubA-5	3.548	0	1.6	0.1	0	2.5	0
SubA-2	SubA-3	7.219	0	1.6	0.1	0	2.5	0
SubA-3	SubA-4	11.261	0	1.6	0.1	0	2.5	0
SubA-4	SubA-10	9.720	0	1.6	0.1	0	2.5	0
SubA-5	SubA-10	4.830	0	1.6	0.1	0	2.5	0
SubA-6	SubA-7	4.325	0	1.6	0.1	0	2.5	0
SubA-7	SubA-11	6.659	0	1.6	0.1	0	2.5	0
SubA-8	SubA-10	4.841	0	1.6	0.1	0	2.5	0
SubA-9	SubA-14	9.667	0	1.6	0.1	0	2.5	0
SubA-10	SubA-14	1.774	0	1.6	0.1	0	2.5	0
SubA-11	SubA-13	6.731	0	1.6	0.1	0	2.5	0
SubA-12	SubA-14	14.748	0	1.6	0.1	0	2.5	0
SubA-13	SubA-14	6.512	0	1.6	0.1	0	2.5	0
SubA-14	SINK	9.200	0	1.6	0.1	0	2.5	0
SubB-1	SubB-3	15.161	0	1.6	0.1	0	2.5	0
SubB-2	SubB-5	2.853	0	1.6	0.1	0	2.5	0
SubB-3	SubB-6	4.682	0	1.6	0.1	0	2.5	0
SubB-4	SubB-6	3.341	0	1.6	0.1	0	2.5	0
SubB-5	SubB-10	2.245	0	1.6	0.1	0	2.5	0
SubB-6	SubB-9	5.022	0	1.6	0.1	0	2.5	0
SubB-7	SubB-9	2.822	0	1.6	0.1	0	2.5	0
SubB-8	SubB-9	1.309	0	1.6	0.1	0	2.5	0
SubB-9	SubB-12	4.236	0	1.6	0.1	0	2.5	0
SubB-10	SubB-12	1.214	0	1.6	0.1	0	2.5	0
SubB-11	SubB-12	2.982	0	1.6	0.1	0	2.5	0
SubB-12	SINK	2.654	0	1.6	0.1	0	2.5	0
SubC-1	SubC-4	8.008	0	1.6	0.1	0	2.5	0
SubC-2	SubC-4	1.306	0	1.6	0.1	0	2.5	0
SubC-3	SubC-4	0.618	0	1.6	0.1	0	2.5	0
SubC-4	SubC-7	0.511	0	1.6	0.1	0	2.5	0
SubC-5	SubC-7	4.140	0	1.6	0.1	0	2.5	0
SubC-6	SubC-7	2.587	0	1.6	0.1	0	2.5	0
SubC-7	SINK	0.776	0	1.6	0.1	0	2.5	0

Post Development Design Stormwater Flow (Un-detained)

Table 8 outlines the parameters used for the post-developed scenario. Critical storm durations were re-evaluated by running the model with numerous durations for each ARI and selection the maximum flow for the catchment. The critical storm duration was found to be 60min for the catchments A and B and 25 min for the catchments C , Fitzmaurice Terrace and Lyons the for all ARI’s in the respective catchments.

Table 8: WBNM parameters for the post- developed scenario

Catchment	Drainage	Area (Ha)	Imp Fraction (%)	Lag Parameters		Rainfall Loss parameters		
				C	Imp Lag	IL (mm)	CLR (mm/hr)	Imp IL (mm)
SubA-1	SubA-5	3.548	100	1.6	0.1	0	2.5	0
SubA-2	SubA-3	7.219	100	1.6	0.1	0	2.5	0
SubA-3	SubA-4	11.261	100	1.6	0.1	0	2.5	0
SubA-4	SubA-10	9.720	100	1.6	0.1	0	2.5	0
SubA-5	SubA-10	4.830	100	1.6	0.1	0	2.5	0
SubA-6	SubA-7	4.325	100	1.6	0.1	0	2.5	0
SubA-7	SubA-11	6.659	100	1.6	0.1	0	2.5	0
SubA-8	SubA-10	4.841	100	1.6	0.1	0	2.5	0
SubA-9	SubA-14	9.667	100	1.6	0.1	0	2.5	0
SubA-10	SubA-14	1.774	100	1.6	0.1	0	2.5	0
SubA-11	SubA-13	6.731	100	1.6	0.1	0	2.5	0
SubA-12	SubA-14	14.748	100	1.6	0.1	0	2.5	0
SubA-13	SubA-14	6.512	100	1.6	0.1	0	2.5	0
SubA-14	SINK	9.200	100	1.6	0.1	0	2.5	0
SubB-1	SubB-3	15.161	100	1.6	0.1	0	2.5	0
SubB-2	SubB-5	2.853	100	1.6	0.1	0	2.5	0
SubB-3	SubB-6	4.682	100	1.6	0.1	0	2.5	0
SubB-4	SubB-6	3.341	100	1.6	0.1	0	2.5	0
SubB-5	SubB-10	2.245	100	1.6	0.1	0	2.5	0
SubB-6	SubB-9	5.022	100	1.6	0.1	0	2.5	0
SubB-7	SubB-9	2.822	100	1.6	0.1	0	2.5	0
SubB-8	SubB-9	1.309	100	1.6	0.1	0	2.5	0
SubB-9	SubB-12	4.236	100	1.6	0.1	0	2.5	0
SubB-10	SubB-12	1.214	100	1.6	0.1	0	2.5	0
SubB-11	SubB-12	2.982	100	1.6	0.1	0	2.5	0
SubB-12	SINK	2.654	100	1.6	0.1	0	2.5	0
SubC-1	SubC-4	6.689	100	1.6	0.1	0	2.5	0
SubC-2	SubC-4	0.814	100	1.6	0.1	0	2.5	0
SubC-3	SubC-4	0.658	100	1.6	0.1	0	2.5	0
SubC-4	SubC-7	0.522	100	1.6	0.1	0	2.5	0
SubC-5	SubC-7	2.914	100	1.6	0.1	0	2.5	0
SubC-6	SubC-7	5.898	100	1.6	0.1	0	2.5	0
SubC-7	SINK	0.361	100	1.6	0.1	0	2.5	0

DCC Subdivision and Development Guidelines state that C for developed subdivisions is to be 1 which equates to 100% impervious fraction within the WBNM model. Initial Loss (IL) and Continuing Loss Rate (CLR) were taken from Australian Rainfall and Runoff Volume 1. CLR was adjusted to obtain peak flows more closely resemble the peak flows calculated by the Rational Method (Appendix 1)

Conceptual Sizing of Detention Basin(s)

Design of detention basins has been conducted in accordance with QUDM, 2007. Initial sizing used QUDM equations

5.02 $V_s / V_i = r$

5.05 $r = (Q_i - Q_o)/Q_i$

These basins were tested with various pipe/culvert configuration with the WBNM program. Critical storm duration was once again tested and found to be 60min for the catchments A and B and 25 min for the catchments C , Fitzmaurice Terrace and Lyons the for all ARI's in the respective catchments. Resizing of the basins was required and was conducted through trial and error approach to find the most suitable combination of basin configuration and pipe/culvert sizes that produces a no worsening effect on the discharge flows leaving the site compared to the pre-developed scenario.

Post Development Design Stormwater Flow (Detained)

Table 9: Preliminary WBNM Modelling Results: Pre and Post Development Peak Flow Rates

Development Status	ARI (Frequency)	Location		
		Sub Catchment A m^3/s	Sub Catchment B m^3/s	Sub Catchment C m^3/s
Catchment Area (Ha)		101.0	48.5	19.0
Pre-development	2yr	16.6	9.5	4.50
Post-development (No attenuation)		24.8	14.1	7.70
Post-development (with attenuation)		16.7	8.0	4.66
Pre-development	10yr	23.3	13.2	6.21
Post-development (No attenuation)		33.6	19.0	10.26
Post-development (with attenuation)		22.9	11.3	6.50
Pre-development	100yr	35.3	19.6	9.10
Post-development (No attenuation)		48.3	26.9	13.79
Post-development (with attenuation)		32.6	16.2	9.11
Attenuation basin volume (m^3)		35562	22572	6844
Base area (m^2)		19352	8964	5162
Top area (m^2)		25400	15750	7874
Depth m		1.5	1.5	1.5
Side slope		1 in 6	1 in 6	1 in 6
Outlet Pipe size (mm)		1 by 2100 x900 and 4 by 3000 x 900	4 by 2100 x 900	1 by 1800 x 900 and 10 600 x 450
Overflow weir width (m)		100	50	35

Table 9 provides a summary of the modelling results show that peak flow rates post development approximate pre-development levels. Results for all ARI's for each catchment can be found in Appendix 1.

Basin Configuration(s)

Whilst some variations in size and configuration can be expected for basins following the detailed design of future Stages of the development, the basin configurations as shown in Appendix 3 are considered a reasonable estimate of their probable size and location.

Water Quality Management

Proposed Management Measures

Various stormwater quality management methods can be employed to reduce impacts to the receiving environment and include both structural and non structural management measures. Water Sensitive Urban Design (WSUD) principles have been applied and measures conceptualised in accordance with DCC guidelines.

Structural measures proposed include:

- Rainwater harvesting;
- Gross Pollutant Traps;
- Surface protection/lining as appropriate to prevent erosion;
- Treed and grassed drainage reserves for additional sediment and nutrient capture; and
- Retention and infiltration of first flush runoff.

Non-structural measures proposed include:

- Rehabilitation and maintenance of disturbed areas until re-established;
- Public education programmes relating to the use of fertilizers and the disposal of pet wastes, litter, etc.; and
- Regular street sweeping programmes.

Water Quality Modelling

Water quality treatment measures have been modelled using MUSIC, a computer modelling program developed by CRC for Catchment Hydrology. Whilst considered conceptual only, MUSIC allows the relative effectiveness of various water quality treatment measures to be compared. MUSIC modelling has been conducted in accordance with the Northern Territory Department of Planning and Infrastructure's Water Sensitive Urban Design Stormwater Quality Modelling Guide (2009).

If there were no in-system control measures put in place, post development loads and concentrations of sediment, nutrients and the gross pollutants would increase significantly. However, by implementing an appropriate suite of water quality management measures, pollutant levels can be retained at target levels.

The treatment measures that have been used and sized in this modelling have been done to achieve the Northern Territory Department of Planning and Infrastructure's Water Sensitive Urban Design Planning Guide which state that stormwater from greenfield subdivisions is to be treated to the following load reduction targets, as compared to a standard development:

- 80% of Total Suspended Solids (TSS)
- 60% of Total Phosphorus (TP)
- 45% of Total Nitrogen (TN)
- 90% of Gross Pollutants

These targets relate to stormwater leaving a development site and therefore all treatment must be within the development boundaries.

MUSIC models were developed for each stormwater drainage catchment for which schematics of the treatment train are shown in Appendix 2. The treatment train has been designed to contain no elements that will have standing pools of water as this is a requirement of DCC's Subdivision and Development Guidelines. The slope of the site enables the use of swales as there are no slopes above 4%.

The models were simulated using rainfall data from Darwin Airport (BOM station 14015) for the period 1st Jan 1987 to 31st Dec 1996 in accordance with the Northern Territory Department of Planning and Infrastructure's Water Sensitive Urban Design Stormwater Quality Modelling Guide (2009).

The results of the MUSIC modelling is set out in the following Tables 10, 11 and 12 for the sub catchments A, B and C respectively. The treatment trains meet the reduction targets without the inclusion of the 3KL water tanks for each residential lot. MUSIC schematics of the treatment train layouts are in Appendix 2 along with a preliminary design layout of the location and sizing of the devices and treatment train in Appendix 3.

Table 10: Pollution Removal Estimates for Various In-System Control Measures using MUSIC for Discharge from Sub-catchment "A" (North East Discharge Point)

Scenario	Parameter									
	Total Phosphorus (TP)			Total Nitrogen (TN)			Total Suspended Solids	Gross Pollutants	Flow
	Mean (mg/L)	90%ile	Mean Annual Load (kg/yr)	Mean (mg/L)	90%ile	Mean Annual Load (kg/yr)	Mean Annual Load (kg/yr)	Mean Annual Load (kg/yr)	Mean Annual Load (ML/yr)
Pre Development	0.145	0.155	253	1.28	1.39	1.81×10^3	88.2×10^3	0	564
Post Development									
a) No Controls	0.182	0.29	278	2.25	3	2.47×10^3	145×10^3	10.2×10^3	897
b) Rain Water Harvesting	0.185	0.297	269 (3.2%)	2.25	2.99	2.35×10^3 (4.9%)	141×10^3 (2.8%)	7.85×10^3 (23.0%)	857 (4.5%)
c) Treatment Train	0.114	0.21	86.3 (69.0%)	1.6	2.51	1.35×10^3 (45.3%)	14.9×10^3 (89.7%)	0.0 (100.0%)	897 (0.0%)
d) Rain Water Harvesting & Treatment Train	0.115	0.211	84.5 (69.6%)	1.61	2.52	1.31×10^3 (47.0%)	14.8×10^3 (86.8%)	0 (100.0%)	861 (4.0%)

Treatment train includes GPTs, Bio-retention, grass-lined swale and sedimentation basin

Table 11: Pollution Removal Estimates for Various In-System Control Measures using MUSIC for Discharge from Sub-catchment "B" (South East Discharge Point)

Scenario	Parameter									
	Total Phosphorus (TP)			Total Nitrogen (TN)			Total Suspended Solids	Gross Pollutants	Flow
	Mean (mg/L)	90%ile	Mean Annual Load (kg/yr)	Mean (mg/L)	90%ile	Mean Annual Load (kg/yr)	Mean Annual Load (kg/yr)	Mean Annual Load (kg/yr)	Mean Annual Load (ML/yr)
Pre Development	0.146	0.161	119	1.29	1.45	860	41.4×10^3	0	268
Post Development									
a) No Controls	0.186	0.291	149	2.26	3	1.33×10^3	81.8×10^3	6.42×10^3	477
b) Rain Water Harvesting	0.189	0.3	147 (1.3%)	2.26	2.99	1.25×10^3 (6.0%)	80.2×10^3 (2.0%)	5.04×10^3 (21.5%)	455 (4.6%)
c) Treatment Train	0.115	0.206	43.3 (70.9%)	1.63	2.46	716 (46.2%)	7.37×10^3 (91.0%)	4.27 (99.9%)	477 (0.0%)
d) Rain Water Harvesting & Treatment Train	0.116	0.206	42.6 (71.4%)	1.64	2.47	693 (47.9%)	7.33×10^3 (91.0%)	4.06 (99.9)	455 (4.6%)

Treatment train includes GPTs, Bio-retention, grass-lined swale and sedimentation basin

Table 12: Pollution Removal Estimates for Various In-System Control Measures using MUSIC for Discharge from Sub-catchment "C" (West Discharge Point)

Scenario	Parameter									
	Total Phosphorus (TP)			Total Nitrogen (TN)			Total Suspended Solids	Gross Pollutants	Flow
	Mean (mg/L)	90%ile	Mean Annual Load (kg/yr)	Mean (mg/L)	90%ile	Mean Annual Load (kg/yr)	Mean Annual Load (kg/yr)	Mean Annual Load (kg/yr)	Mean Annual Load (ML/yr)
Pre Development	0.148	0.171	44.1	1.3	1.53	324	15.6×10^3	0	99.1
Post Development									
a) No Controls	0.191	0.298	58.1	2.29	3.03	526	31.3×10^3	2.64×10^3	187
b) Rain Water Harvesting	0.142	0.253	56.8 (2.2%)	1.79	2.83	491 (5.6%)	31.8×10^3 (1.5%)	2.12×10^3 (21.5%)	177 (4.8%)
c) Treatment Train	0.113	0.212	16.2 (72.1%)	1.55	2.51	282 (46.4%)	2.76×10^3 (91.2%)	15.5 (99.4%)	187 (0.0%)
d) Rain Water Harvesting & Treatment Train	0.113	0.212	17.3 (70.2%)	1.55	2.51	275 (47.1%)	2.99×10^3 (90.7%)	1.06 (100.0%)	177 (4.8%)

Treatment train includes GPTs, Bio-retention and grass-lined swales

The following provides general information regarding each adopted stormwater treatment measure.

Rainwater Tanks

In accordance with stormwater treatment best management practices (BMPs), rainwater tanks will be included within the treatment train to retain stormwater collected as roof runoff. Collection of roof runoff will reduce catchment stormwater quantities and provide increased infiltration and filtration through the utilisation of tank water for residential irrigation and non-potable use. Studies by the University of Newcastle have shown that provided storage volumes are available rainwater tanks can significantly reduce peak stormwater discharges, help mitigate localised urban flooding, improve stormwater quality and reduce demand on town water supply. First flush bypass systems will be installed, as appropriate, to divert any pollutants that may collect on the roofs. Although rainwater tanks may provide reduction of some nutrients, these capabilities have not been included in the modelling procedures of this study.

This will keep “clean” stormwater from the roofs separate from the hardstand runoff. Any overflow from the tanks will be discharged to the local stormwater pipe network should it occur.

Water quality monitoring will need to be undertaken on a 6 monthly basis to evaluate the integrity of the tanks and ensure the quality remains suitable for the proposed uses.

<u>Maintenance</u>

Rainwater tanks involve regular preventative maintenance in order to avoid the need for corrective action. Recommended maintenance includes:

- 6-monthly inspections of roof areas and gutters to ensure they are relatively free of leaves and debris.
- Vegetation and trees that overhang the roof may need to be pruned.
- First flush devices should be checked and cleaned out once every 3-6 months.
- Bypass screens at inlet and overflow points should be inspected each 6 months to check for fouling and clean them.
- Every 2-3 years, tanks should be checked for accumulation of sludge. Sludge may become a problem if it is deep enough to reach the level of the out take pipe and so produce discoloured or sediment-laden water, or when it affects storage capacity. When necessary, sludge can be removed by vacuum, by siphon, by suspending the sludge and washing it through, or by completely emptying the tank.
- If a pump system is used, the pump manufacturer should be consulted for advice on necessary maintenance.

Gross Pollutant Traps (GPT’s)

GPTs, as per *Darwin City Council, Subdivision and Development Guidelines, 2005,* have been included to remove trash and reduce litter, suspended solids and nutrient concentrations in stormwater prior discharge.

Based on the guidelines listed above, the Brisbane City Council (1999b) Draft *Design Guidelines for Stormwater Quality Improvement Devices and* research by Walker et al (1999), pollutant removal efficiencies have been estimated at 50% for sediments for all concentrations. Removal rates of phosphate at 20% and nitrogen at 0%. Gross pollutants removal rate is 90%.

Maintenance

Regular maintenance is essential to ensure the performance of GPTs. Normally cleanouts are required around once every 3 months, however each trap should be monitored during the first few years of operation to determine the required cleanout frequency. Poorly maintained GPTs can:

- Fail to trap pollutants;
- Release contaminants by leaching from the collected pollutants;
- Reduce the capacity of the drainage system and potentially lead to upstream flooding; and
- Lead to unpleasant odours and reduced visual amenity.

The nature of maintenance activities depends to a large extent on the type of trap installed; this should be considered during the design stage. GPT suppliers are able to provide information on maintenance methods.

Sedimentation Basins

Sediment basin have not been included in the final operational treatment layout but will be used in the construction stage to reduce the sediment load of the stormwater runoff prior to discharge. These basins slow the flow of stormwater causing the suspended sediment to settle out of the water column. The basins can be included within the attenuation basins to reduce the required earth works which will later accommodate the bio-retention basins to reduce the demand on public open space.

Maintenance

Sedimentation basins are designed with a sediment storage capacity to ensure sediment removal is only required approximately every 5 years (triggered when sediment accumulates to half the basin depth, determine from regular monitoring of sediment depth with a measuring post during maintenance visits). Accessibility for maintenance is an important design consideration. If an excavator is able to reach all parts of the basin from the top of the batter then an access ramp may not be required; however, an access track around the perimeter of the basin will be required and will affect the overall landscape design. If sediment collection requires earthmoving equipment to enter the basin, a stable ramp will be required into the base of the sedimentation basin (maximum slope 1:10).Machinery must be restricted to the access tracks and should not be placed on the bottom of the basin.

Maintenance access must be ensured to all sediment removal areas.

It is recommended that a sedimentation basin is constructed with a hard (ie. rock) bottom (with a bearing capacity to support maintenance machinery when access is required within the basin). This serves an important role by allowing excavator operators to detect when they have reached the base of the basin during desilting operations.

Swales

Vegetated swales are used to convey stormwater in lieu of, or with, underground pipe drainage systems. Vegetated swales are both a stormwater conveyance and treatment mechanism. They are effective for removal of suspended solids, particularly coarse sediments, and will also reduce some phosphorus and nitrogen loads. They are commonly combined with buffer strips and bio-retention systems, or may be used as a pre-treatment measure upstream of a wetland. Swales utilise overland flow and mild slopes to convey water slowly downstream. They provide a means of disconnecting impervious areas from downstream waterways, assisting in protecting waterways from damage by frequent storm events, by reducing flow velocity compared with piped systems. The interaction between stormwater flow and vegetation within swale systems facilitates pollutant settlement and retention. Even swales with relatively low vegetation height (such as mown grass) can achieve significant sediment deposition rates provided flows are well distributed across the full width of the swale and the longitudinal grade of the swale is kept reasonably low (typically less than 4 % grade) to maintain slower flow conditions.

Swales alone cannot provide sufficient treatment to meet current best practice stormwater treatment/water quality objectives, but can provide an important pre-treatment function for other WSUD measures in a treatment train, enabling water quality objectives to be met. Swales are particularly good at coarse sediment removal as a pre-treatment for wetlands and bio-retention systems.

Table 13 lists the swales and their sizes for each of the catchments within the proposed development these are only the preliminary sizing, final sizing and layout will depend on final development layout.

Table 13: Swale sizing for the proposed layout

Catchment	Swale no.	Length (m)	Base width (m)	total width (m)	Depth (m)
A	1	150	1	7	0.5
	2	130	3	12	0.75
	3	180	18	27	0.75
	4	160	20	32	1
	5	260	1	11	0.75
	6	50	7.5	16.5	0.75
	7	130	7.5	16.5	0.75
	8	430	9	18	0.75
	9	160	20	32	1
	10	70	5.5	11.5	0.5
B	1	200	7	16	0.75
	2	140	10	19	0.75
	3	500	1	1	0.5
	4	200	2	8	0.5
	5	150	3	9	0.5
	6	50	22	31	0.75
C	1	120	6	16	0.8
	2	100	1	11	1
	3	300	0.9	9	0.9

Maintenance

Swale treatment relies upon good vegetation establishment and therefore ensuring adequate vegetation growth is the key maintenance objective. In addition, they have a flood conveyance role that needs to be maintained to ensure adequate flood protection for local properties. The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments may impact on plant growth, particularly in developing catchments with an inadequate level of erosion and sediment control.

The potential for rilling and erosion along a swale needs to be carefully monitored, particularly during establishment stages of the system. Other components of the system that will require careful consideration are the inlet points (if the system does not have distributed inflows) and surcharge pits.

The inlets can be prone to scour and build up of litter and occasional litter removal and potential replanting may be required. Swale field inlet pits also require routine inspections to ensure structural integrity and that they are free of blockages with debris.

Typical maintenance of swale elements will involve:

- routine inspection of the swale profile to identify any areas of obvious increased sediment deposition, scouring of the swale invert from storm flows, rill erosion of the swale batters from lateral inflows or damage to the swale profile from vehicles;
- routine inspection of inlet points (if the swale does not have distributed inflows), surcharge pits and field inlet pits to identify any areas of scour, litter build up and blockages;
- removal of sediment where it is impeding the conveyance of the swale and/or smothering the swale vegetation and if necessary reprofiling of the swale and revegetating to original design specification;
- repairing damage to the swale profile resulting from scour, rill erosion or vehicle damage;
- clearing of blockages to inlet or outlets;
- regular watering/ irrigation of vegetation until plants are established and actively growing;
- mowing of turf or slashing of vegetation (if required) to preserve the optimal design height for the vegetation;

Note: Heavy machinery for mowing/ slashing should be avoided.

- removal and management of invasive weeds;
- removal of plants that have died (from any cause) and replacement with plants of equivalent size and species as detailed in the plant schedule;
- pruning to remove dead or diseased vegetation material and to stimulate new growth;
- litter and debris removal;
- vegetation pest monitoring and control; and
- inspections are also recommended following large storm events to check for scour.

Buffer/Filter Strips

Flush kerbs and vegetated roadside drains/swales are proposed throughout the residential areas. As a method of water quality improvement, these drains can provide infiltration and removal of sediment and nutrients. These devices will also ensure that stormwater is directed to treatment. The reduction qualities of these devices has not been included in the study, as detailed design layouts for each sub-development is yet to be completed. Figure 19 presents an example of flush kerb, swale and filter strip combined measure to treat road generated runoff.

Figure 19. An example of flush kerbs, swale and filter strips

Maintenance

Maintenance for buffer strips is typical of open landscaped gardens, with vegetation growth the key objective. This is because the vegetation in buffer strips provides most of the pollutant removal. Good vegetative growth is the key maintenance objective since the vegetation in buffer strips supports the pollutant removal. Typical maintenance requirements for buffer strips include:

- Monitoring for scour and erosion, and sediment or litter build-up
- Weed removal and plant re-establishment
- Monitoring overflow pits for structural integrity and blockage

Bio-Retention Systems

Bio-retention systems are defined as 'modified infiltration basins that treat stormwater through adsorption, filtration, volatilisation, ion exchange and microbial decomposition.' The six basic components of a bio-retention system include; a grassed buffer strip, a sand bed, a ponding area, an organic or mulch layer, soil and plants. Bio-retention areas can be altered to accommodate surrounding soils with low hydraulic conductivity by inserting a drainage system into a gravel layer at the base of the system. It is recommended that bio-retention areas be at least 4.6 metres wide, however 7.6 metres is preferable, and a minimum length of 12 metres. The length to width ratio should be approximately 2:1 (Young et al. 1996). Bio-retention areas are reported to operate best where input is derived from direct rainfall and sheet flow from surrounding allotments in a small catchment. Water captured in the ponding area should be no more than 30 cm deep for a maximum of 4 days to prevent anaerobic conditions, plant death and insect breeding.

Bio-retention areas are proposed for the open space areas throughout the development, directly adjacent to the residential developments, therefore providing treatment of run-off before it enters stormwater corridors. The size of the bio-retention basins is as shown in Table 14.

Table 14: Bio-retention basins sizes

Catchment	Basin no.	Length (m)	Width (m)	Area (m^2)
A	1	236	82	19352
B	1	332	27	6750
	2	40	20	800
C	1	40	2.5	100
	2	120	40	4800

Modelling investigations have indicated that they may potentially remove over 80% of suspended solids and greater than 50% of nutrients from runoff received. A typical Bio-retention cross section can be found below in Figure 20.

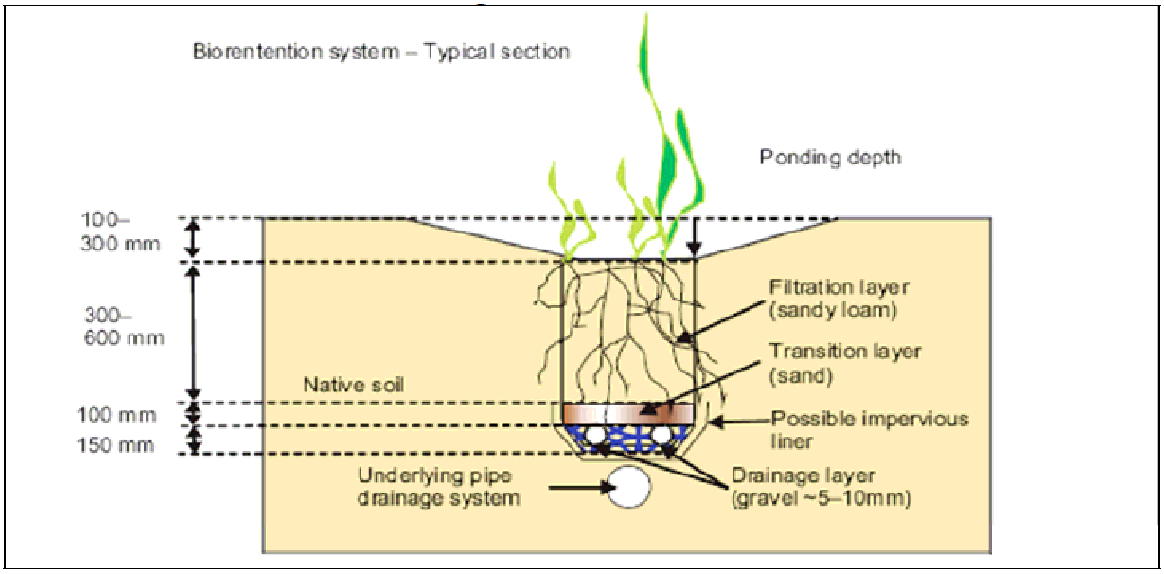

Figure 20. Typical Bio-retention Cross Section (CSIRO 2005)

<u>Maintenance</u>

Bio-retention systems require regular maintenance particularly in the establishment phase. If maintenance is not undertaken, the performance of the system will not reach design requirements. Most maintenance requirements will be on an as needs basis. Anticipated maintenance work will include the following:

- regular clearing of infiltration area and outlets - required whenever debris and litter have accumulated on screens to an unacceptable level or sufficient coarse sediments have accumulated in the filter area;
- removal of debris and plant litter - required based on accumulation to unacceptable levels. Care must be taken to schedule periodic removal

operations at times when vegetation may be routinely shedding leaves and foliage;
- desilting of infiltration areas and replacement of filter media - this will be driven by monitoring of silt depth and infiltration rate. It is expected that desilting will be achieved through removal by bobcat or small excavator/backhoe and may be necessary every 5-10 years;
- treatment/removal of diseased trees and shrubs – to be performed as required;
- inspection after rainfall events to repair eroded areas – as required after storm events; and
- mowing of turfed areas and pruning of trees and shrubs to maintain the appearance of the treatment system.

Planting

Bio-retention systems need to be planted with sufficient density to ensure sufficient biological processing of nutrients and active growth in the upper layers of the filter media. Typical overall densities of vegetation are a minimum of 6 plants per square metre with densities of 8 plants per square metre recommended. Higher planting densities are also suitable, but increase the cost of planting.

Planting should incorporate several growth forms – trees, shrubs, tufted plants and groundcover species, to ensure that the plant roots occupy all parts of the media. It is recommended to plant either shrubs or small to medium trees within bio-retention systems where possible. Trees are able to provide shade, higher evapotranspiration rates, deeper rooting depths and a degree of local climate control.

In general it is recommended to plant a mixture of species within a bio-retention system. A range of species provides reduced risk of failure of all the vegetation if a particular species is not suited to the microclimate. Using several species reduces the risk that insect attack, disease or adverse weather will harm all of the plants at once.

Bio-retention systems will commonly comprise a minimum of five to ten species, depending on the size and hydrologic conditions within individual systems. In general larger bio-retention systems will have more species than smaller bio-retention systems. Table 15 below outlines species for different types and zones of bio-retention systems as set out in the Northern Territory Department of Planning and Infrastructure's Vegetation Selection Guide 2009.

Table15: Indicative Species List for Bio-retention Systems

Scientific Name	Common Name	Type of Plant	Maximum Height (m)
Bio-retention Media - Trees on sandy media			
Eucalyptus miniata	Woollybutt	Tree	8-20
Eucalyptus tetradonta	Stringybark	Tree	10-30
Melaleuca dealbata	Paperbark	Amphibious tree	12
Melaleuca viridiflora	Paperbark	Amphibious tree	12
Pandanus spiralis	Screw palm	Amphibious tree	10
Bio-retention Media - Shrubs on sandy media			
Boronia gradisepala		Shrub	0.5
Boronia lanuginosa		Shrub	0.5-1.5
Bossaiea bossaioides		Shrub	1-2
Calytrix exstipulata	Turkey bush	Shrub	1-4
Grevellea pungens		Shrub	1-1.5

Grevillea angulata		Shrub	1-4
Jacksonia dilatata		Shrub	2-4
Templetonia hookeri		Shrub	1-3
Verticordia cunninghamii		Shrub	1.5-5
Bio-retention Media - understorey on sandy media			
Grevillea formosa		Shrub	0.5
Imperata cylindrica	Blady grass	Shrub	1
Platyzoma microphyllum	fern	Shrub	0.15-0.5
Cynodon dactylon	Couch	Grass	0.6
Isoetes coromandelina	Quillwort	Amphibious fern	0.8
Sorghum plumosum		Grass	
Sorghum stipodeum		Grass	
Extended Detention Area/Upper Batter Trees on clay soils			
Melaleuca dealbata	Paperbark	Amphibious tree	12
Melaleuca viridiflora	Paperbark	Amphibious tree	12
Extended Detention Area/Upper Batter - Understorey on clay soils			
Cyperus scariosis	Sedge	Amphibious sedge	0.8
Fimbristylis dichotoma	Sedge	Amphibious sedge	1
Isoetes coromandelina	Quillwort	Amphibious fern	0.8
Extended Detention Area Upper Batter (terrestrial vegetation)			
Eucalyptus miniata	Woollybutt	Tree	8-20
Eucalyptus tetradonta	Stringybark	Tree	10-30
Sorghum plumosum		Shrub	
Sorghum stipodeum		Shrub	
Themeda australis	Kangaroo grass	Grass	0.75

Protection of Waterways, Remnant vegetation and Ecological Linkages

The Casuarina Coastal Reserve and Buffalo Creek Management Area are two significant regionally based ecosystems located in proximity to the site.

The Casuarina Coastal Reserve protects about 1500 ha of coastal habitats between the estuaries of Rapid Creek and Buffalo Creek. It includes 13 km of sandy beaches, dramatic cliffs and shady casuarina trees. Behind the dunes lie common coastal plant communities including patches of woodlands, monsoon forests, mangroves and paperbarks.

Buffalo Creek is classed as a tidal flat/tidal creek and has naturally high turbidity. Buffalo creek was nominated in 1987 for inclusion in the National Estate. It was never registered and is still an ‘Indicative Place’. However the Place Report describes the site as:

‘The Casuarina/Lee Point/Buffalo Creek area is a strip of coast to the north of Darwin city. There are sandy beaches and dunes along the whole strip, saline mud flats, mangrove communities along the creeks, and closed vine thicket and monsoon forests behind the beaches. The area is mostly flat although there are some steeper sections behind the beach. The soils are mostly erodible gravels and there is much lateritic outcrop. There are a number of historic army pillboxes along the Casuarina/Lee Point coastline. Casuarina Coastal Reserve is a popular recreational beach within the Darwin urban area. The mangrove and monsoon forest vegetation is largely undisturbed, and its less developed

character contrasts with other beaches in the Darwin area.

Significant Indigenous values are known to exist in this area. The Commission is currently consulting with relevant Indigenous communities about the amount of information to be placed on public record.'

The site suffers from 'e*rosion on the access tracks, litter, damage to dunes from vehicles, trampling and vandalism'*

Management of Disease Vector and Nuisance Insects

In accordance with DCC development guidelines the midge/biting insect buffer zone that restricts development to Rural residential on the eastern side of the development. To avoid mosquito breeding, all drainage systems and associated structures are proposed to drain fully with no ponding of water.

Normal levels of maintenance to the stormwater system will be required to ensure it operates as designed.

Management of Subdivisional Construction Works

Land development sites have the potential to be a major source of stormwater pollution. Contaminants such as sediment, solvents, paints, adhesives, cement, cement mixer wash water, lime and packaging maybe transported via stormwater to receiving environments. These contaminants have the potential to harm aquatic ecosystems and cause adverse harm to receiving environments.

As the proposed site is close to local watercourses, contaminants from construction works, could potentially enter the creek system, thus strict construction management practices are proposed in accordance with DCC guidelines. The following general measures outlined in Table 16 are proposed to be adopted during the construction phases of the staged development.

Table 16: Proposed Practices During Construction Activities

Construction Activity	Management Practices Proposed
Litter and waste management (non-hazardous material)	• A designated waste collection area that does not receive runoff from upland areas and does not drain directly to a water body or a road; • Ensure light-weight wastes are retained in strong winds; • Ensure waste containers have covers and are covered before periods of rain; • Clean up spills immediately; • Schedule waste collection events to prevent waste containers overfilling; • Ensure all wastes are recycled or taken to authorised disposal sites that are appropriate for the types of wastes generated on site.
Litter and Waste Management (hazardous materials)	• As above; • The original product label should never be removed from hazardous waste containers; • A contingency plan for accidental chemical spills should be devised;
Washing down practices	• Designate a wash-down area for the site away from roads, water bodies and drainage discharge areas. Temporary bunds should be utilized if the wash down area is close to roads, water bodies or drainage discharge areas; • Clean equipment before washing.
Water conservation	• Conserve water by turning off taps after use, ensuring water drums are not leaking and minimising the volume of water used during washing-down practices.
Erosion & sediment control practices	The Contractor shall implement all measures specified in the Northern Territory Government approved Erosion and Sediment Control Plan prepared for each Stage of development. The measures shall include but not be limited to: • Site planning to identify the most appropriate location(s) for stockpiles such as soil; • All erosion and sediment control measures to be installed prior to any site disturbance;

Construction Activity	Management Practices Proposed
	• All NO-GO zones must be flagged or fenced to restrict access and inspected by Northern Territory - Natural Resources Environment and the Arts (NRETA) prior to any site disturbance; • Minimising the area of disturbance; • Limit and fill batter gradients to 1(V):4(H) maximum; • Frequent watering of areas disturbed by the Contractor to control dust; • Barriers to trap wind-blown sediment, sand and litter (erection of wind fencing); • Staging site clearing and rehabilitation to minimise the length of time disturbed areas are left exposed; • Operations with dust creating potential not to be carried out when wind velocity and direction create a nuisance; • On completion of stormwater inlet pits protection measures to be immediately installed; • The timely stabilisation of completed earthworked areas; • Sediment traps, check dams , runoff diversions and other erosion protection measures as specified for the protection of the works in progress, to minimise soil erosion and to retain all sediment on site; • All sediment control structures to be inspected after each rain fall event for damage and effectiveness. Trapped sediment to be removed to a nominated site; • Divert all stormwater runoff away from disturbed soil into intact native vegetation or stormwater drainage system; • All erosion and sediment control measures to be undertaken to the satisfaction of NRETA; • Minimise earth works to be conducted during the wet season; • Establish and maintain a street sweeping program for the duration of the works; • Any changes to the erosion and sediment control plan shall be submitted to NRETA for approval prior to works commencing.
Dewatering and acid-sulphate soils	Not applicable
Contaminated sites	Not applicable

An Erosion and Sediment Control Plans (ESCP) will be developed for each stage of the staged development proposals. Construction of sedimentation basins will be required during the construction phase of each stage. The proposed attenuation/bio-retention basin can be used as sedimentation basin as this will reduce the require earthworks and reduce the require land needed to construct these devices. The basin will need to be lined with

Gold Coast City Council Land Development Guidelines have set construction phase performance criteria as follows in Table 17 these are considered best management practices for the construction phase.

Table 17: Construction Phase Guidelines Performance Criteria

Pollutant	Criteria
Total Suspended Solids	90^{th} %ile <50mg/L
pH	6.5 - 9.0
Dissolved Oxygen	90^{th} %ile >80% saturation or 6mg/L
Hydrocarbons	No visible sheen on receiving waters
Litter	No visible litter washed from site

Erosion and Sedimentation Controls

Erosion and sedimentation controls will be implemented for the construction and operation phases of the Muirhead development to mitigate the impacts of the proposed development on nearby watercourses and the surrounding environment. Standard erosion and sediment control techniques will be used in accordance with the requirements of QUDM (2007). A detail erosion and sedimentation control plan will be developed when the development layout is finalised and will be done for each of the stages of the development.

Construction Phase

Prior to site disturbance erosion and sediment controls must be established and approved by the DCC. Specific erosion and sediment controls will contained in the construction plans for works on the site. In addition to these controls, the following measures will be adopted:

- minimising all disturbed areas and stabilisation by progressive rehabilitation as soon as practicable;
- construction of diversion drains upslope of areas to be disturbed to direct clean runoff away from disturbed areas. These drains will be designed to ensure effective segregation of sediment-laden runoff and allow clean surface water to return to natural watercourses;
- construction of catch drains to capture runoff from disturbed areas and direct runoff into sediment dams;
- construction of other erosion and sediment controls works such as silt fences and sediment basins prior to construction works commencing within the catchment area;
- construction of drainage controls such as table drains at roadsides and on hardstand areas;
- construction of all temporary drains as earthen drains at grades no steeper than 1.2 percent to minimise scouring, otherwise ensuring that adequate scour protection is provided;
- All drains are to be grassed to minimise erosion;
- placement of geotextile liners and rock check dams in drains as required to reduce water velocities and prevent scouring;
- regular maintenance of all controls and inspection of all works weekly and immediately after storm events to ensure erosion and sediment controls are performing adequately;
- maintaining earthworks stockpiles in a condition that minimises windblown dust using water sprays;

- vegetation of stockpiles if stored for longer than 3 months;
- construction of road and earthworks cut and fill batters at slopes of 1V: 4H (vertical : horizontal) or less, where possible, to maximise long term stability;
- bunding of fuel and oil storage areas and other pollutant-generating areas;
- immediate repair or redesign of erosion and sediment controls that are not performing adequately;
- placement of ‘oil booms’ (or other devices performing the same function), where practical at the outlets of dams which have the potential to capture any hydrocarbon related spills; and
- In addition, the construction plans for the site will detail the specific inspection, maintenance and revegetation requirements for each works area.

Operational Phase

Water quality measures will be implemented for the project during the operational phase to minimise impact on the surrounding environment. These controls will be designed and constructed to a standard consistent with QUDM (2007). The measures to minimise erosion and the generation of sediment include the following:

- regular maintenance of all erosion and sediment controls and rehabilitated areas;
- regular inspections of access tracks/roads to ensure that drainage is working effectively and that the tracks/roads are stable, particularly after rain;
- prompt revegetation of areas as soon as earthworks are complete;

Erosion and Sediment Controls

The controls to be implemented at the Muirhead development will be designed in accordance with QUDM (2007) and include the following controls:

- clean diversion drains and banks;
- catch drains;
- silt fences; and
- sediment basins.

<u>Clean Water Diversion Drains and Banks</u>

Diversion drains are to be designed in accordance with QUDM (2007) to cater for a 1 in 10 year Average Recurrence Interval (ARI) storm event. The side batters are to have a maximum grade of 1V: 4H (vertical: horizontal). The drains are to be located and designed with base widths so as to minimise peak velocities. Where peak design velocities exceed 1 m/s in clean water catchments and along the roadsides of permanent roads rock bars will be placed along the invert of the drain every 100 metres to reduce the peak velocities.

Clean water runoff from undisturbed areas will be diverted through drains and banks into nearby watercourses. Appropriate protection will be established where diverted waters enter creeks through the use of level spreaders prior to draining into rock armoured creek banks and, if required, additional planting of grass, small shrubs and riparian species to achieve the required bank stability.

<u>Catch Drains</u>

Catch drains are to be used to collect water for treatment in sedimentation dams. All catch drains are to be designed in accordance with Department of Natural Resources, Environment and The Arts Erosion and Sediment Control Guidelines Technical Note criteria to cater for a 1 in 20 year ARI storm event and will provide a minimum of 0.5 metre freeboard. The side batters are to have a maximum grade of 1V: 4H (vertical: horizontal). The drains will be grassed where practical and will be located and designed with base widths so as to minimise peak velocities. Where peak design velocities exceed 1 m/s in clean water catchments and along the roadsides of permanent roads the drains are to be lined with geofabric and rock bars placed along the inverts of the drains every 100 metres to reduce the peak velocities and minimise erosion potential.

Silt Fences

Silt fences are to be designed in accordance with Department of Natural Resources, Environment and The Arts Erosion and Sediment Control Guidelines Technical Note 3 Where necessary, silt fences are to be constructed immediately downslope of the areas to be disturbed to minimise the potential for sediment transport into receiving catchments and waterways. They are to be constructed along site contours if practicable. Fences are to be constructed using geotextile filter fabric with structural post to be spaced no more than 1.5 metres apart. Where practicable, the catchment areas of silt fences are to be limited by constructing the fences with small returns at 20 metre intervals to create smaller contributing sub-catchments. This is necessary as silt fences are prone to failure in larger storm events, and should be designed to ensure a maximum of 50 L/s passes through the silt fence during a storm event.

Sediment Basins

Sediment basins will be designed in accordance with the minimum requirements of Brisbane City Council's Sediment Basin Design Construction and Maintenance (SBDCM) 2001 based on the topsoil and overburden characteristics and contributing area of the disturbance area. The basins will capture and treat dirty runoff to accommodate at least a 1 in 20 year ARI design storm event for each disturbed catchment. The dams will be installed where appropriate prior to any land disturbance activities occurring and maintained following completion. The erosion and sediment controls requirements will be based on the Revised Universal Soil Loss Equation (RUSLE) as described in SBDCM 2001.

According to the geotechnical assessment undertaken by Douglas Partners, the site is underlain by tertiary aged soils comprising unconsolidated sand, ferrinous, clayey, sandy and gravelly soil, Type C basins are the appropriate type to be implemented (SBDCM, 2001). Sediment basin sizes for the Muirhead site have been determined in accordance with SBDCM (2001). Any sediment basins required will be designed in accordance with these guidelines. The current planned attenuation basins will used as sediment basins during the construction phase. This will decrease the need for additional earthworks.

Further detailed investigation of the sedimentation basin requirements will be provided during the detailed design phase of the project

Operation and Maintenance

On completion of the 12 month construction defects liability period for each Stage of development and the acceptance of the fully completed permanent drainage works by the City, the operation and maintenance of those drainage assets will rest with the City. The operation and maintenance of all temporary works will remain the responsibility of the Developer.

Developer Cost Contribution Arrangements

All costs associated with design, site investigations and construction within Lot 9793 Lee Point Rd, Darwin will be met by the Developer. Maintenance and monitoring costs until take over by Council will also be met by the Developer.

Responsibilities and Timing

Table 18 outlines various responsibilities and associated timing relevant to the SMP.

Table 18: Responsibilities and Timing

Item	Responsibility	Timing/Deadline
Operational Works Design	Appointed Consultant	TBA
Control Implementation	Owner/contractor	TBA
Water Quality Monitoring & Reporting	Appointed Consultant – commissioned by developer	Following single rain events in excess of 25 mm per day during the construction phase. Following 3 rain events in the operational phase
Control Maintenance	Contractor under supervision of engineer	Continuous until off maintenance
Supervision on an as needs basis	Appointed Consultant	During Construction Phase
Corrective action	Owner/contractor under direction of Appointed Consultant	Continuous until off maintenance
Compliance Certification	SMEC Urban	At completion of works

Where requested by the approving agency, SMEC Urban Pty Ltd may agree to provide certification of the SMP and ESCP provided the contractor and appointed consultant furnish the required information.

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EcOZ Environmental Services, *Flora and Fauna survey for Proposed Residential subdivision Lots 9737 &9370 Lee Point Rd, Muirhead, NT,* 2008

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Walker, T.A., R.A. Allison, T.H.F. Wong, and R.M.Wootton. *Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap,*1999

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality*. FHWA-PD-96-032, Federal Highway Administration, 1996.

Appendix 1: Data

WBNM output Catchment A

Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Pre	11.975	15.44	19.322	21.709	25.267	29.443	33.256
Post	15.675	19.823	24.331	27.063	31.131	35.992	40.277
Post + Basin	11.75	15.103	18.763	20.959	24.135	28.222	30.937

WBNM output Catchment B

Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Pre	7.201	9.203	11.431	12.789	14.816	16.966	19.078
Post	10.892	13.89	17.06	18.987	21.822	24.014	26.098
Post + Basin	6.378	7.978	10.025	11.268	13.022	14.658	16.203

WBNM output Catchment C

Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Pre	3.155	4.114	5.155	5.793	6.741	7.436	8.396
Post	5.237	6.62	8.02	8.866	10.099	11.345	12.604
Post + Basin	3.107	3.938	4.783	5.277	5.962	6.84	7.394

WBNM output Lyons and Fitzmaurice Terrace

Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Fitzmaurice Terrace	5.689	7.078	8.509	9.37	10.625	11.257	12.467
Lyons	1.812	2.252	2.707	2.98	3.378	3.558	3.94

Rational Method Catchment A

Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Pre	7.44	9.98	13.32	15.47	18.32	24.27	26.80
Post	14.86	19.89	26.66	30.82	36.77	48.64	53.93

Rational Method Catchment B

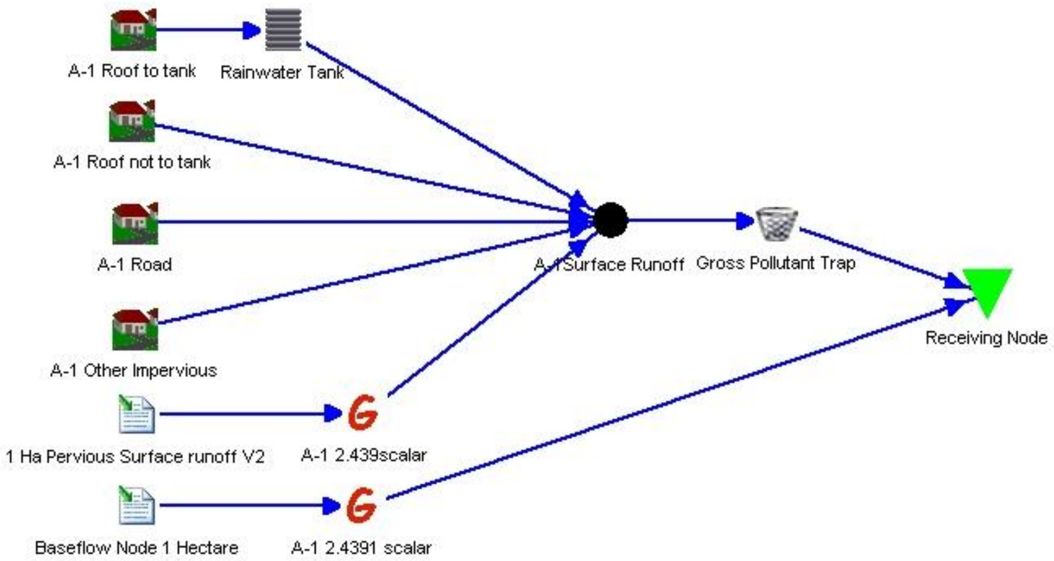
Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Pre	5.78	7.76	10.42	12.09	14.31	18.94	20.94
Post	11.46	15.35	20.59	23.98	28.41	37.58	41.71

Rational Method Catchment C

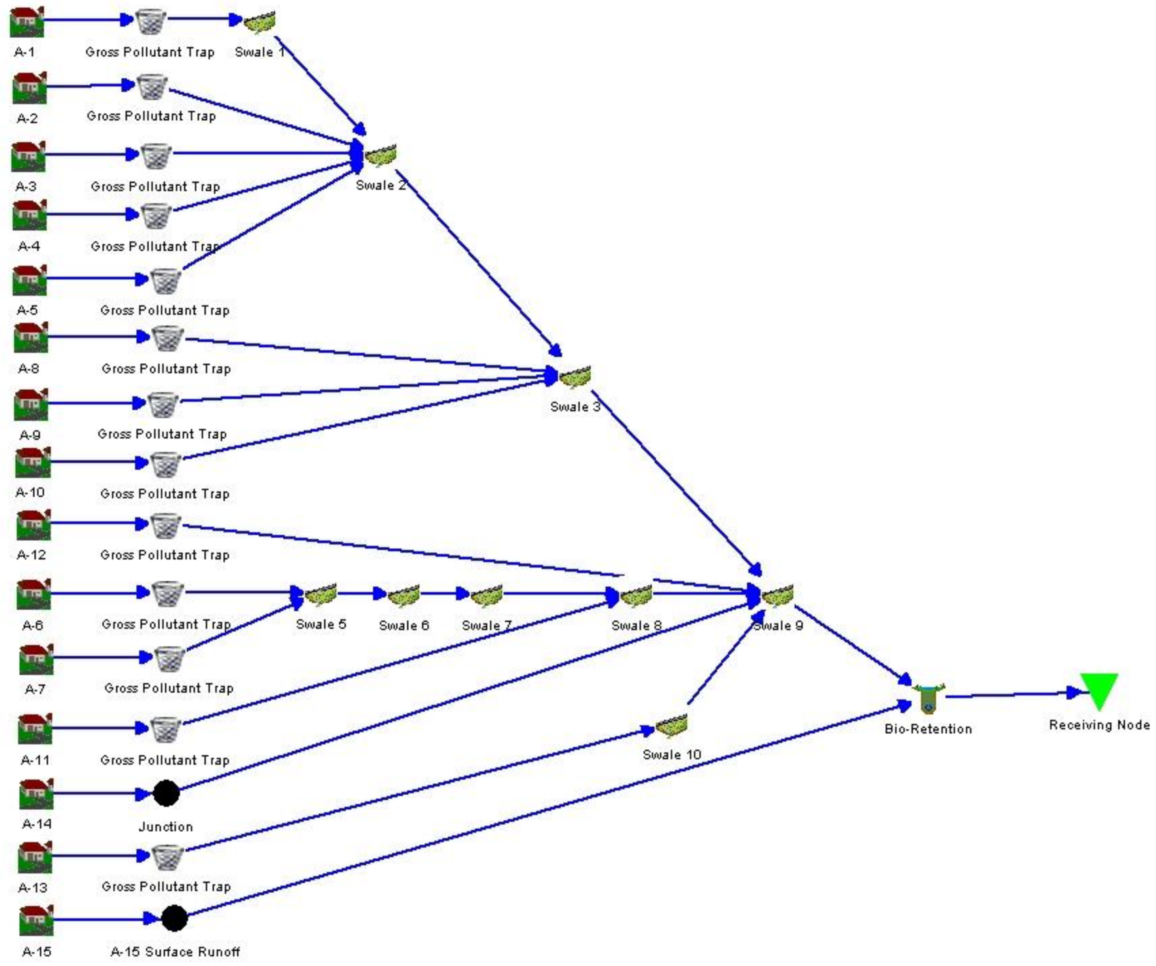
Condition	Q_1 Flow m^3/s	Q_2 Flow m^3/s	Q_5 Flow m^3/s	Q_{10} Flow m^3/s	Q_{20} Flow m^3/s	Q_{50} Flow m^3/s	Q_{100} Flow m^3/s
Pre	2.16	2.91	3.91	4.52	5.37	7.13	7.88
Post	3.81	5.11	6.86	7.96	9.47	12.53	13.90

Appendix 2: Stormwater Management

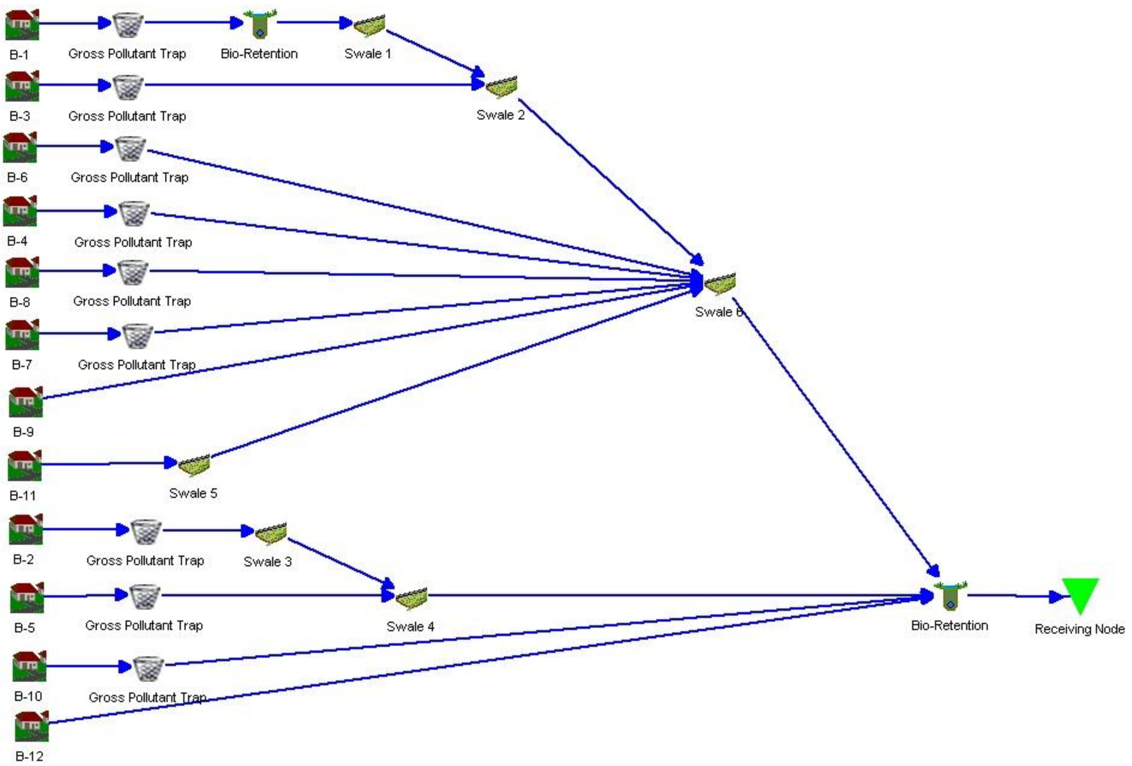
Representative sub-catchment set up for MUSIC Modelling.



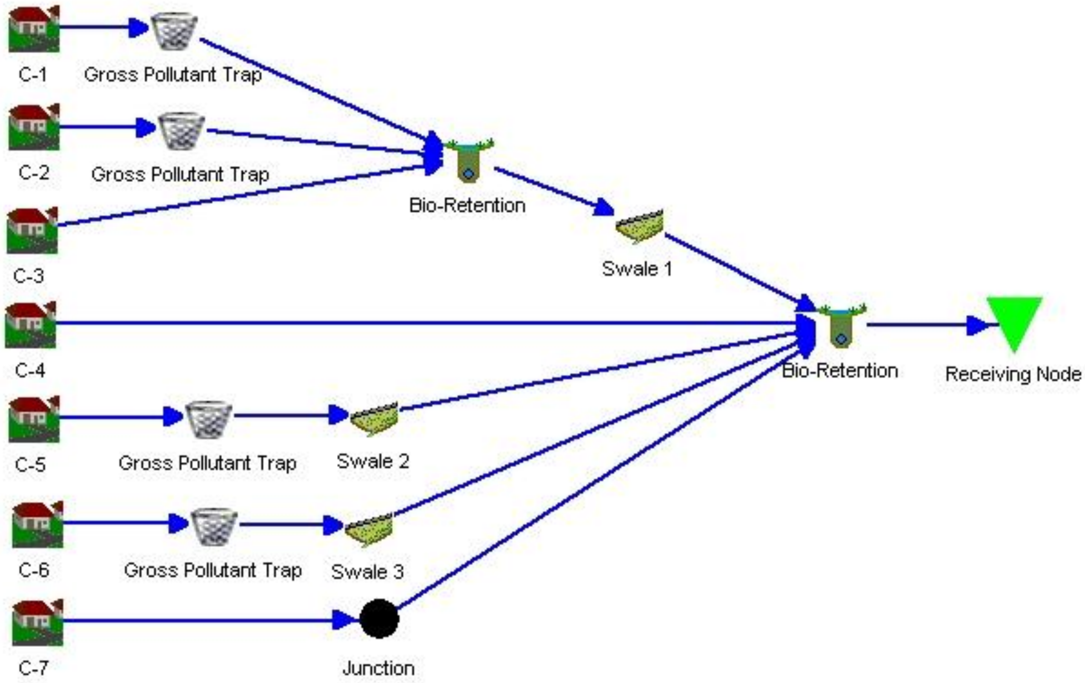
Catchment A Post development with WUSD



Catchment B Post-development with WSUD



Catchment C Post-development with WUSD



Rainwater Harvesting Design Calculations

The maximum volumes of water that can be collected from a roof and annual rainfall are calculated using the formula (Stormwater Management Manual, 2007):

*Runoff (litres) = A * (rainfall – B) * roof area*

Where:

A (fraction) = is the efficiency of collection. Values typically used are 0.8 to 0.85 (80 to 85%).

B (mm/year) = is the loss associated with absorption and wetting surfaces. A value of 24mm per year is typically used

Rainfall (mm)

Roof area (m2)

Table A 2-1 shows the maximum volume of water collected on site based on various roof areas and the average annual rainfall for Darwin (Darwin airport 14015).

Table A 2-1: Maximum Volume of Water Collected for Muirhead Development based on the recorded average annual rainfall of 1710.7mm/yr

Roof Area (m^2)	**Maximum Volumes of Rainwater per year (kL)** **Based on average annual rainfall of 1715 mm/yr (002056)**
200	270
250	337
300	405
350	472
400	540
450	607
500	675

*These volumes were calculated using a value of 0.8 for A and 24mm for B

Appendix 3: Proposed layout of Attenuation basins, Swales and Bio-retention basins