Redland CITY COUNCIL

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.....Beyond Engineering

In association with .....

O2 environmental

CONICS

Sargent Consulting

NATIVE DOG CREEK AND TORQUAY CREEK - SOUTHERN REDLAND BAY CATCHMENT (PART 22)

INTEGRATED WATERWAYS PLANNING REPORT





6 May 2010

M8000_001

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Cover Photos: -

- Left – Native Dog Creek Central Creek Channel taken at the Mount Cotton Community Park
- Right – Torquay Creek Northern Creek Channel taken upstream of Cleveland-Redland Bay Road

PROJECT M8000_001 - NATIVE DOG CREEK AND TORQUAY CREEK - SOUTHERN REDLAND BAY CATCHMENT (PART 22)

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1. EXECUTIVE SUMMARY

Redlands City Council (RCC) is responsible for the management of waterways, surface water quality and stream health, stormwater runoff and infrastructure, pollution and flooding in the Redland City Council area. EnGenY Management and Resourcing (EnGenY) in association with Conics Pty Ltd, O2 Environmental Pty Ltd and Sargent Consulting Pty Ltd have been commissioned by RCC to prepare an Integrated Waterway Plan (IWP) for the Native Dog Creek and Torquay Creek - Southern Redland Bay Catchment 22. The study catchments comprise one major catchment and one sub-catchment within Redland City Council as illustrated in **Figure 1.0**.

The IWP project aims to merge the existing planning methods into a single integrated tool for waterway planning. The project would also include application of the new planning tool to both the Torquay and Native Dog Creek Catchments.

The key objectives of the study include the following elements of works:

- Develop an Integrated Planning and Management Approach for waterways and catchments;
- Produce an Integrated Waterway Plan (IWP) for both Torquay and Native Dog Creeks;
- Document the information requirements and methodology for producing an IWP; and
- Identify areas for improvement with regard to RCC's policies, plans, strategies, procedures, key performance indicators (KPIs), systems, databases and practices.

The preparation of the Integrated Waterway Plan for the catchments has included three (3) key technical elements of works comprising: -

- Waterway and Environmental Assessment (prepared by EnGenY in association with Conics Pty Ltd);
- Water Quality Assessment (prepared by EnGenY in association with O2 Environmental Pty Ltd); and
- Regional Flood Assessment (prepared by EnGenY in association with Sargent Consulting Pty Ltd).

1.1 Waterway and Environmental Assessment

The environmental and waterway assessments undertaken for this study have incorporated a range or approaches and techniques including:

- Desktop assessments comprising:
  - Literature review;
  - Analysis of geology, soils, landscape and Land use spatial information;
  - Assessment of existing water quality data.
- Reach classification of each waterway;

- Waterway health assessments including:
  - Ground-truthing of the spatial information;
  - Geomorphic assessment based on the Index of Stream Condition (ISC) system;
  - Ecological assessments;
  - Evaluating the ecological values of the waterways and risks to those values.
- Setting Water Quality Objectives (WQOs) (for protection of aquatic ecosystems) as benchmarks for Council planning strategies;
- Identification of recommended water quality monitoring requirements;
- Defining current condition and feasible target condition for each reach; and
- Determining management actions and indicative priorities to improve the health of study waterways and achieve the feasible target conditions.

Native Dog Creek and Torquay Creek have been impacted mainly by vegetation clearing, agriculture, urban development and major roads. Riparian and catchment vegetation has been cleared in parts of both catchments for agricultural and urban development. Both catchments contain areas of high habitat value, including remnant terrestrial vegetation, intertidal vegetation (Torquay Creek), freshwater wetlands, and forests, including Eucalypt forest and small areas of rainforest. However, extensive weeds exist throughout the riparian zones of both waterways.

Barriers to connectivity exist in both catchments, including roads and culverts (barriers to both aquatic and terrestrial fauna) and vegetation clearing (fragmenting terrestrial habitat). Rehabilitation works will enhance both the longitudinal connectivity (along the waterways) and latitudinal connectivity to surrounding bushland areas, particularly to the large bushland area west of the Torquay Creek catchment.

Desirable rehabilitation actions include riparian revegetation and weed control, erosion control, and education programs to catchment residents (particularly those adjacent to the riparian buffers) on weed management, fertiliser use and stormwater runoff, and to agricultural land owners on best practices. Retention and rehabilitation of the proposed buffers is essential to protecting and enhancing the ecological health of the waterways. Some clearing and development has already taken place within these buffers.

1.1.1 Water Quality – Native Dog Creek

Water quality data are limited, but preliminary conclusions are that Native Dog Creek contains very high nutrient and sediment concentrations. The highest concentrations were recorded during a period of high rainfall. Due to the particularly high concentrations of nutrients and poor correlation between nutrients and turbidity / suspended solids, it appears that the water quality degradation is primarily caused by a point source of pollution, which may be related to the poultry farm in the upper reaches of this catchment.

While the available datasets are limited, fish and macro invertebrate monitoring also indicate Native Dog Creek is degraded, with relatively low diversity and no sensitive taxa observed.

In light of the available datasets and limited water quality data, further sampling is likely to be required to more accurately draw conclusions from the data sets as well as better quantifying and assessing the origin of the high nutrient concentrations.

1.1.2 Water Quality – Torquay Creek

Water quality data in Torquay Creek is also limited, but indicates the waterway is close to achieving the WQOs (although dissolved oxygen concentrations were very low). It does contain elevated total nitrogen concentrations, although much lower than Native Dog Creek.

A monitoring program has been recommended to address the limitations of the water quality dataset.

The scope of this Waterway Health Assessment report does not include actions to improve pollutant sources, but some of the proposed actions will impact water quality, such as erosion control. Riparian rehabilitation works are likely to lead to improved overall waterway health, by stabilising the banks, improving vegetation condition and habitat resources, and improving habitat connectivity.

1.2 Water Quality Assessment

The water quality analysis works undertaken for this study has incorporated approaches and techniques not traditionally used previously including:

- The inclusion of water tanks as part of the MUSIC model to result in a cost saving;
- Focusing the water quality analysis on protection of local waterways as well as Moreton Bay. This was completed by using treatments at a more local scale and not within waterways. Waterways have an inherent environmental value and should also be protected in preference to be used as a treatment device; and
- Integrated broader catchment management actions and Water Sensitive Urban Design (WSUD) into one modelling package to demonstrate achievable water quality objectives using WaterCAST.

MUSIC modelling indicates that total load pollutant reduction targets can be achieved for urban areas in both the Torquay Creek and Native Dog Creek catchments in the ultimate development scenario. Targets have been achieved by utilizing rainwater tanks on houses, swales on rural roads and bio-retention devices sized to 1.5% of the contributing catchment with coarse sediment forebays.

The application of filtering modules within WaterCAST provides justification to allow for the investment in ‘green infrastructure’ in a treatment train approach with WSUD to achieve end of catchment water quality targets. Riparian zones are a cost effective means of achieving

load reductions compared to more engineered solutions such as WSUD and have many other additional ecosystem service benefits.

The case study presented indicates that an integrated mitigation approach incorporating both riparian rehabilitation and WSUD can achieve water quality objectives at the end of the catchment. This integrated approach achieves better Triple Bottom Line outcomes i.e. financial, social and ecological than WSUD implementation alone.

The *Environmental Protection (Water) Policy 1997* requires councils with urban stormwater systems "*develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system*" Reliance on water any water treatment that may occur in natural wetlands or ponds to in-stream 'treatment' that may occur through the action of natural wetlands or in-stream devices does not serve to protect these waters and therefore does not comply with the section of the EPP provided above. The stormwater quality management plan proposed in this report relies only on treatment by off-line devices, and requires that load reduction targets are met prior to discharge to waterways. This results in load reduction targets being achieved not only at discharge to Moreton Bay, but at every discharge point to all waterways within the catchment.

Bioretention devices should be dispersed throughout each sub-catchment as close as possible to each source, ideally at each field or gully inlet. In situations where installation at field or gully pits is not possible due to site constraints (i.e. existing infrastructure, hydraulic gradient, underground services), bioretention devices may be located at discharge points including the potential locations as have been identified within this study. Locating and sizing of each bioretention devices throughout sub-catchments will be required at the detail design stage.

Achieving load based reductions may not result in concentration based water quality objectives being achieved at the discharge point to each waterway. Load based targets represent achievable best practice for stormwater management infrastructure in South East Queensland (SEQ) climate and pollutant export conditions operating near the limit of its economic performance. Substantial extra cost is required to achieve low concentration based targets at a very small additional water quality benefit. This outcome is not inconsistent with current research and implementation guidelines (South East Queensland Regional Plan 2005-2026 - Implementation Guideline No. 7 by Department of Infrastructure and Planning, 2008).

1.3 Regional Flood Assessment

Regional flooding works undertaken for this study are based on a rainfall-runoff XP-RAFTS hydrological model in combination with a 2 dimensional (2D) XP-Storm model. Both models are commercially available software packages.

Hydrological modelling of the catchment has culminated in the quantification of design flood estimates for a range of design storm events for the 1 in 10, 20, 50 and 100 year Average Recurrence Interval (ARI) storm events under a range of critical storm durations. The

catchment hydrology undertaken for both Native Dog and Torquay Creek catchments has quantified the various catchment inflow hydrographs which have been incorporated directly into the hydraulic model.

The regional hydraulic modelling performed using a 2 dimensional TUFLOW model has been successful in quantifying flooding throughout the various catchment areas. The flood assessment works have facilitated in the assessment of flood levels, flood depths and flood extents within the various waterway systems throughout Native Dog Creek and Torquay Creek catchments. The flood modelling works have been successful in identifying the following flooding issues in the catchments:

- Overland sheet flows were found to affect a discrete number of property allotments with depths of flow generally less than 200mm. In the absence of floor level survey data and based on the limited sheet flow depths, no flood inundation of existing properties to above floor level was found to occur in the 100 year ARI event for both Native Dog and Torquay Creek catchments. As such, no flood mitigation measures to alleviate and mitigate property flooding were required;
- The flood immunity for a number of road crossings were found to be deficient and upgrades to improve the level of road immunity to meet the normal design criteria were investigated and have been listed in the relevant sections of this report. The principle adopted for road immunity upgrade works was to provide the required flood conveyance capacity by increasing the waterway area only wherever this was possible and only to incorporate raising of the road pavement level in situations in which waterway area increases were ineffective or only partially effective;
- The hydraulic modelling confirmed that the proposed waterway management measures comprising the establishment of waterway buffers and the associated global increase in channel roughness parameters that would result do not adversely impact on flood levels at key locations throughout either catchment area. The proposed establishment of waterway buffers recommended as part of the waterway management measures in addition to the similar recommendations provided as part of the water quality assessment works are therefore appropriate within the context of being supported by the regional flood assessment works. Reference is made to the respective sections of this report for further details.

No allowance for potential climate change impacts (either in the form of sea level rise, or increased rainfall intensity) has been made in the work presented in this report. The flood models prepared as part of this study can be readily applied for any future climate change assessments as may be required. It is recommended that these works be undertaken in due course and following formal advice and recommendations from either the Federal or State Governments by way of a policy stance in this regard. To pre-empt these outcomes, it is also possible that Council look to undertake the assessment of a range of climate change scenarios in order to proactively quantify any potential flood related impacts throughout the catchments for future Local Government policy direction and code revisions.

1.4 Recommendations Summary

In light of the above outcomes and subsequent findings made from this study, the following recommendations are made:

1.4.1 Waterway and Environmental Assessment

- Dedicate, maintain and / or rehabilitate the proposed waterway buffer widths as natural areas to achieve the target conditions;
- Use planning mechanisms to allow dedication of land within the proposed buffer widths and to allow for conservation works to be undertaken within areas that may not be dedicated;
- Adopt the additional water quality monitoring items identified in the proposed Water Quality Monitoring Program;
- Retain gullies upstream of the waterways (i.e. confined upper drainage lines) as naturalised channels;
- Undertake the actions as outlined in the Management Action Plan as detailed; and
- Review Planning Scheme to incorporate proposed changes.

1.4.2 Water Quality Assessment

- The previous recommendations from WBM (2008) regarding improving catchment modelling and reducing uncertainty are equally valid for this study;
- That WaterCAST model should be used as a first run conceptual design tool for IWMP and initial costing, allowing for the inclusion of green infrastructure in infrastructure charges;
- The MUSIC model be adapted at the detailed planning stage and undertaken at a finer streetscape scale allowing for the protection of waterways and the bay; and
- Any future MUSIC modelling to include the modelling of rain water tanks and roads.

1.4.3 Regional Flood Assessment

- A property floor level survey be undertaken to quantify the existing floor levels for selected residential properties in Native Dog and Torquay Creek catchments. Further, the floor level surveys be used in conjunction with the flood levels defined in this study to quantify if properties are subject to flooding to above floor level flooding.
- The following road and drainage infrastructure items be upgraded to comply with current design standards: -

Native Dog Creek

- Heinemann Road – Rising of roadway to eliminate sag.

- Although under the jurisdiction and ownership of the Department of Main Roads (DMR), Mount Cotton Road was found to be deficient in various locations and required upgrading as follows:
  - Increase in waterway area at 5 culvert crossings (nos. 13, 15, 17, 18 and 19);
  - Raising of road level to eliminate sags at 2 culvert crossings (nos. 13 and 19);
  - Construction of table drains of up to 1m deep adjacent to 4 culvert crossings (between culverts nos. 14 and15, 17, 18, and 19).

Torquay Creek

- Serpentine Creek Road to be upgraded as follows:
  - Increase in waterway area at culvert crossings (no. 11);
  - Raising of roadway to eliminate sag; and
  - Construction of open channel drain to the west of Serpentine Creek Road to eliminate over road flow in the relatively steep are north of the crossing.
- Oakland Avenue to be upgraded as follows:
  - Rising of roadway to eliminate sag.
  - It is also recommended from the regional flood assessment works that additional model runs be undertaken in order to quantify the impact of currently perceived levels of sea level rise and increases in rainfall intensity due to climate change. These assessments will assist in quantifying the various climate change impacts in the respective catchments and therefore provide Council with base information under which policy revisions and code amendments can be formulated as may be required.

2. INTRODUCTION AND BACKGROUND

Redlands City Council (RCC) is responsible for the management of waterways, surface water quality and stream health, stormwater runoff and infrastructure, pollution and flooding in the Redland City Council area. EnGenY Management and Resourcing (EnGenY) in association with Conics Pty Ltd, O2 Environmental Pty Ltd and Sargent Consulting Pty Ltd have been commissioned by RCC to prepare an Integrated Waterway Plan (IWP) for the Native Dog Creek and Torquay Creek - Southern Redland Bay Catchment 22. These catchments comprise two (2) of the 16 major catchments within the Redlands City Council area. The study area is illustrated in **Figure 1.0**.

The IWP project aims to merge the existing planning methods into a single integrated tool for waterway planning. The project would also include application of the new planning tool to both the Torquay and Native Dog Creek Catchments.

The key objectives of the study include the following elements of works:

- Develop an Integrated Planning and Management Approach for waterways and catchments;
- Produce an Integrated Waterway Plan (IWP) for both Torquay and Native Dog Creeks;
- Document the information requirements and methodology for producing an IWP; and
- Identify areas for improvement with regard to RCC's policies, plans, strategies, procedures, key performance indicators (KPIs), systems, databases and practices.

The above study objectives have been addressed through the review and assessment of the overall strategic approach to waterways and catchment management generally as well as the completion of various technical investigations. Each of these aspects are discussed and presented in detail as part of this study report.

This Draft (Final) Study Report presents and documents the Integrated Waterway Management Plan for Native Dog Creek and Torquay Creek – Southern Redland Bay Catchment (Part 22). The report includes both the technical detail associated with the various elements of works undertaken as well as presenting a revised approach for Integrated Planning and Management for catchments and waterways.

3. CATCHMENT DESCRIPTIONS

The study area for this investigation includes two (2) discrete catchments within the Redlands City Council Local Government Area (LGA) that comprise:

- The Native Dog Creek catchment; and
- The Torquay Creek Catchment (Southern Redland Bay (Part 22).

These catchments comprise two (2) of the 16 major catchments within the Redlands City Council area. The location of the catchments within the context of the South East Queensland region is illustrated in **Figure 1.0**. Individual catchment plans illustrating the respective catchment study areas and overall characteristics are presented in **Figure 2.0** and **Figure 3.0** respectively for Native Dog Creek and Torquay Creek – Southern Redland Bay Catchment Part 22.

The following provides a brief description of the two catchment areas.

3.1 Native Dog Creek Catchment

This catchment includes a large portion of the Mount Cotton suburb with the Native Dog Creek branch following the eastern side of the catchment. The catchment is traversed by Mount Cotton Road in the west as well as both Heinemann and German Church Roads in the east. The catchment includes the Mount Cotton Village and Community Park on the northern side. The main channel branch originates in three (3) separate tributaries within the catchment before flowing in a southerly direction to converge to form the larger main creek branch. The catchment discharge is in a southerly direction to ultimately discharge to the Logan River within the Logan City Council Local Government Area. The discharge point for this study resides at the Local Government Administration Boundary between Redland City Council and Logan City Council and is not subject to tidal influences at this point. The total catchment area subject to this study is approximately 957.35 Hectares. The catchment is typified by runoff slopes which range from steep (approx. 25% in the upper reaches) to a flatter slope of only 0.1% in the lower tributary reaches.

3.2 Torquay Creek Catchment

The Torquay Creek catchment includes a portion of the Redland Bay suburb. The catchment extends from the upper reaches to the west of Cleveland Redland Bay Road through to Moreton Bay downstream of Serpentine Road. There are three (3) discrete tributaries in the upstream reaches which combine immediately upstream of Serpentine Road to form the single Torquay Creek waterway which flows in an eastern direction before discharging to Moreton Bay near Point Talburpin. The waterway is subject to tidal influences in the lower reaches. The total catchment area is approximately 261.17 Hectares. The runoff slope for this catchment ranges from approximately 6.8% in the upper reaches of the catchment to a flat 0.1% slope in the lower reaches at the catchment outlet.

Figure 1.0 Study Location

Figure 2.0 Native Dog Creek Catchment

Figure 3.0 Torquay Creek Catchment

4. WATERWAY AND ENVIRONMENTAL ASSESSMENT

4.1 Introduction

Redlands City Council (RCC) is responsible for the management of waterways, surface water quality and stream health, stormwater runoff and infrastructure, pollution and flooding in the Redland City Council area. Previously, RCC has relied on two (2) separate planning approaches to waterways and stormwater. The separate planning approaches were: -

- Catchment trunk stormwater infrastructure studies; and
- Waterway management plans (WMP's).

Catchment trunk stormwater infrastructure studies were used to identify new infrastructure for funding under a Priority Infrastructure Charge Policy and Schedule for stormwater. The WMP's were based on technical studies and mainly focussed on specific aspects of stormwater, water quality and ecosystem health of waterways, rather than being integrated with catchment management.

EnGenY Management and Resourcing (EnGenY), Sargent Consulting and Conics Pty Ltd have been commissioned by RCC to prepare an Integrated Waterway Plan (IWP) for Native Dog Creek and Torquay Creek. Specifically, Conics Pty Ltd has been engaged to undertake a waterways assessment and identify management actions to be implemented into the IWP.

The IWP aims to merge the existing planning methods into a single integrated tool for waterway planning. The project would also include application of the new planning tool to both Torquay and Native Dog Creek Catchments. The key objectives of the study are to:

1. Develop an Integrated Planning and Management Approach for waterways and catchments;
2. Produce an Integrated Waterway Plan (IWP) for both Torquay and Native Dog Creeks;
3. Document the information requirements and methodology for producing an IWP; and
4. Identify areas for improvement with regard to RCC's policies, plans, strategies, procedures, key performance indicators (KPIs), systems, databases and practices.

This Waterway Assessment Report is one component of the overall study and will inform the IWP of requirements relating to waterway health management. The study area includes the catchments, sub-catchments and drainage catchments of Torquay Creek – Southern Redland Bay Catchment (Part 22) (herein known as Torquay Creek) and Native Dog Creek shown in **Appendix A.**

The purpose of the waterways assessment is to be a component of the overall IWP. The scope of the work addresses: -

- Waterway health and values;
- Ambient water quality;

- Water quality objectives; and
- Waterway rehabilitation and protection.

4.2 Method

4.2.1 Overview

An assessment of both Native Dog Creek and Torquay Creek was undertaken as follows:

1. Desktop assessment:
    - Literature review;
    - Analysis of geology, soils, landscape and Land use spatial information; and
    - Assessment of existing water quality data.
2. Reach classification of each waterway;
3. Waterway health assessment:
    - Ground-truthing of the spatial information;
    - Geomorphic assessment based on the Index of Stream Condition (ISC) system (see **Appendix B** for field sheets):
        - Assessment of the fluvial form; and
        - Assessment of behaviour and characteristics of the waterways.
    - Ecological assessment:
        - Riparian vegetation;
        - Fauna habitat;
        - Ecological significance;
        - Barriers to fauna movement; and
        - Threatening processes such as erosion.
    - Evaluating the ecological values of the waterways and risks to those values.
4. Setting Water Quality Objectives (WQOs) (for protection of aquatic ecosystems) as benchmarks for Council planning strategies;
5. Identification of recommended water quality monitoring requirements;
6. Defining current condition and feasible target condition for each reach; and
7. Determining management actions and indicative priorities to improve the health of study waterways and achieve the feasible target conditions.

4.2.2 Literature Review

A review of relevant reports that contain information on waterway health of Native Dog Creek and Torquay Creek was carried out. This included:

- An overview of existing legislation, policies and regulatory instruments relevant to waterway management and assessment (refer **Appendix K**);
- Ecological Assessment of the Non-Tidal Waterways of Redland Shire. Autumn 2007 (NRW, 2007);
- Redland Waterway Assessment and Priority Plan – Second Edition (Natural Solutions Environmental Consultants, 2007);
- Soils and Water Quality in Mainland Redlands City – Final Report (LARM, 2008); and
- State of the Environment Report (RSC, 2008).

4.2.3 Reach Classification

Reach classification is a commonly used technique in waterway management studies to define reaches which can be considered homogeneous for management purposes.

Geomorphology is used in many studies as a basis for a reach breakdown because reaches which are characterised by the same geology, slope, flow rate etc. may generally be expected to change in a similar way following management intervention. For this study, reach classification was based on the Riverstyles™ method. The benefit of this technique is that it considers processes as well as physical description.

Natural Drainage Lines were not defined as part of the stream network for this assessment, although general assessments were undertaken of their physical condition (stability and modification). In identifying stream reaches reference was given to the methodology and reach classifications outlined in the report *Redland Waterway Assessment and Priority Plan* by Natural Solutions Environmental Consultants (now Conics) dated November 2007. This classification was based on:

- Tidal and non-tidal reaches;
- Council waterway mapping;
- Channel armouring (rock or concrete lined);
- Dominant sediment deposition type (coarse or fine);
- Tributaries; and
- Major infrastructure such as roads, bridges and culverts.

4.2.4 Field Assessment

Introduction

A site assessment was undertaken on 29 May 2009 to assess the geomorphology and ecology of the two catchments. Five sites on Native Dog Creek, and three sites on Torquay Creek, were selected (refer to **Figure 1.0** and **Figure 2.0** in **Appendix C**). Representative sites were chosen within each reach based on aerial photography, vegetation mapping and accessibility.

Geomorphology and Aquatic Habitat

The method combined key elements of a number of condition assessment techniques:

- RiverStyles™;
- Physical characteristics (bed material, bed and bank stability – ISC indices);
- Artificial barriers (ISC/State of the Rivers (SOR) indices);
- Processes and key drivers of condition (hydrology, sediment transport);
- Habitat and ecological condition (hydraulic units, floodplain links, habitat condition (ISC), longitudinal connectivity (ISC), cover of exotic vegetation (ISC); aquatic ecology); and
- Summaries of processes, threats and values.

The field assessment was based on an integrated approach, which primarily combined a River Styles™ type geomorphic classification with structural sub-indices of the Index of Stream Condition (ISC) (Ladson and White 1999). A field proforma (refer to **Appendix B** for proformas and results) was used to:

- Combine the key elements of a number of condition assessment techniques;
- Provide outputs consistent with previous and regional studies (e.g. RiverStylesTM);
- Provide an overall condition assessment score (ISC);
- Ensure that an interpretation of processes, as well as features, was recorded; and
- Ensure that the information could be used for the values (i.e. values of the catchment and the risks to these values).

In addition, the assessment recorded GPS waypoint coordinates and field tracks to assist with map preparation, and site reference photographs were assembled as baseline information.

Riparian Vegetation and Habitat

The riparian vegetation assessment consisted of a quaternary survey to identify the extent, condition, floristic structure and composition of vegetation communities.

This involved:

- Verification of the mapping and classification of Regional Ecosystems (REs);
- Targeted searches for significant species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), Nature Conservation Act 1994 (NCA) and local council schedules; and
- Identification of declared pest species listed under the Land Protection (Pest and Stock Route Management) Act 2002 (LPA) and local council schedules.

During the site visit, a list of incidental observations of fauna species observed was recorded. A brief targeted search was undertaken for significant fauna species identified in the database search. The following traces were briefly searched for during the site visit to establish the presence of species that may occur on the site:

- Scats, tracks and other traces;
- Fruit and seed falls;
- Ground diggings; and
- Nests in banks and trees.

The habitat assessment included identification of key habitat features for native flora and fauna, such as:

- Habitat (hollow-bearing) trees;
- Important food tree species;
- Fallen / felled timber, including hollow-bearing logs;
- Wetlands and aquatic features;
- Arboreal and terrestrial termite mounds;
- Coarse leaf litter;
- Shrubs and other dense ground layer and under-storey vegetation; and
- Roost trees.

4.3 Water Quality Objectives

Available water quality data was compared to relevant water quality guidelines to derive proposed local water quality objectives (WQOs) (refer to **Section 4.9**).

4.4 Feasible Target Condition, Management Actions and Priorities

Rehabilitation management actions were outlined (**Section 4.11**) in order to meet the feasible target conditions. Indicative priorities were assigned to these actions with consideration of the environmental values of the catchments, risks to these values and the degree to which the waterways could be improved (i.e. feasible target condition). Refer to

Section 4.8 and **Section 4.12** for more detail regarding feasible target condition, management actions and priorities.

4.5 Catchment Descriptions

4.5.1 Native Dog Creek

Waterways

Native Dog Creek is a fresh water stream that flows into the Carbrook wetlands and the Logan River and is mostly located within the Logan Shire. It is 3215 hectares in area with 1130 hectares in the Redland City and 2085 hectares in Logan Shire (LRAM, 2008). The drainage density (the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin) is 190 ha / km.

The section of Native Dog Creek located within the Redlands City consists of both Natural Drainage Lines (stream order 1) and Minor Waterways (stream order 2), as shown in Councils Waterways, Wetlands and Moreton Bay Overlay map shown in **Appendix D**, and defined in **Table 4.1.**

Table 4.1 Waterway types in Native Dog Creek (As mapped in RCC Waterways, Wetlands and Moreton Bay Overlay Map)

Waterway	Definition
Natural Drainage Lines (Stream order 1)	Ephemeral (intermittent), confined, stable and with little evidence of instability or gullying. Their main geomorphic function is to transport water and sediments. These are generally in steeper vegetated western and northern areas of the catchment, with some small agricultural land uses occurring in the western areas, where riparian vegetation has been cleared. These are generally not defined as a “watercourse” as defined in the *Water Act 2000*.
Minor Waterways (Stream order 2)	Permanent, mid basin streams with varying degrees of impacts from human activities. They generally have a defined channel and are in partly confined valleys with a meandering form. These waterways are generally defined as a “watercourse” in the *Water Act 2000*.

Geology

Redland City is situated on low coastal hills which rise from the coastal plain of Moreton Bay as well as undulating to hilly valley slopes flanking creek and river flood-plains. The topography is characterised by prominent hill and associated hill-slopes and drainage lines. Overall the landform can be described as gentle to moderately steep low hill-slopes of meta-sedimentary geology.

The predominant geological unit throughout the Redland City is the Neranleigh-Fernvale metasediments, which are deformed, lightly to heavily folded rocks derived from ancient marine sediments. The underlying rock of the area is hard unweathered or decomposed rock (Whitlow, 2000 in Natural Solutions, 2007).

Native Dog Creek supports underlying sedimentary rock with alluvial deposits along the main channel of the waterway.

Soils

The dominant red / yellow podzolics soils formed on sedimentary rock make up approximately 70% of the landscape of Redland City (Conics, 2007). These soils are duplex soils, having a distinct loamy surface-soil (A horizon) and clayey sub-soil (B horizon), they generally have very low agricultural potential with high acidity (pH < 5.5) and low chemical fertility and commonly have low water-holding capacity and are often sodic.

High sodicity causes clay to swell excessively when wet. The clay particles move so far apart that they separate (disperse). This weakens the aggregates in the soil, causing structural collapse and closing-off of soil pores. For this reason water and air movement through sodic soils is severely restricted. Waterlogging is common in sodic soils, since swelling and dispersion closes off pores, reducing the internal drainage of the soil. Sodicity of the surface soil is likely to cause dispersion of surface aggregates, resulting in surface crusts. Run-off from sodic soils carries clay particles into waterways and reservoirs causing water turbidity, or cloudiness. In addition, run-off from sodic soils is more likely to carry higher levels of nitrogen and phosphate into waterways and reservoirs.

Due to the sodic nature of the soils and clayey sub-soils there is a high risk of pollution to local waterways from disturbed land runoff. Sodic sediments stay in suspension longer than most other sediments increasing the length of time pools and other aquatic refuges stay turbid.

Native Dog Creek is made up of podzolic soils with approximately 70% yellow podzolics on sedimentary and metamorphic rock, with the remaining being red podzolic soils in the western part of its catchment.

Vegetation

Vegetation mapping by Redland City Council (refer to **Appendix E**) indicates that Native Dog Creek contains remnant vegetation consisting of '*Eucalyptus pilularis* on metasediments' covering a large portion of the catchment; 'freshwater Riparian mix' along two small sections of Native Dog Creek; and a community along the western boundary of the catchment consisting of *Corymbia hynryi*, *C. citriodora*, *Angophora leiocarpa*, *Eucalyptus fibrosa*, *E. siderophloia*, *E. tindaliae*, *E. acmenoides* and *E. carnea*.

Regional Ecosystem mapping (EPA, Version 5.0) (**Appendix F**) identifies remnant vegetation in Native Dog Creek catchment as outlined in **Table 4.2**.

Table 4.2 Regional Ecosystems in Native Dog Creek Catchment

Regional Ecosystem	Description	VMA Status
12.11.23	Tall open forest of *Eucalyptus pilularis* open forest on metamorphics and interbedded volcanics	Endangered
12.11.5	Open forest complex with *Corymbia citriodora*, *Eucalyptus siderophloia*, *E. major* on metamorphics ± interbedded volcanics	Not of Concern
12.3.5	*Melaleuca quinquenervia* open forest on coastal alluvium	Not of Concern
12.3.6	Melaleuca quinquenervia, Eucalyptus tereticornis, Lophostemon suaveolens woodland on coastal alluvial plains	Not of Concern

4.5.2 Torquay Creek

Waterways

Torquay Creek flows into Moreton Bay and is part of the larger Southern Redland Bay catchment, which includes a number of waterways. The Southern Redland Bay catchment is 1410 hectares in area and has multiple streams. The Torquay Creek catchment is approximately 226 hectares excluding the localised catchments to the north which discharge directly to the ocean. Its network consists of Natural Drainage Lines (stream order 1), Minor Waterways (stream order 2) and a Major Waterway at the mouth of the creek (stream order 3) as shown in Councils Waterways, Wetlands and Moreton Bay Overlay map shown in **Appendix D**, and defined in **Table 4.3.**

Table 4.3 Waterway types in Torquay Creek (As mapped in RCC Waterways, Wetlands and Moreton Bay Overlay Map)

Waterway	Definition
Natural Drainage Lines (Stream order 1)	Ephemeral (intermittent), confined, stable and with little evidence of instability or gullying. Their main geomorphic function is to transport water and sediments. These are generally in steeper vegetated western and northern areas of the catchment, with some small agricultural land uses occurring in the western areas, where riparian vegetation has been cleared. These are generally not defined as a "watercourse" as defined in the *Water Act 2000*.
Minor Waterways (Stream order 2)	Permanent, mid basin streams with varying degrees of impacts from human activities. They generally have a defined channel and are in partly confined valleys with a meandering form. In sections, the channel is not clear on flatter topography. In these sections also, the waterway spreads out to form broad wetland features or chains of linked ponds. Typically, minor waterways are generally defined as a "watercourse" in the *Water Act 2000*.
Major Waterways (Stream order 3)	For Torquay Creek this is a permanent stream with tidal influence with a defined channel. It is defined as a "watercourse" in the *Water Act 2000*.

Geology

Refer to **Section 4.5.1** for information on the geology of the surrounding area. Torquay Creek has underlying sedimentary rock throughout most of the catchment with sand along the coast.

Soils

Refer to **Section 4.5.1** for information on the soils of the surrounding area. Torquay Creek soils are yellow podzolics on sedimentary and metamorphic rock with a small section at the mouth of the Creek being soils from transported material.

Vegetation

Large parts of the Torquay Creek catchment have been cleared for rural and urban development and associated land uses. However, vegetation mapping by Redland City Council (**Appendix E**) indicates that this catchment contains remnant vegetation including *Eucalyptus racemosa* on metasediments in the western areas of the catchment, 'Freshwater Riparian mix' along Torquay Creek, 'Mangal areas' (mangroves) along the coastline, and saltmarsh and mudflats along the coastline in the southern extent of the catchment.

According to EPA Regional Ecosystem mapping (Version 5.0) (**Appendix F**), the western extent of the catchment includes a heterogenous polygon of RE 12.11.5 (Not of Concern) and RE 12.11.23 (Endangered) (refer to **Table 4.4**).

Table 4.4 Regional Ecosystems in Torquay Creek Catchment

Regional Ecosystem	Description	VMA status
12.11.23	Tall open forest of *Eucalyptus pilularis* open forest on metamorphics and interbedded volcanics	Endangered
12.11.5	Open forest complex with *Corymbia citriodora*, *Eucalyptus siderophloia*, *E. Major* on metamorphics ± interbedded volcanics	Not of Concern

4.6 Reach Classification

Both Native Dog Creek and Torquay Creek were divided into four (4) reaches to assist with management planning. As noted in **Section 4.5.1** and **4.5.2**, Natural Drainage Lines were not defined as part of the stream network for this assessment.

The reaches of the two waterways are described in **Table 4.5**. These have been mapped in **Appendix G**.

Table 4.5 also identifies the waterway types as mapped in the RCC Overlay Map "Waterways, Wetlands and Moreton Bay" (defined in **Section 4.5.1** and **Section 4.5.2**).

Table 4.5 Reach Classification

Reach	Description	RCC Water Types
Native Dog Creek		
ND1	Transitional mid-slope reaches downstream from upper confined drainage lines, with primarily agricultural uses adjoining the creek	Minor Waterway Natural Drainage Line
ND2	Alluvial meandering fine grained reach, where the valley opens out and the stream slope reduces, primarily where rural residential land uses are adjoining the creek	Minor Waterway
ND3	Alluvial meandering fine grained reach, where valley opens out and stream reduces slops, primarily uses are residential with increasing development pressures along this section of creek	Major Waterway
ND4	Alluvial meandering fine grained reach, where valley opens out and the stream slope reduces. Primarily residential uses adjoining the creek	Minor Waterway
Torquay Creek		
TOR1	Alluvial meandering fine grained reach, primarily agricultural uses adjoining the creek	Minor Waterway

Reach	Description	RCC Water Types
TOR2	Alluvial meandering fine grained reach, where valley opens out and stream reduces slops, primarily uses are residential	Major Waterway
TOR3	Alluvial meandering fine grained reach, primarily agricultural uses adjoining the creek, with increasing development pressures along this section of creek	Minor Waterway
TOR4	Tidal reach	Major Waterway

4.7 Waterway Health Assessment

This section summarises the analysis undertaken of existing data found in previous studies of the area, Council and State Government monitoring programs and information gathered during field assessments.

4.7.1 Native Dog Creek

Fish

No sampling of fish communities were undertaken as part of this assessment. An ecological assessment of the non-tidal waterways of Redland City was previously undertaken by Natural Resources and Water (NRW) in 2007 (NRW, 2007). This former assessment included one (1) site located on Native Dog Creek with data collected on fish communities using standard Freshwater EHMP operating procedures and methods. Reference is made to the NRW report for further details (NRW, 2007). A summary of the results from the NRW 2007 report are detailed in **Table 4.6**.

Table 4.6 Fish Species Collected in Native Dog Creek

SPECIES	COMMON NAME	COUNT[1]	% INDIVIDUALS	EPP (WATER) WQO (%)[2]
NATIVE				
Anguilla Australis	Short-finned Eel	6	15%	
Anguilla Reinhardtii	Long-finned Eel	5	13%	
Hypseleotris Galii	Fire-tail Gudgeon	25	64%	
ALIEN				
Cyprinus Carpio	Common Carp	3	8%	< 5%
TOTAL		39		

Notes

1. Source: Appendix IV of "Ecological Assessment of the non-Tidal Waterways of Redland Shire" (NRW, 2007) (data for Site RSC-002)
2. Source: Table 3 – Aquatic ecosystem EV: Biological WQOs for estuarine and freshwater streams from (EPA, 2007)

Table 4.7 outlines the results of the fish monitoring in relation to the EHMP fish indices compared to the Environmental Protection Policy (Water) water quality objectives. Comparing the values found for Native Dog Creek in **Table 4.6** and **Table 4.7** against the WQO stated in EPP (Water), there is a higher percentage of alien fish species found in Native Dog Creek and lower ratings for the Percent of Native Species Expected (PONSE) and Observed to Expected species ratio (O/E), than expected.

In addition, all fish species observed are relatively tolerant of poor water quality (Pusey *et al.* 2004). Therefore, the fish communities recorded at Native Dog Creek – Site RSC-0002 in NRW (2007) indicate fish communities are generally in poor ecological condition. The above site is indicative of degraded water quality and likely competition from exotic species.

Table 4.7 Standardised Scores for the EHMP Fish Indicator and component Indices for Native Dog Creek site (RSC – 0002) compared to EPP (Water) Biological WQOs

SITE	WATERWAY	PONSE (Proportion of Native Species Expected)	0/E50 (Observed to Expected Species Ratio)	PROPORTION OF ALIEN FISH
RSC-0002	Native Dog Ck[1]	0.5	0.37	0.8
EPP (Water) WQO		0.8[2]	0.8-1.2	< 0.05[3]

Notes

1. Source of data: Table 21 of NRW (2007)
2. Source Table 3 from "Environmental Values and Water Quality Objectives of the Logan River Estuary Catchment" where 0.8 is 80% for Lowland freshwater stream that is SMD (slightly to moderately disturbed).
3. Where 0.05 is WQO of 5% alien individuals.

Macroinvertebrates

No sampling of aquatic macroinvetebrate communities were undertaken as part of this assessment. NRW (2007) carried out an assessment of ecological assessment of the non-tidal waterways of the Redland City area. This assessment included one site on Native Dog Creek (RSC-002) and collected data on macroinvertebrate communities, using methods as per standard Freshwater EHMP operating procedures as detailed in the report (2007, NRW).

A summary of the results from the above report are detailed in **Tables 4.8** and **4.9**.

Table 4.8 Macroinvertebrates collected at Site RSC – 00021 – Native Dog Creek

ORDER/TAXON GROUP	FAMILY/TAXON GROUP	COMMON NAME
	NATIVE	
Acarina	Acaridae	Tick
Decapoda	Atyidae	Freshwater Shrimps
Diptera	Ceratopogonidae	Biting Midge
Diptera	Chaoboridae	Blind mosquitoes
Odonata	Hemicordulliidae	Dragonflies
Coleoptera	Hydraphilidae	Beetle
Odonata	Isostictidae	Damselflies
Odonata	Libellulidae	Damselflies
Oligochaeta	Nematoda	Round worms
Oligochaeta	Oligochaeta	Earth Worms
Decapoda	Parastacidae	Crayfish
Diptera	s-f Chironominae	Non-biting midges
Diptera	s-f Tanypodinae	Non-biting midges

Notes

Source of data: Appendix IV of NRW (2007)

Table 4.9 Standardised scores for the Freshwater EHMP Aquatic Macroinvertebrate Indicator and component indices for Native Dog Creek and compared to EPP (Water) biological WQOs

SITE	WATERWAY	TAXA RICHNESS	PET RICHNESS	SIGNAL SCORE	INDICATOR	RANK
RSC-0002	Native Dog Ck[1]	0.59	0	0.66	0.42	11
EPP (water) WQO[2]			> 3	> 3.5		

Notes

1. Source of data Table 20 of NRW (2007)

2. Source Table 3 from "Environmental Values and Water Quality Objectives of the Logan River Estuary Catchment" where 0.8 is 80% for Lowland freshwater stream that is SMD (slightly to moderately disturbed).

Total Richness

The absolute richness across the RSC-0002 site was 13 families. These are all below the EPP (Water) objective of 17 families for lowland freshwater sites in the Logan River catchment.

PET Richness

It is generally accepted that three orders of aquatic insects, the Plecoptera (Stoneflies), Ephemeroptera (Mayflies) and Trichoptera (Caddisflies) are particularly sensitive to changed ecological conditions. The total number of PET families can be used to assess habitat degradation and water quality.

No PET (taxa sensitive to human disturbance) taxa was observed for this site on Native Dog Creek. The PET richness for site RSC-0002 is therefore 0 which is below the EPP (Water) guideline for PET taxa in the Logan River catchment (lowland freshwater) of 3.

It is difficult to draw any conclusions about the health of Native Dog Creek from the results of NRW (2007) due to only one sample site being on Native Dog Creek and the limited sampling regime. However the results detailed above do indicate a waterway with low abundance and diversity.

Water Quality

Water quality monitoring programs that exist in Redlands, both Environmental Health Monitoring Program and Redlands City Council have generally focused on catchments in the north of the City. Both Native Dog Creek and Torquay Creek have had limited water quality monitoring undertaken along their reaches.

Council undertook six (6) water quality sampling events on six (6) sites on Native Dog Creek between February and May 2009. These monitoring sites were called ND1, ND2, ND3, ND4, ND5 and ND6 (shown in **Appendix H**). Sampling was also undertaken in the Logan Shire on Native Dog Creek during 1999 and 2000. These were allocated site names of NAT1, NAT2, and NAT3. **Table 4.10** outlines the median concentrations of analytes measured at the various sites. Redland City Council's water quality sampling sites reference ND1 through ND6 in **Table 4.10** should not be confused with the waterway reach sections ND1 – ND4 for Native Dog Creek.

Caution should be taken when analysing these two different data sets due to the different sampling periods as identified in **Table 4.10**. While the monitoring at sites ND1 – ND6 involved six monitoring events in early 2009, the monitoring at sites NAT1, NAT2 and NAT3 involved 18, 19 and 22 events respectively in 1999 and 2000.

Median values are given in **Table 4.10** and assessed against the WQOs as outlined in the EPP (Water) Environmental Values and Water Quality Objectives of the Logan River Estuary Catchment. Environmental Values and WQOs are discussed further in **Section 4.9**.

Table 4.10 Median vales for water quality sampling sites on Native Dog Creek

SITE	LOCATION	SAMPLING PERIOD	NUMBER OF EVENTS	pH	TN (mg/L)	TP (mg/L)	TSS (mg/L)	DO (mg/L)	DO (%sat)[2]	Chlorophyll-a (ug/L)	Turbidity (NTU)	EC (uS/cm)
ND1	Sunrise Street	2009	6	6.5	4.5	0.89	213	5.7	60.0	N/A	16	524.5
ND2	Oval Large Inflow	2009	6	6.1	1.1	0.07*	13*	1.5	17.1	N/A	39*	343
ND3	Oval Main Channel	2009	6	6.5	3.9	0.74	102	5.5	56.9	N/A	23*	519.5
ND4	Valley Way Main Road	2009	6	6.5	1.8	0.14	227	4.2	41.6	N/A	360	315
ND5	Pimelea Way	2009	6	6.6	3.5	0.62	58	6.3	69.8	N/A	54	424
ND6	Hardwood Drive	2009	6	6.8	0.7	0.05	66	4.6	48.1	N/A	99	280.0
NAT1	End of Fischer Road	1999/2000	18	5.9	1.0	0.2	17.0	1.7	17.1	15.4	29.7*	295.0
NAT2	Bridge on Coorang Road	1999/2000	19	6.5	1.2	0.5	14.0*	4.6	49.5	15.3	40.0*	355.0
NAT3	End of Habermann Road	1999/2000	22	5.4	0.7	0.1	16.0	4.2	46.5	2.7	37.0*	143.5
EPP (Water) WQOs[1]				6.5 – 8.0	0.5	0.05	6	N/A	85-110	5	50	N/A
Redland Planning Scheme Objectives				6.5 – 8.0	0.65	0.07	15	N/A	80-105	8	20	400

Notes:

1. Lowland freshwater (comprising lowland streams, wallum/tannin stained streams and coastal streams) (excluding Brisbane City) (Logan River Environmental Values and Water Quality Objectives (EPA 2007a));
2. The percent saturation data are an approximation calculated using DO (mg/L) and temperature;
   *value complies with one water quality objective.

Graphical representations of the water quality results are shown in **Appendix I**. Locations of water quality sampling sites are mapped in **Appendix H**.

Water quality in Native Dog Creek consistently does not achieve compliance with EPP (Water) WQOs for a number of variables, particularly Total Nitrogen (TN), Total Suspended Solids (TSS) and Dissolved Oxygen (DO) at all sites. Further, compliance with EPP (Water) WQO's is not achieved for Total Phosphorus (TP) at sites ND1 through ND5 in addition with turbidity at sites ND2 through ND6.

The data are highly variable. It should also be noted that the number of sites is not statistically significant. As noted above, the two datasets (sites ND1 – ND6, and sites NAT1 – NAT3) were taken over different collection periods and the compatibility of these results is unknown. While it is assumed that both water quality sampling programs (RCC and Logan Shire Council) use NATA-accredited laboratories for analysis, these two datasets may not be directly comparable. This may account for some variability in the data. For example, early 2009 was a period characterised by particularly high rainfall. Therefore results collected earlier (i.e. sites NAT1 – NAT3) may provide an insight to catchment conditions in drier conditions and over a longer time period.

The concentrations of TN and TP regularly exceed the WQO by an order of magnitude, with the peak median TP concentration (0.89 mg/L) approximately 18 times higher than the WQO. NRW (2007) noted that a site on Native Dog Creek also had extremely high nutrient concentrations, with 0.66 mg/L TP (approximately 13 times the WQO) and 1.3 mg/L TN (2.6 times the WQO).

Concentrations of Total Suspended Solids (TSS) exceeded the EPP (Water) WQOs at all sites (the peak of 227 mg/L at ND4 is approximately 38 times the WQO of 6 mg/L). Median values at two sites (ND2 and NAT2) complied with the Redland planning scheme objectives. Similarly, median turbidity concentrations exceeded the EPP (Water) WQOs at all sites except one (the peak of 360 NTU being over 7 times the WQO), while five of these sites (ND2, ND3, NAT1, NAT2 and NAT3) complied with the Redland planning scheme objectives.

High turbidity leads to inhibition of photosynthesis within waterways. Ecological impacts of high TSS concentrations include smothering of benthic organisms and habitats, transport of contaminants, and may also lead to depletion of dissolved oxygen concentrations if caused by particulate organic matter.

The concentration of dissolved oxygen is below the EPP (Water) WQO at all sites, when compared to the EPP (Water) WQOs. These low dissolved oxygen levels are a sign of a degraded waterway and are expected to have a deleterious effect on both aquatic macroinvertebrate and fish communities.

Unusually, the concentrations of TN, TP and turbidity and TSS are not tightly correlated in the available data. For example, site ND4 has the highest concentrations of turbidity (360

NTU) and TSS (227 mg/L), but relatively low concentrations of TP (0.14 mg/L) and (to a lesser extent) TN (1.8 mg/L). In addition, at site ND6, while the median turbidity is high (99 NTU) and the median TSS is moderately high (66 mg/L), the TP is compliant with WQOs. It is also unusual that turbidity is much more variable than TSS.

From urban stormwater runoff, it would be expected that TN, TP, turbidity and TSS would increase further downstream, reflecting the more urbanised areas within the catchment. This trend was not observed in the available data. The unusually high nutrient concentrations recorded and the lack of a clear correlation with turbidity and suspended solids suggests that these issues are not caused by general urban stormwater runoff, but a likely point source of pollution, which could be caused by overflowing ponds or some other release from the poultry farm in the upper catchment. However, this particular point source does not explain elevated nutrients in all areas of the catchment, such as site 5.

The dataset is limited and some anomalies exist. Monitoring data is required over a much longer time period to be valid. However, from the existing data it appears that water quality in Native Dog Creek is extremely poor, possibly due to a pollution point source in the upper catchment, which may be related to the poultry farm. However, this observation is speculative and requires investigation.

Riparian Vegetation and Habitat

The riparian vegetation and habitat of Native Dog Creek is described below separately for each reach. The locations of these reaches are mapped in **Appendix G**. The riparian vegetation and habitat has been assessed based on a combined filed assessment at one location per reach in addition with a desktop aerial photograph analysis.

Reach ND1

Vegetation

This reach is characterised by a highly modified vegetation community that has been subjected to historical clearing for agricultural and farming land-uses. The riparian and surrounding vegetation has been extensively cleared and now bears little resemblance to the original vegetation. A narrow (<5m either side of the creek) and disjointed riparian corridor is dominated by weed species, particularly Slash Pine (*Pinus elliottii*) and Camphor Laurel (*Cinnamomum camphora*) in the canopy layer, Devils Fig (*Solanum hispidum*), Lantana (*Lantana camara*) and Wild Tobacco (*Solanum mauritianum*) in the shrub layer and Mistflower (*Ageratina riparia*), Guinea Grass (*Megathyrsus maximum*), Blue Billygoat Weed (*Ageratum houstonianum*) and South African Pigeon Grass (*Setaria sphacelata*) in the ground layer. Brazilian Nightshade (*Solanum seaforthianum*) and White Glycine (*Neonotonia wightii*) commonly grow throughout this reach.

A low cover and diversity of native vegetation occurs in this reach. Occasional Hoop Pine (*Araucaria cunninghamii*) occurs in the canopy and the mid-storey is dominated by pioneering species Blackwood (*Acacia melanoxylon*), Hickory wattle (*A. disparrima*) and

Brisbane Golden Wattle (*A. fimbriata*). Spiny-headed Mat-rush (*Lomandra longifolia*) commonly occurs along the creek banks.

Habitat

The disturbed nature of this reach has significantly reduced the quality and quantity of habitat for many native fauna species. Consequently the reach provides habitat for generalist and disturbance tolerant species and particularly pests such as the Cane Toad (*Rhinella marinus*). A lack of canopy cover, shade and habitat trees renders this reach as having a very low habitat value for native fauna in its current condition.

Reach ND2

Vegetation

ND2 has also been highly disturbed through historical land management. However this reach has retained a patchy cover of riparian vegetation with more natural recruitment of native vegetation evident, particularly in the upper part of the reach. The riparian vegetation ranges from 0 to 20m either side of the creek. Adjacent bushland increases the existing riparian buffer to over 100m in several parts of the reach. These bushland areas provide connectivity with surrounding habitats including endangered regional ecosystems and important Koala habitat to the east and west of Native Dog Creek.

Small patches of highly disturbed riparian rainforest were evident in the upper reach along the western branch. Several large Maiden's Blush (*Sloanea australis)* occur in the canopy of this area as well as numerous Camphor Laurel and Slash Pine. Blackwood, Foambark Tree (*Jagera pseudorhus*), Hickory Wattle, Swamp Mahogany (*Lophostemon suaveolens*) and Turpentine (*Syncarpia glomulifera*) were all recorded in the mid-storey. Native shrub species include Creek Sandpaper Fig (*Ficus coronata*) and Python Tree (*Gossia bidwillii*), however this stratum is dominated by weeds such as Brazilian Cherry (*Eugenia uniflora*), Devils Fig, Wild Tobacco and Easter Cassia (*Senna pendula* var. *glabrata*). Creek Mat-rush (*Lomandra hystrix*) dominates the creek banks with numerous weeds interspersed amongst clumps including Brazilian Nightshade (*Solanum nigrum*), Blue Billygoat Weed and South African Pigeon Grass. Climbing Asparagus (*Asparagus plumosus*) is also abundant through this area.

The eastern branch occurs below the hills to the east and consists of a disturbed Eucalypt Open-forest community. Common canopy species consist of Tallowwood (*Eucalyptus microcorys*), Grey Gum (*E. propinqua*), Pink Bloodwood (*Corymbia intermedia*) and Blackwood (*E. pilularis*).

Recent revegetation works along the lower part of the reach through the Mount Cotton Community Park has failed to stabilise the creek banks where significant erosion was evident. The riparian vegetation in this area consists of a mixture of native species. Several mature Queensland Blue Gums (*Eucalyptus tereticornis*) are scattered throughout this area. Occasional weed species have invaded this area and the lack of native vegetation cover

though this area is likely to favour opportunistic weed species. Native aquatic species such as Bullrush (*Typha sp*.) have colonised patches of the creek bed through the lower reach.

Habitat

This reach generally has very poor habitat for native fauna, however several large trees including the Maiden's Blush provide habitat opportunities for arboreal species. The lack of canopy cover and shade limits the reaches habitat values for many native species, particularly amphibians, small mammals and reptiles that are likely to have previously occupied the area. The lower part of the reach in particular provides minimal cover required by such fauna species.

However this open and grassy floodplain environment is suitable foraging areas for a variety of water birds including ducks, hens, egrets, herons and ibis. Additionally, some significant species may use this area, such as Cattle Egret (*Ardea ibis*), Great Egret (*Egretta alba*), White-necked Heron (*Ardea pacifica*) and Latham's Snipe (*Gallinago hardwickii*). This habitat type also provides suitable habitat for small perching birds, including Australian Reed-Warbler (*Acrocephalus australis*), Tawny Grassbird (*Megalurus timoriensis*), Red-backed Fairy-wren (*Malurus melanocephalus*) and Superb Fairy-wren (*Malurus cyaneus*).

Reach ND3

Vegetation

ND3 has been impacted through relatively recent urban development that has encroached within the riparian zone as well as historical clearing, resulting in minimal buffering to the creek. Stormwater treatment devices have also been constructed within the riparian corridor. Consequently the riparian corridor width ranges from 0-20m in width.

The vegetation consists of disturbed Eucalypt Open-forest and Melaleuca wetlands in the lower portion of the reach. Canopy trees occurring in this reach include Northern Grey Ironbark (*Eucalyptus siderophloia*) and Tallowwood with Broad-leaved Paperbark (*Melaleuca quinquenervia*), Flax-leaf paperbark (*M. linariifolia*), Blackwood, Hickory Wattle and Brisbane Golden Wattle dominating the mid-storey. The shrub layer was dominated by very dense weed invasions, especially Lantana that was impenetrable in many areas. Other common weeds species in this reach include Easter Cassia, Wild Tobacco and Devils Fig. Scattered native shrubs consist of Hairy Pea Bush (*Pultenaea villosa*), White Bottlebrush (*Melaleuca salignus*), Creek Sandpaper Fig and Wild May (*Leptospermum polygalifolium*). Creek Mat-rush and Spiny-headed Mat-rush commonly occur along the creek banks amongst a variety of environmental weeds such as Blue Billygoat Weed, Ludwigia peruviana, Brazilian Nightshade, South African Pigeon Grass and Scotch Thistle (*Cirsium vulgare*). Dense clumps of Slender Cucumber (*Neoachmandra cunninghamii*) were also observed in this reach.

A variety of rushes and sedges including Frogsmouth (*Philydrum lanuginosum*), Water Chestnut (Eleocharis dulcis), Grey Rush (*Lepironia articulata*), Triangular Club-rush

(*Schoenoplectus mucronatus*), Bunchy Sedge (*Cyperus polystachyos*) and Jointed Twig-rush (*Baumea articulata*) occur on the fringes of the stormwater basin. Most of these appear to have been planted as part of the basins construction.

Habitat

Although this area has been aggressively invaded by understorey weeds, it provides suitable habitat for a variety of native fauna. Koala food trees dominate the canopy layer and although the dense understorey consists of weeds, they provide cover and shelter for small birds and mammals. Numerous native birds were observed in this reach including Eastern Whipbird (*Psophodes olivaceus*), Red-back Fairy-wren, Bar-shouldered dove (*Geopelia humeralis*), White-throated Gerygone (*Gerygone olivacea*) and White-naped Honeyeater (*Melithreptus albogularis*). The constructed wetland and creek zone provide suitable habitat for common native frogs such as Eastern Sedge Frog (*Littoria fallax*) and Striped Marsh Frog (*Limnodynastes peronii*).

Reach ND4

Vegetation

This reach represents the highest condition riparian ecosystem in the Native Dog Creek catchment. Large areas of near-pristine *Melaleuca quinquenervia* Open-forest dominate this reach. The riparian vegetation is approximately 20-30m wide throughout ND4. Recent construction of a residential subdivision to the south of the creek has reduced the riparian buffers for part of the reach with a road crossing breaking the longitudinal connectivity of the creek.

Despite these recent disturbances the reach currently remains in good condition with a good canopy cover that is dominated by Broad-leaved Paperbark and only minor occurrences of weed invasion. Other native canopy trees observed in this reach include Queensland Blue Gum, Grey Gum, Northern Grey Ironbark and Blackbutt that generally occur on the fringes of the wetlands. Swamp Mahogany, Cheese Tree (*Glochidion ferdinandi*) and White Bottlebrush commonly occur in the mid-storey.

A sparse shrub layer consists of occasional Umbrella Cheese tree (*Glochidion sumatranum*), Creek Sandpaper Fig and Rough Saw-sedge (*Gahnia aspera*) as well the weed species Devils Fig and Groundsel (*Baccharis halimifolia*). Blady Grass (*Imperata cylindrica*) and Wiry Panic (*Entolasia stricta*) dominate the groundcover.

Aquatic species occurring in the ephemeral pools include Frogsmouth, Bullrush, Grey Rush and Water Chestnut.

Habitat

This reach provides good quality habitat for a variety of native fauna species, in particular numerous frogs and reptiles that require semi-permanent water for breeding. ND4 provides

habitat for several threatened species such as Wallum Froglet (*Crinia tinnula*) as well as secondary habitat for Koalas (*Phascolarctos cinereus*). Koala scratches were observed on several Eucalypts in this reach.

Connectivity

Clearing of vegetation for urban development, quarrying, rural residential and agricultural purposes has fragmented much of the catchment. In particular, clearing has reduced the riparian corridors along portions of the creek and longitudinal connectivity is poor. Consequently much of Native Dog Creek has lost the ability to function as an effective movement corridor for many species. The riparian zone provides a stepping stone corridor for mobile species that are tolerant of disturbed environments.

The lower portions of Reach ND3 and most of ND4 retain a good cover of riparian vegetation that is well connected to surrounding bushland. Surrounding bushland to ND2 provides east - west linkages for terrestrial and arboreal fauna including Koalas. In particular, bushland to the east and north provide fairly continuous connections to large areas of remnant bushland. Mount Cotton Road provides a major barrier to fauna movements, especially terrestrial species and Koalas.

4.7.2 Torquay Creek

Fish and Macroinvertebrates

There was no fish or macroinvertebrate sampling data available for Torquay Creek. However Weinam Creek, the adjoining catchment to the north of Torquay Creek, was subject to an assessment and limited monitoring as reported in BCC (2003).

BCC (2003) found that Weinam Creek's macrobenthic community was characterised by low abundance and diversity. The mean densities of macrobenthos in Weinam Creek were comparable to some of the sites sampled recently in other estuaries within Redland City. It could therefore be concluded that Torquay Creek would be similar and would also be low in abundance and diversity.

Increased urbanisation and nutrient input is likely to have a detrimental impact on the diversity of macroinvertebrate fauna in both Native Dog and Torquay Creek. In their investigation of estuarine macroinvertebrates, SKM (2006) found that community diversity and richness was consistently reduced where sediment nutrient concentrations exceeded certain threshold nutrient concentrations (20,000 mg/kg total organic carbon, 1,700 mg/kg total organic nitrogen and 500 mg/kg total phosphorus).

NRW (2007) found that within most mainland Redland City waterways, increased urbanisation and nutrient input, low dissolved oxygen concentrations are factors contributing to the poor ecological condition of both aquatic macroinvertebrates and fish communities.

More extensive monitoring and longer term monitoring would be necessary in both Native Dog Creek and Torquay Creek to undertake a conclusive and extensive investigation into the health of these waterways fish and aquatic macroinvertebrate communities.

Water Quality

Council carried out two (2) water quality sampling events on three (3) sites in Torquay Creek in May 2009. These sites are known as TC1, TC2 and TC3. **Table 4.11** summarises the median values of water quality parameters and the EPP (Water) and Redland Planning Scheme WQOs.

Environmental Values and WQOs are discussed further in **Section 4.9**.

Table 4.11 Median Values for water quality sampling sites on Torquay Creek

SITE	LOCATION	SAMPLING PERIOD	NUMBER OF EVENTS	pH	TN (mg/L)	TP (mg/L)	TSS (mg/L)	DO (mg/L)	DO (%sat)[2]	Chlorophyll-a (ug/L)	Turbidity (NTU)	EC (uS/cm)
TC1	Kidd Road	May 2009	2	5.4	0.5	0.03	5	3.3	33.4	N/A	7.5	262
TC2	Cleveland-Redland Bay Road	May 2009	2	5.6	0.8	0.05	16	4.2	42.5	N/A	74.0	604.0
TC3	Serpentine Creek Road	May 2009	2	6.3	0.7	0.05	9*	2.8	28.0	N/A	64.5	382.0
EPP (Water) WQOs[1]				6.5 – 8.0	0.5	0.05	6	N/A	85-110	5	50	N/A
Redland Planning Scheme Objectives				6.5 – 8.0	0.65	0.07	15	N/A	80-105	8	20	400

Notes:

1. Lowland freshwater (comprising lowland streams, wallum/tannin stained streams and coastal streams) (Redland Creeks Environmental Values and Water Quality Objectives (EPA 2007a));
2. The percent saturation data are an approximation calculated using DO (mg/L) and temperature;
3. *value complies with one water quality objective.

Graphical representation of the results in **Table 4.11** is shown in **Appendix I**. locations of water quality sampling sites are mapped in **Appendix H**.

The available data for Torquay Creek show generally elevated nutrient and particulate concentrations, with TN, TSS and turbidity exceeding the WQOs at two of the three sites. TC1 appears in better condition than the other two sites, complying with these WQOs. Torquay Creek appears to have better water quality than Native Dog Creek. TN concentrations were considerably lower in Torquay Creek than Native Dog Creek, and median TP concentrations were compliant with the WQO at all sites.

All sites were slightly acidic, and non-compliant with the pH WQO. This may be caused by runoff from disturbed of acid sulfate soils, or other causes such as decomposition of organic matter, point source pollution, or acid deposition from aerial sources.

Given the very limited sampling results from Torquay Creek, these results need to be interpreted with caution. Further detailed water quality assessment (of both physicochemical and biological parameters) is recommended to develop a set of reliable baseline values (refer to **Section 4.10** for the recommended monitoring program).

Riparian Vegetation and Habitat

Reach TOR1

Vegetation

This reach has been highly disturbed through agriculture and grazing, with most of the native vegetation cleared. This reach is dominated by exotic species with only occasional native trees and patches of regrowth occurring. A patch of regenerating woodland vegetation occurs in the upper part of this reach. This area is dominated by Black She-oak (*Allocasuarina littoralis*) with occasional eucalypts such as Scribbly Gum (*Eucalyptus racemosa*) occurring.

Habitat

The highly modified environment is likely to exclude many native fauna species from using this area. This area is likely to be dominated by disturbance tolerant generalist species such as Noisy Miner (*Manorina melanocephala*), Australian Magpie (*Gymnorhina tibicen*), Torresian Crow (*Corvus orru*) and Cane Toads.

Reach TOR2

Vegetation

TOR2 consists of a *Melaleuca quinquenervia* Open-forest that is in relatively good condition. The riparian vegetation ranges from approximately 10 to 30m wide either side of the creek

and has been fragmented by several roads. Residential development has encroached within the riparian zone in several locations, reducing the riparian buffers.

A dense canopy is dominated by Broad-leaved Paperbark with occasional Queensland Blue Gum. The mid-storey consists of Cheese Tree, Macaranga (*Macaranga tanarius*), Bangalow Palm (*Archontophoenix cunninghamiana*) and White Bottlebrush as well as the weed species Camphor Laurel, Cocos Palm (*Syagrus romanzoffiana*) and Umbrella Tree (*Schefflera actinophylla*).

The shrub layer is fairly sparse, although pioneering species such as Red Ash (*Alphitonia excelsa*) and weeds, Easter Cassia, Devils Fig, Lantana, Ochna (*Ochna serrulata*) and Mock Orange (*Murraya paniculata*) were common along the edges of the vegetation. Rough Saw-sedge, Umbrella Cheese Tree and Pink Eudia (*Melicope elleryana*) are scattered throughout. The groundcover has been heavily invaded by weeds, in particular Singapore Daisy (*Sphagneticola trilobata*), along the edges. Native groundcovers include *Persicaria* sp., Spiny-headed Mat-rush, River Lily (*Crinum pedunculatum*), False Bracken (*Calochlaena dubia*) and Tape Vine (*Stephania japonica*). Blue Morning Glory (*Ipomoea indica*), Mile-a-minute (*Ipomoea cairica*) and Monkey Rope Vine are smothering many of the trees in this reach.

Habitat

This reach provides moderate quality habitat for a variety of native fauna species, in particular numerous frogs, including the threatened Wallum Froglet, and reptiles that require semi-permanent water for breeding. TOR2 also provides secondary habitat for Koalas.

Reach TOR3

Vegetation

TOR3 has also been heavily disturbed and is mostly in a similar condition to TOR1. However a narrow band of regenerating riparian vegetation does occur along parts of the reach. Furthermore, the headwaters of the reach contain near-pristine woodland.

The canopy vegetation in this reach is dominated by Scribbly Gum with Pink Bloodwood, Northern Grey Ironbark and Broad-leaved Paperbark along the drainage line. The mid-storey consists of Swamp Mahogany, Black She-oak and Cheese Tree. An open shrub layer consists of Rough Saw-sedge, Blue Tongue (*Melastoma affine*), White Bottlebrush and Wild May. Dense clumps of Rough Saw-sedge occur within the drainage line. The ground layer consists of a variety of native grasses, in particular Blady Grass, Wiry Panic, Creeping Beard Grass (*Oplismenus aemulus*) and Graceful Grass (*Ottochloa gracillima*). Bracken Fern (*Pteridium esculentum*) forms dense clumps on the lower slopes in particular and Star Goodenia (*Goodenia rotundifolia*), Spiny-headed Mat-rush, White Root (*Lobelia purpurascens*), Native Sarsaparilla (*Hardenbergia violacea*) and Molucca Raspberry (*Rubus moluccanus*) all commonly occurring.

Habitat

The upper section of this reach provides excellent habitat for a range of species. The vegetation structure and condition provide suitable habitat for a diverse range of birds, terrestrial mammals, reptiles and frogs. Several Swamp Wallabies (*Wallabia bicolor*) were observed in the area and Northern Brown Bandicoot (*Isodon macrourus*) diggings were common. Hollow-bearing trees were common throughout the area and provide potential habitat and dens for arboreal mammals such as Gliders and birds including owls, cockatoos, parrots and lorikeets.

The middle and lower sections of this reach have less structural integrity and habitat features for native fauna. However the open grassy areas provide good grazing habitat for Red-necked Wallabies (*Macropus rufogriseus*) that were observed in the area.

Reach TOR4

Vegetation

The tidal reaches of Torquay Creek consist of a Mangrove Low Closed-forest dominated by Grey Mangrove (*Avicennia marina*). River Mangrove (*Aegiceras corniculatum*) and Mangrove Fern (*Acrostichum speciosum*) also commonly occur within the estuarine zone.

Swamp She-oak (*Casuarina glauca*) commonly occurs on the fringe and at the limit of the tidal areas. Other native species occurring along the edge of the tidal wetlands include Common Reed (Phragmites australis), Saltwater Couch (*Sporobolus virginicus*), Coastal Pigface (*Carpobrotus glaucescens*), Cotton Tree (*Hibiscus tiliaceus*) and Crabs Eye (*Abrus precatorius*). Numerous weed species have invaded the tidal fringes including Easter Cassia, Asparagus Fern (*Asparagus aethiopicus*), Stinking Passion Flower (*Passiflora foetida*), Brazilian Nightshade and Mile-a-minute.

The adjacent non-tidal areas have been largely cleared for recreational parks and residential development. Scattered Queensland Blue Gum and Tallowwood occur in these areas with Broad-leaved Paperbark, Weeping Bottle-brush (*Melaleuca viminalis*), Silky Oak (*Grevillia robusta*) and Tuckeroo (*Cupaniopsis anacardioides*) in the mid-storey. The shrub layer is dominated by weed species such as Lantana, Easter Cassia, Cocos Palm and Umbrella Tree with occasional natives including River Tea-tree (*Melaleuca bracteata*), Black She-oak and Blue Tongue. The groundcover is largely manicured lawn with occasional weeds such as Red Natal Grass (*Melinis repens*), Corky Passion Vine (*Passiflora suberosa*), Cobblers Pegs (*Bidens pilosa*), Blue Billygoat Weed, Guinea Grass and Blackberry Nightshade.

Habitat

This reach has a low species diversity that is typical of this environment. However it provides important breeding habitat for many marine species as well as foraging and shelter for a large number of birds including migratory waders and shorebirds (Egrets, Herons, Curlews, etc), forest birds such as Mangrove Gerygone (*Gerygone levigaster*), Collared Kingfisher

(*Todiramphus chloris*) and Mangrove Honeyeater (*Lichenostomus versicolour fasciogularis*) as well as raptors, particularly Whistling Kite (*Haliastur sphenurus*), Brahminy Kite (*Haliastur indus*) and White-bellied Sea-eagle (*Haliaeetus leucogaster*). A Koala was recorded in a Queensland Blue Gum in the adjacent non-tidal area.

Connectivity

The majority of the catchment has been cleared for rural and urban land uses and several roads bisect the creek corridor. As a result connectivity in the Torquay Creek catchment is very poor and limited to a stepping stone corridor along the creek. Cleveland-Redland bay Road is a major barrier for terrestrial and arboreal fauna, especially Koalas. The riparian vegetation is very narrow and degraded for much of the catchment. However the headwaters in TOR1 and TOR3 are well connected to a large tract of remnant bushland to the west of the catchment.

4.7.3 Geomorphology, Habitat and Vegetation Summary

Table 4.12 below summarises the results of the field surveys. This data was entered into a spreadsheet and an overall score for each site was given – these results are shown in **Appendix B** (in addition to field sheets with site observations).

Table 4.12 Summary of Assessment of Reaches

REACH	SURVEY SITES	CHARACTERISITCS OF EACH REACH
ND1	5	**Dominant bed material**: Clay / Gravel **Bed Stability**: Limited Infilling / Instability **Artificial barriers**: road culverts, small farm dams **Bank Stability**: Moderate Erosion **Habitat Condition**: Marginal **Diversity of natural processes**: few natural process in action **Hydrology**: Moderate Flow **Riparian Condition**: ▪ Significant disturbance to canopy and understorey species ▪ Very narrow riparian width <5m ▪ Low (65-80%) longitudinal connectivity – large breaks in riparian vegetation and low proportion of vegetated bank length ▪ Low species diversity ▪ Weeds species abundant ▪ Upper natural drainage lines have minimal vegetation disturbances
ND2	1 & 2	**Dominant bed material**: Clay / Silt **Bed Stability**: Limited Infilling / Instability **Artificial barriers**: road crossings, pathway crossings, one major dam **Bank Stability**: Moderate Erosion **Habitat Condition**: Poor **Diversity of natural processes**: few natural process in action **Hydrology**: Moderate Flow

REACH	SURVEY SITES	CHARACTERISITCS OF EACH REACH
		Riparian Condition: ▪ Significant disturbance to canopy and understorey species ▪ Very narrow riparian width < 5m (adjacent bushland in lower section of reach increases buffer width on northern side of creek) ▪ Low (0-65%) longitudinal connectivity – large breaks in riparian vegetation and low proportion of vegetated bank length ▪ Low species diversity ▪ Weeds species abundant ▪ Some revegetation works have been undertaken in lower section of ND2 however recent rainfall event had eroded some of this work.
ND3	4	**Dominant bed material**: Clay **Bed Stability**: Limited Instability / Deepening (may be more stable along other sections) **Artificial barriers**: Road culverts **Bank Stability**: Extensive erosion **Habitat Condition**: Poor **Diversity of natural processes**: few natural process in action **Hydrology**: Moderate Flow **Riparian Condition**: survey site and adjacent urban development the following comments are relevant *(however 200m downstream of survey site buffer width increases dramatically for a length of 600m this reach may have much higher values)* ▪ Significant disturbance to canopy and understorey species ▪ Very narrow riparian width generally < 5m (ranging from 0 – 20m) ▪ Low (0-40%) longitudinal connectivity (however downstream of survey site buffer width increases dramatically) ▪ Low species diversity ▪ Weeds species abundant ▪ Upper natural drainage lines have minimal vegetation disturbances
ND4	3	**Dominant bed material**: Silt **Bed Stability**: Stable **Artificial barriers**: No downstream barriers, one road crossing **Bank Stability**: Stable **Habitat Condition**: Excellent **Diversity of natural processes**: some natural process in action **Hydrology**: Moderate flow **Riparian Condition**: ▪ Limited disturbance to canopy and understorey species – however new development to south of survey site had constructed a road across the creek and other development impacts would be expected. ▪ Riparian width < 25m ▪ Very good (95-100%) longitudinal connectivity ▪ Moderate species diversity ▪ Weeds species present

REACH	SURVEY SITES	CHARACTERISITCS OF EACH REACH
TOR1	*No survey site, but using aerials and mapping the following assumptions are made.*	**Dominant bed material**: Clay / Sand **Bed Stability**: Limited Infilling / Instability **Artificial barriers**: road crossings, small farm dams **Bank Stability**: Moderate Erosion **Habitat Condition**: Marginal to Poor **Diversity of natural processes**: few natural process in action **Hydrology**: Moderate flow **Riparian Condition**: ▪ Significant disturbance to canopy and understorey species ▪ Very narrow riparian width <5m ▪ Low longitudinal connectivity – large breaks in riparian vegetation and low proportion of vegetated bank length ▪ Low species diversity ▪ Weeds species abundant ▪ Upper natural drainage lines have minimal vegetation disturbances
TOR2	7	**Dominant bed material**: Silt **Bed Stability**: Stable **Artificial barriers**: road crossings **Bank Stability**: Limited Erosion **Habitat Condition**: Good **Diversity of natural processes**: some natural processes in action **Hydrology**: Moderate Flow **Riparian Condition**: ▪ Some disturbance to canopy and understorey species ▪ Riparian width < 30m ▪ Good (80-95%) longitudinal connectivity ▪ Good species diversity ▪ Weeds species present
TOR3	8	**Dominant bed material**: Silt **Bed Stability**: Stable **Artificial barriers**: road crossings and farm dams **Bank Stability**: Stable **Habitat Condition**: Marginal **Diversity of natural processes**: some natural processes in action **Hydrology**: Moderate Flow **Riparian Condition**: ▪ Significant disturbance to canopy and understorey species ▪ Riparian width average < 10m (western section has larger buffers) ▪ Very good (95-100%) longitudinal connectivity ▪ Average species diversity ▪ Weeds species present

REACH	SURVEY SITES	CHARACTERISITCS OF EACH REACH
TOR4	6	**Dominant bed material**: Sand / Silt **Bed Stability**: Stable **Artificial barriers**: pathway culvert **Bank Stability**: Stable **Habitat Condition**: Good **Diversity of natural processes**: natural processes in action **Hydrology**: Moderate Flow **Riparian Condition**: ▪ Some disturbance to canopy and understorey species ▪ Riparian width < 50m one side, <10m other side ▪ Very good (95-100%) longitudinal connectivity ▪ Moderate species diversity ▪ Weeds species present

4.8 Feasible Target Conditions

4.8.1 Introduction

Table 4.13 identifies the current condition of each reach, based on the information in **Section 4.7**, in addition to the feasible target conditions. Feasible target condition (or recovery potential) is the optimum biophysical condition (i.e. natural values) that can be achieved without fundamental change to existing land uses or water infrastructure. Examples of fundamental change are removal of dams, or conversion of private urban land to forest. Reference photographs defining typical 'target conditions' are included as examples.

Table 4.13 Feasible Target Conditions

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
ND1	 Survey Site 5 on Reach ND1. Degraded riparian zone – abundance of weeds.	**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions (culvert) **Riparian Condition** ▪ Significant disturbance to canopy and understorey species ▪ Narrow (<5m) riparian vegetation width ▪ 65-80% longitudinal connectivity ▪ Upper natural drainage lines have minimal vegetation disturbances ▪ Low species diversity ▪ Weeds species abundant		**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions (culverts) **Riparian Condition** ▪ 80-95% structurally intact riparian vegetation bank cover ▪ 60m riparian vegetation width ▪ Good to excellent cover of natural riparian species ▪ High species diversity ▪ 100% longitudinal connectivity. ▪ Endangered Regional Ecosystems present (12.3.1; 'Gallery rainforest (notophyll vine forest) on alluvial plains')

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
	 Survey Site 5 on Reach ND1 – upstream riparian zone is cleared, fencing across waterway.	**Habitat Integrity** ▪ Marginal aquatic habitat ▪ Riparian and terrestrial habitat for generalist and disturbance-tolerant species. **Aquatic fauna** ▪ Low native fish species diversity ▪ Abundant exotic fish ▪ Low diversity of macroinvertebrate taxa (no monitoring in this study; based on NRW (2007) **Bed and Bank Stability** ▪ Limited infilling / instability		▪ Less than 10% weeds present **Habitat Integrity** ▪ Abundant fallen timber, rocks and groundcover ▪ Abundant cover of aquatic vegetation, woody debris, rocks and leaf litter **Aquatic fauna** ▪ Moderate native fish species diversity ▪ Moderate exotic fish species ▪ Increased trophic diversity in fish community ▪ Moderate to good diversity of macroinvertebrate taxa

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		▪ Some minor bank erosion **Water Quality** ▪ Poor water quality (no sites within this reach; based on other sites in the catchment)		**Bed and Bank Stability** ▪ Well vegetated and stable banks ▪ Minor bed erosion and sedimentation **Water Quality** ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)
ND2	 Survey Site 1 on ND2 showing limited riparian vegetation.	**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions e.g. culverts **Riparian Condition** ▪ Low structural integrity of vegetation bank cover ▪ Narrow (0 - 20m) riparian vegetation width		**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions e.g. culverts **Riparian Condition** ▪ High structurally intact riparian vegetation bank cover ▪ Good cover of native riparian species

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
	 Survey Site 2 on ND2 showing recent erosion of banks.	▪ Low (0 – 65%) longitudinal connectivity ▪ Low riparian vegetation diversity ▪ Riparian vegetation community absent in areas. ▪ Weeds abundant **Habitat Integrity** ▪ Poor - minor snags, bed disturbance and few habitat values ▪ Occasional habitat trees ▪ Habitat for rare and threatened species ▪ Lack of canopy cover and shade limits the habitat values (particularly the lower part of the reach) ▪ Open grassy area provides		▪ 60m riparian vegetation width ▪ 80-95% longitudinal connectifity ▪ Moderate to good riparian vegetation diversity ▪ Riparian vegetation community extending to high banks on both banks ▪ < 10% weeds present and minor amount of canopy weeds present, but no canopy creepers (e.g. Cats Claw Creeper, Madeira Vine) ▪ Endangered regional ecosystem (12.3.3; '*Eucalyptus tereticornis* woodland to open forest on alluvial plains') **Habitat Integrity** ▪ Good – some large woody debris, and bed mostly coarse and stable ▪ Abundant habitat trees

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		foraging area for water birds **Aquatic fauna** ▪ Low native fish species diversity ▪ Abundant exotic fish ▪ Low diversity of macroinvertebrate taxa (no monitoring in this study; based on NRW (2007) **Bed and Bank Stability** ▪ Moderate deepening/instability or infilling/instability of bed ▪ Moderate bank erosion **Water Quality** ▪ Very poor water quality		▪ Habitat for rare and threatened species (e.g. Koala, *Phascolarctos cinereus* and Wallum Froglet, *Crinia tinnula*) **Aquatic fauna** ▪ Moderate native fish species diversity ▪ Moderate exotic fish species ▪ Increased trophic diversity in fish community ▪ Moderate to good diversity of macroinvertebrate taxa **Bed and Bank Stability** ▪ Limited deepening/instability or limited infilling/instability ▪ Limited bank erosion

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
				Water Quality ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)
ND3	 Survey Site 4 on Reach ND3 – degraded site with many weeds and limited riparian vegetation.	**Aquatic Connectivity** ▪ Moderate barrier – Valley Way crossing ▪ Barriers often passable **Riparian Condition** ▪ Low structural integrity of vegetation bank cover ▪ Shrub layer dominated by weeds ▪ Narrow (0 – 20m) riparian vegetation width ▪ 0-40% longitudinal connectivity (in vicinity of site 4)		**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions e.g. culverts **Riparian Condition** ▪ High structurally intact riparian vegetation bank cover ▪ Good cover of natural riparian species ▪ 60m riparian vegetation width ▪ Moderate to good riparian vegetation diversity ▪ Riparian vegetation community

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		▪ Low riparian vegetation diversity ▪ Riparian vegetation community absent in areas. ▪ Weeds abundant ▪ Remnant Melaleuca wetlands and Eucalypt forest **Habitat Integrity** ▪ Poor - minor snags, bed disturbance and few habitat values ▪ Koala food trees dominate the canopy ▪ Habitat for rare and threatened species **Aquatic fauna** ▪ Low native fish species diversity		extending to high banks on both banks ▪ 100% longitudinal connectivity ▪ < 10% weeds present and minor amount of canopy weeds present, but no canopy creepers (e.g. Cats Claw Creeper, Madeira Vine) ▪ Remnant Melaleuca wetlands **Habitat Integrity** ▪ Good – some large woody debris, and bed mostly coarse and stable ▪ Abundant habitat trees ▪ Habitat for rare and threatened species (e.g. Koala, *Phascolarctos cinereus* and Wallum Froglet, *Crinia tinnula*) **Aquatic fauna**

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		▪ Abundant exotic fish ▪ Low diversity of macroinvertebrate taxa (no monitoring in this study; based on NRW (2007) **Bed and Bank Stability** ▪ Limited deepening/instability of bed ▪ Extensive bank erosion **Water Quality** ▪ Very poor water quality		▪ Moderate native fish species diversity ▪ Moderate exotic fish species ▪ Increased trophic diversity in fish community ▪ Moderate to good diversity of macroinvertebrate taxa **Bed and Bank Stability** ▪ Stable bed ▪ Limited bank erosion **Water Quality** ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
ND4	 Survey Site 3 on Reach ND4	**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions e.g. culverts **Riparian Condition** ▪ Good structural integrity, good native cover ▪ Narrow (20-30m) riparian vegetation width ▪ Minor weed invasions ▪ Remnant Melaleuca wetlands ▪ 95-100% longitudinal connectivity **Habitat Integrity** ▪ Excellent aquatic habitat ▪ Secondary habitat for koalas		**Aquatic Connectivity** ▪ Minor barriers passable under most flow conditions e.g. culverts **Riparian Condition** ▪ High structurally intact riparian vegetation bank cover ▪ Excellent cover of native riparian species ▪ 60m riparian vegetation width ▪ Riparian vegetation community extending to high banks on both banks ▪ < 10% weeds present and minor amount of canopy weeds present, but no canopy creepers (e.g. Cats Claw Creeper, Madeira Vine) ▪ Remnant Melaleuca wetlands ▪ 100% longitudinal connectivity

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
	 Survey Site 3 on Reach ND4	▪ Habitat trees ▪ Habitat for rare and threatened species **Aquatic fauna** ▪ Low native fish species diversity ▪ Abundant exotic fish ▪ Low diversity of macroinvertebrate taxa (no monitoring in this study; based on NRW (2007) **Bed and Bank Stability** ▪ Stable bed ▪ Stable banks		**Habitat Integrity** ▪ Excellent aquatic habitat ▪ Abundant habitat trees ▪ Habitat for rare and threatened species (e.g. Koala, *Phascolarctos cinereus* and Wallum Froglet, *Crinia tinnula*) **Aquatic fauna** ▪ Moderate native fish species diversity ▪ Moderate exotic fish species ▪ Increased trophic diversity in fish community ▪ Moderate to good diversity of macroinvertebrate taxa

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		Water Quality ▪ Poor water quality		**Bed and Bank Stability** ▪ Stable bed ▪ Stable banks **Water Quality** ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)
TOR1	N/A	**Aquatic Connectivity** ▪ Minor barriers passable under most conditions (e.g. culverts) **Riparian Condition** ▪ Most native vegetation cleared ▪ Riparian vegetation width (<5m) ▪ Dominated by weed species	N/A	**Aquatic Connectivity** ▪ Minor barriers passable under most conditions (e.g. culverts) **Riparian Condition** ▪ Intact canopy and understorey ▪ Contiguous remnant vegetation ▪ Moderate species diversity

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		Habitat Integrity ▪ Marginal to poor habitat ▪ Low species diversity **Aquatic fauna** ▪ N/A (no available information) **Bed and Bank Stability** ▪ Limited infilling / instability ▪ Moderate bank erosion **Water Quality** ▪ Moderate to good water quality		▪ >60m riparian vegetation width ▪ <2% cover of weed species **Habitat Integrity** ▪ Abundant fallen timber, rocks and groundcover ▪ Abundant cover of aquatic vegetation, woody debris, rocks and leaf litter ▪ Habitat for rare and threatened species (e.g. Koala, *Phascolarctos cinereus* and Wallum Froglet, *Crinia tinnula*) **Aquatic Fauna** ▪ N/A **Bed and Bank Stability**

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
				▪ Well vegetated and stable banks ▪ Minor bed and bank erosion and sedimentation **Water Quality** ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)
TOR2	 Survey Site 7 on Reach TOR2 – low diversity and high presence of weeds in groundcover.	**Aquatic Connectivity** ▪ Moderate barriers – e.g. Cleveland Redland Bay Road crossing ▪ Barriers often passable **Riparian Condition** ▪ Minimal canopy and understorey disturbances ▪ Riparian vegetation width <30m		**Aquatic Connectivity** ▪ Minor barriers passable under most conditions (e.g. culverts) **Riparian Condition** ▪ Intact canopy and understorey ▪ Contiguous remnant vegetation ▪ High species diversity

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
	 Survey Site 7 on Reach TOR2 – lack of riparian vegetation on southern side.	▪ High species diversity ▪ Weed species abundant in understorey ▪ 80-95% longitudinal connectivity **Habitat Integrity** ▪ Good habitat condition ▪ Habitat for rare and threatened species ▪ Secondary habitat for Koalas ▪ Moderate cover of aquatic vegetation and woody debris, rocks and leaf litter **Aquatic fauna** ▪ N/A (no available information)		▪ >100m riparian vegetation width ▪ <2% cover of weed species ▪ 100% longitudinal connectivity **Habitat Integrity** ▪ Abundant fallen timber, rocks and groundcover ▪ Core habitat for rare and threatened species (e.g. Koala, *Phascolarctos cinereus* and Wallum Froglet, *Crinia tinnula*) ▪ Abundant cover of aquatic vegetation, woody debris, rocks and leaf litter **Aquatic Fauna** ▪ N/A

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		Bed and Bank Stability ▪ Stable bed ▪ Limited bank erosion **Water Quality** ▪ Moderate water quality		**Bed and Bank Stability** ▪ Well vegetated and stable banks ▪ Stable bed **Water Quality** ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)
TOR3	N/A	**Aquatic Connectivity** ▪ Some farm dams and road crossings ▪ Minor barriers passable under most conditions (e.g. culverts) **Riparian Condition**	N/A	**Aquatic Connectivity** ▪ Minor barriers passable under most conditions (e.g. culverts) **Riparian Condition** ▪ Intact canopy and understorey ▪ Contiguous remnant vegetation

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		▪ Low diversity ▪ Riparian vegetation width <10m ▪ Near-pristine woodland in headwaters ▪ 95 - 100% longitudinal connectivity (at site 8) **Habitat Integrity** ▪ Upper section of reach provides excellent habitat for a range of fauna ▪ Habitat trees common in upper section ▪ Middle and lower sections poor structural integrity ▪ Open grassy areas provide grazing habitat for wallabies		▪ High species diversity ▪ >60m riparian vegetation width ▪ <2% cover of weed species ▪ 100% longitudinal connectivity **Habitat Integrity** ▪ Abundant fallen timber, rocks and groundcover ▪ Habitat for rare and threatened species (e.g. Koala, *Phascolarctos cinereus* and Wallum Froglet, *Crinia tinnula*) ▪ Abundant cover of aquatic vegetation, woody debris, rocks and leaf litter **Aquatic Fauna** ▪ N/A

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		Aquatic fauna ▪ N/A (no available information) **Bed and Bank Stability** ▪ Stable bed ▪ Stable banks **Water Quality** ▪ Moderate water quality (no sites in this reach, based on catchment results)		**Bed and Bank Stability** ▪ Stable bed ▪ Well vegetated and stable banks **Water Quality** ▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
TOR4	 Survey Site 6 – Reach TOR4 – mouth of Torquay Creek  Survey Site 6 – Reach TOR4 – Narrow riparian vegetation adjacent to parkland	**Aquatic Connectivity** ▪ Boardwalk culvert prevents some movement, but passable under most conditions **Riparian Condition** ▪ Mostly intact canopy and understorey, localised areas of clearing ▪ Riparian vegetation width 10 – 50m ▪ 95-100% longitudinal connectivity ▪ Low species diversity (natural characteristic of mangrove communities) ▪ Minor weed invasions **Habitat Integrity**		**Aquatic Connectivity** ▪ No barriers to movement **Riparian Condition** ▪ Intact canopy and understorey ▪ 'Not of Concern' REs present ▪ >100m riparian vegetation width ▪ 100% longitudinal connectivity ▪ Low species diversity (natural characteristic of mangrove communities; high diversity is not feasible) ▪ <1% cover of weed species **Habitat Integrity** ▪ Habitat for rare and threatened

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		▪ Marginal habitat for rare and threatened species ▪ Mangroves provide extensive intertidal habitat ▪ Patchy cover of fallen timber, rocks and groundcover ▪ Patchy cover of aquatic vegetation and woody debris, rocks and leaf litter **Aquatic fauna** ▪ N/A (no available information and TOR4 is a tidal reach) **Bed and bank stability** ▪ Minimal erosion **Water Quality**		species (e.g. False Water Mouse, *Xeromys myoides* and Koala, *Phascolarctos cinereus*) ▪ Abundant mangroves provide extensive intertidal habitat ▪ Patchy cover of fallen timber, rocks and groundcover ▪ Patchy cover of aquatic vegetation and woody debris, rocks and leaf litter **Aquatic fauna** ▪ N/A **Bed and bank stability** ▪ Minimal erosion **Water Quality**

REACH	CURRENT CONDITION		TARGET CONDITION	
	REPRESENTATIVE PHOTOS	DESCRIPTION (CURRENT WATERWAY HEALTH)	REPRESENTATIVE PHOTOS	DESCRIPTION (FUTURE WATERWAY HEALTH)
		▪ Moderate water quality (no sites in this reach, based on catchment results)		▪ 85-90% compliance with Guideline Water Quality Values (nb. Consistently meets WQOs)

4.8.2 Riparian Buffers

The Redland City Council's Waterways, Wetlands and Moreton Bay Overlay code specifies the minimum buffer distances listed in **Table 4.14.**

Table 4.14 Redland City Council minimum buffer distances and revegetation requirements

WATERWAY CATEGORY	BUFFER REQUIREMENTS	RIPARIAN VEGETATION REQUIREMENTS	
		CORE AND FORESHORE	OUTER
Major Waterway	(1) 100 metres measured from top bank, except where there is- Tidal influence (See Note 1), in which case 100 metres from the line of Highest Astronomical Tide (HAT) or the top of the bank whichever is the greater; or No definable bank, in which case 100 metres measured from the mid point between the 1 percent AEP (100 year ARI) lines on both sides of the waterway as illustrated in Diagram 1 – Determining Buffer Distances Where No Definable Bank.	40 metres	60 metres
Minor Waterway	(1) 60 metres measured from the top of bank, except where there is - No definable bank, in which case 100 metres measured from the mid point between the 1 percent AEP (100 year ARI) lines on both sides of the waterway as illustrated in Diagram 1 – Determining Buffer Distances Where No Definable Bank.	40 metres	20 metres

Source:
Redlands Planning Scheme Version 2 (2008): Part 5 – Overlays, Division 12 – Waterways, Wetlands and Moreton Bay Overlay – Page 11

Existing development within the study area has already encroached within the prescribed buffers in the Redlands Planning Scheme. Therefore these buffers are generally unachievable along most of both Native Dog and Torquay Creeks. Redlands Planning Scheme does not differentiate in the recommended buffers for different reach types.

However recommended buffers for estuarine wetlands are often larger due to the highly sensitive nature of these ecosystems. For example, the Department of Environment and Natural Resources (DERM) and the Department of Primary Industries (DPI) both recommend 100m buffers to tidal reaches (**Table 4.15**). Conversely, lower order branches of the catchment have lower recommended riparian buffers under DERM vegetation codes and DPI Fisheries Guidelines (**Table 6.3**).

The recommended buffers outlined in **Table 4.15** below (refer also **Appendix J**) for the Native Dog and Torquay Creeks consider the ecological function that each reach can feasibly provide. In particular, buffering for water quality, habitat for aquatic and terrestrial fauna and connectivity are considered to primary objectives of the riparian buffers for these creeks.

Table 4.15 Recommended Riparian Buffers

REACH	Existing Width (m)	RECOMMENDED Buffer Distances (m)			Proposed Buffer (m)
		RCC	DERM	DPI	
ND1	5 - 20	60	25	50	60
ND2	10 - 200	60	25	50	60
ND3	15 - 500	60	25	50	60
ND4	25 - 250	60	25	50	60
TOR1	0 - 300	60	50	50	60
TOR2	30 - 75	60	100	100	100
TOR3	5- 300	60	25	50	60
TOR4	20 - 50	60	100	100	100

Notes

1. RCC: Redland City Council Planning Scheme (2008)
2. DERM: EPA (2001) and DNRW (2006)
3. DPI: DPI (2000)

The recommended buffer widths outlined above take into account ecosystem function associated with riparian habitat and does not consider buffer widths for water quality purposes. The use of buffers for water quality treatment purposes are identified and discussed separately in the water quality modelling sections of this report.

4.9 Environmental Values and Water Quality Objectives

4.9.1 Environmental Values

Environmental Values (EVs) reflect the ecological, social and economic values and uses of a waterway. They give an indication of the environmental qualities, characteristics or uses that are recognised by the community as needing protection. The determination of EVs is a vital component in the planning of creek catchments as they assist in prioritising management actions.

The Environmental Values recommended by this study are those specified under Schedule 1 of the EPP (Water), specifically the *Redland Creeks Environmental Values and Water Quality Objectives [Basin No.145 (part)*] (EPA, 2007a) and *Logan River Environmental Values and Water Quality Objectives – Basin No. 145(part)* (EPA, 2007b).

The EVs identified in the EPP (Water) for the Redland Creeks catchments (which includes Torquay Creek) and the Logan River catchment (which includes Native Dog Creek) for freshwater and estuarine tributaries are identified in **Table 4.16**.

For other EVs related to health, amenity, water supply and animal and crop health, guidelines from ANZECC, NHMRC and other sources are recommended, as set out in **Table 4.16.**

Table 4.16 Environmental Values from EPP (Water) 1997

ENVIRONMENTAL VALUE		RELEVANT CREEK	WQOS
	Aquatic ecosystems	Native Dog Creek Torquay Creek	Physiochemical WQOs: refer to **Sections 7.2** and **7.3.** Biological: refer to **Section 7.3**. Riparian WQOs: as per EPP (Water). Target conditions are outlined in **Section 6**.
	Human consumer	Native Dog Creek Torquay Creek	Objectives as per ANZECC (2000) and *Food Standards Code*, Australia New Zealand Food Authority (1996) and updates.
	Primary recreation	Native Dog Creek Torquay Creek	Objectives as per ANZECC (2000)
	Secondary recreation	Native Dog Creek Torquay	Objectives as per ANZECC (2000)

ENVIRONMENTAL VALUE		RELEVANT CREEK	WQOS
		Creek	
	Visual recreation	Native Dog Creek Torquay Creek	Objectives as per ANZECC (2000)
	Cultural and spiritual values	Native Dog Creek Torquay Creek	Protect and restore indigenous and non-indigenous cultural heritage consistent with relevant policies and plans (as per EPP (Water)).
	Aquaculture	Native Dog Creek Torquay Creek	
	Irrigation	Native Dog Creek Torquay Creek	Objectives as per ANZECC (2000)
	Stock water	Native Dog Creek Torquay Creek	Objectives as per ANZECC (2000)
	Farm supply	Native Dog Creek Torquay Creek	Objectives as per ANZECC (2000)
	Oystering	Native Dog Creek	Objectives as per AWQG (2000) and Australia New Zealand Food Standards Code, Food Standards Australia New Zealand, 2007 and updates. Fish and Crab Health Health of individuals – absence of pollutant induced disease or deformity. Tissue – no evidence of pollutant accumulation.

ENVIRONMENTAL VALUE		RELEVANT CREEK	WQOS
	Seagrass	Torquay Creek	The minimum WQOs[1] to restore seagrass where it has been lost are: ▪ median TSS <10 mg/L; ▪ median secchi depth >1.7m; and ▪ light attenuation coefficient >0.9. In areas where seagrass is intact, maintain existing water quality. Therefore the WQOs are: ▪ local TSS, turbidity, secchi and light attenuation is maintained; and ▪ local seagrass distribution and composition is maintained, as measured by: ▪ extent of seagrass, ▪ species diversity, and ▪ seagrass depth limit.

Notes

1. Sourced from EPP (Water) EV and WQOs of the Logan River Estuary Catchment Table 2; Water type "Marine/estuarine waters with seagrass EV chosen"
2. EPP (Water) 2009.

4.9.2 Water Quality Objectives

Introduction

The EPP (Water) classifies water into four broad categories:

- Coastal / marine waters (open coastal, enclosed coastal waters/lower estuary);
- Estuarine waters (upper estuary, middle estuary, tidal canals/constructed estuaries/marinas and boat harbours);
- Lowland freshwaters (<150m) (lowland freshwaters, wallum/tannin-stained streams, coastal streams); and
- Upland freshwater (>150m).

The EPP (Water) attributes water quality objectives (WQOs) to waterways based on these water types. Three levels of aquatic ecosystem protection are ascribed to different waters under the National Water Quality Management Strategy (NWQMS) according to their ecological condition. These are as follows:

- High ecological value (HEV);
- Slightly to moderately disturbed (SMD); and

- Highly disturbed (HD) waters.

Neither Native Dog Creek nor Torquay Creek is located in areas of high ecological value. Therefore, as detailed in **Section 3.1** of both EPA (2007a) and EPA (2007b), they can be classified as Slightly to Moderately Disturbed (SMD) waters.

The physico-chemical and biological guidelines for SMD waters aim for median values within the 20th and 80th percentiles of reference values. The relevant EPP (Water) WQO at a particular site is determined by the water type and the level of aquatic ecosystem protection.

Table 4.17 defines each reach under the EPP (Water) type classification and determines its aquatic ecosystem protection level. These are relevant for comparison of monitoring results undertaken in the waterway against existing guideline values within the EPP (Water) and Redlands Planning Scheme.

Table 4.17 Reaches, water quality sites and corresponding classifications and levels

Reach	Water Quality Site	Waterway Type (EPP Water)	Aquatic Ecosystem Protection[1]	Catchment
Reach ND1	--	Lowland Freshwaters – lowland streams	SMD[2]	Logan River
Reach ND2	ND1, ND2, ND3	Lowland Freshwaters – lowland streams / coastal streams (all monitoring sites are 'lowland streams')	SMD	Logan River
Reach ND3	ND4, ND5	Lowland Freshwaters – lowland streams	SMD	Logan River
Reach ND4	ND6	Lowland Freshwaters – lowland streams	SMD	Logan River
Logan Shire	NAT1	Lowland Freshwaters – lowland streams	SMD	Logan River
Logan Shire	NAT2	Lowland Freshwaters – lowland streams	SMD	Logan River
Logan Shire	NAT3	Lowland Freshwaters – lowland streams	SMD	Logan River
Reach	TC1	Lowland Freshwaters –	SMD	Redland Creeks

Reach	Water Quality Site	Waterway Type (EPP Water)	Aquatic Ecosystem Protection[1]	Catchment
TOR1		coastal stream / lowland streams		
Reach TOR2	TC3, TC2	Lowland Freshwaters – coastal stream / lowland streams	SMD	Redland Creeks
Reach TOR3	--	Lowland Freshwaters – coastal stream	SMD	Redland Creeks
Reach TOR4	--	Marine/Estuarine waters – middle estuary	SMD	Redland Creeks

Notes:

1. Levels or protection defined in the National Water Quality Management Strategy (NWQMS)
2. Slightly to moderately disturbed

Local WQOs

Available water quality data was limited for both Native Dog Creek and Torquay as discussed previously. However, the available water quality results have been compared to relevant water quality guidelines as outlined in **Table 4.18**, **Table 4.19** and **Table 4.20**. The guidelines values as presented are based on the EPP (Water) values in addition with the Redland Planning Scheme – Schedule 11 – Water Quality Objectives. The proposed WQO values identified within each table have been taken from both the EPP (Water) and Redland Planning Scheme and has been selected based on what is considered to be the most appropriate value. EPP (Water) outlines the relevant water quality objectives (WQO) as follows: -

> *"Section 3.1 (Tables 2 to 4) outlines WQOs to protect the aquatic ecosystem EV. The aquatic ecosystem EV is a default applying to all waters, and therefore the WQOs for aquatic ecosystems form the minimum WQOs for all waters. Where no human use EVs are identified, the WQOs identified for aquatic ecosystem protection remain applicable."*

Table 4.17 presents the values for adoption as WQOs for both the Native Dog Creek and Torquay Creek catchments. These values are to be used within the waterways management plan project. As the EPP (Water) is subordinate legislation under the *Environment Protection Act 1994*, these WQOs are the default guidelines in the absence of suitable local reference sites.

Table 4.18 Comparison of Water Quality Results from Native Dog Creek to Guideline WQOs (EPP (Water) – Lowland Freshwater – to protect aquatic ecosystem - Slightly to Moderately Disturbed)

SITE	Chlorophyll-a (ug/L)	DO (%sat)	pH	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTU)	Secchi Depth (m)	EC (uS/cm)	OIL AND GREASE	FAECAL COLIFORMS
ND1	NA	60.0	6.5	4.5	0.89	213	16.0	N/A	524.5	N/A	N/A
ND2	NA	17.1	6.1	1.1	0.07*	13*	39.0*	N/A	343.0	N/A	N/A
ND3	NA	56.9	6.5	3.8	0.74	102	23.0*	N/A	519.5	N/A	N/A
ND4	NA	41.6	6.5	1.8	0.14	227	360.0	N/A	315.0	N/A	N/A
ND5	NA	69.8	6.6	3.5	0.62	58	54.0	N/A	424.0	N/A	N/A
ND6	NA	48.1	6.8	0.7	0.05	66	99.0	N/A	280.0	N/A	N/A
NAT1	15.4	17.1	5.9	1.0	0.2	17	29.7*	0.3	295.0	N/A	N/A
NAT2	15.3	49.5	6.5	1.2	0.5	14*	40.0*	0.3	355.0	N/A	N/A
NAT3	2.7	46.5	5.4	0.7	0.1	16	37.0*	0.3	143.5	N/A	N/A
WATER QUALITY OBJECTIVES											
EPP (Water) WQOs[1]	5	85-110	6.5 – 8.0	0.5	0.05	6	50	NA	NA	NA	NA
Redland Planning Scheme Objectives	8	80-105	6.5 – 8.0	0.65	0.07	15	20	> 0.2m	400	No visible film or colour	< 1000 org/100mL and < 230 entercocci org/100mL
Proposed	**8 ug/L**	**85 – 110 %**	**6.5 – 8.0**	**0.5 mg/L**	**0.05 mg/L**	**6 mg/L**	**20 NTU**	**> 0.2 m**	**400 uS/cm**	**No visible film or colour**	**< 1000 org/100mL and < 230 entercocci org /100mL**

Note:

[1]Lowland freshwater (comprising lowland streams, wallum/tannin stained streams and coastal streams) (Logan River Environmental Values and Water Quality Objectives); Orange values do not comply with water quality objectives;

*value complies with one water quality objective.

Table 4.19 WQOs for Torquay Creek – Southern Redland Bay Catchment (Part 22) – Lowland Freshwater

SITE	Chlorophyll-a (ug/L)	DO (mg/L)	DO (%sat)	pH	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTU)	Secchi Depth (m)	EC (uS/cm)	OIL AND GREASE	FAECAL COLIFORMS
TC1	N/A	3.3	33.4	5.4	0.5	0.03	5	7.5	N/A	262	N/A	N/A
TC2	N/A	4.2	42.5	5.6	0.8	0.05	16	74.0	N/A	604.0	N/A	N/A
TC3	N/A	2.8	28.0	6.3	0.7	0.05	9*	64.5	N/A	382.0	N/A	N/A
WATER QUALITY OBJECTIVES												
EPP Water RedlandCreeks WQOs –	< 5ug/L	N/A	85 - 110	6.5 – 8.0	< 0.5mg/L	< 0.05mg/L	< 6mg/L	< 50 NTU	N/A	---	N/A	N/A
Redlands Planning Scheme – Schedule 11 – Water Quality Objectives (Table 4)	8 ug/L	N/A	80 – 105	6.5 – 8.0	0.65mg/L	0.07 mg/L	15 mg/L	20 NTU	> 0.2m	< 400	No visible film or colour	< 1000 org/100mL And < 230 entercocci org / 100mL
Proposed	**5 ug/L**	**N/A**	**85 – 110 %**	**6.5 – 8.0**	**0.65mg/L**	**0.05 mg/L**	**6 mg/L**	**20 NTU**	**0.2 m**	**400 uS/cm**	**No visible film or colour**	**< 1000 org/100mL and < 230 E org/100mL**

Table 4.20 WQOs for Torquay Creek – Southern Redland Bay Catchment (Part 22) – Marine Estuarine – Middle Estuary (Area S2 – Southern Bay)

SITE	Chlorophyll -a (ug/L)	DO (%sat)	pH	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTU)	Secchi Depth (m)	EC (uS/cm)	OIL AND GREASE	FAECAL COLIFORMS	SEAGRASS
No sites available	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WATER QUALITY OBJECTIVES												
EPP Water RedlandCreeks WQOs –	< 2 ug/L	95% - 105% saturation	8.1- 8.4	< 0.2mg/L	< 0.024mg/L	N/A	< 7 NTU	> 1.2m	---	n/a	n/a	
Redlands Planning Scheme – Schedule 11 – Water Quality Objectives (Table 4)	8 ug/L	80 – 105	6.5 – 8.0	0.65mg/L	0.07 mg/L	15 mg/L	20 NTU	> 0.2m	< 400	No visible film or colour	< 1000org/100mL And < 230 entercocci org / 100mL	Maintain the existing seagrass depth limit for *Zostera muelleri* of -1.3m AHD (50th percentile)
Proposed	**2 ug/L**	**95 – 105%**	**8.1 – 8.4**	**0.2 mg/L**	**0.024 mg/L**	**15 mg/L**	**7 NTU**	**1.2m**	**N/A**	**No visible film or colour**	**< 1000org/100 mL And < 230 entercocci org / 100mL**	**Maintain the existing seagrass depth limit for *Zostera muelleri* of -1.3m AHD (50th percentile)**

4.9.3 Water Quality Objectives Summary

Table 4.21 summarises the proposed water quality objectives for Native Dog Creek and Torquay Creek.

Table 4.21 Proposed Water Quality Objectives

INDICATOR	LOWLAND FRESHWATER	MIDDLE ESTUARY
PHYSIOCHEMICAL		
Chlorophyll a (mg/L)	5	2
DO (% saturation)	85 - 110	95 – 105
pH	6.5 – 8.0	8.1 – 8.4
TN (mg/L)	0.5	0.2
TP (mg/L)	0.05	0.024
TSS (mg/L)	6	15
Turbidity (NTU)	50	7
Secchi depth (m)	0.2m	1.2m
Conductivity (mS/cm)	< 400	-
FISH		
Percent of native species expected (PONSE)	80%	80%
Fish assemblage O/E	0.8 – 1.2	0.8 – 1.2
% exotic individuals	< 5%	< 5%
MACROINVERTEBRATES		
Richness (family) (20th %ile)	17	--
PET taxa (20th %ile)	3	--
SIGNAL score (1 = most tolerant, 10 = most sensitive) (20th %ile)	3.5	--
AQUATIC MACROPHYTES		
Introduced individuals	< 5% low biomass	--
ECOLOGICAL RPOCESSES		
Gross Primary Production (GPP) (gC/m^2/day)	0.43	--
Respiration (R24) (gC/m^2/day)	0.29	--
Carbon isotope ratio measure (Del ^{13}C) (delta units)	-45	--
Chl a (mg Chl a/m^2/day)	11.1	--
NUTRIENT CYCLING		
Algal bioassay (N+P)/C	19	3.5
Nitrogen isotope ratio measures (Del ^{13}C) (delta units)	2.9	5
SEAGRASS		
Seagrass limit	--	Maintain the existing seagrass depth limit for Zostera muelleri of – 1.3m AHD (50th %)
Restoring seagrass where lost	--	Secchi depth 1.7m

4.10 Monitoring Program

4.10.1 Background and Objectives

Water quality monitoring is an important component of the Waterway Management Plan that this waterway health assessment feeds into. The objectives of this proposed monitoring program are to:

- Gather baseline to determine a good understanding of the current state of Native Dog Creek and Torquay Creek;
- Detect spatial and temporal trends;
- Establish cause and effect relationships between risk factors and waterway responses (biotic and abiotic);
- Assess the suitability of water quality to support identified environmental values (public health, ecology, landscape, boating etc);
- Separate local (proximal) changes from large scale (catchment-wide) changes;
- Compare to other waterways of similar classification (e.g. lowland coastal streams or other streams within the Southern Redland Bay catchment);
- Assess the appropriateness of the proposed local WQOs; and
- Determine if management actions implemented are assisting in achieving the WQOs.

ANZECC & ARMCANZ (2000) sets out recommendations for monitoring ecosystem condition at High Ecological Value (HEV) and Significantly-Moderately Disturbed (SMD) sites by sampling 4 to 6 of the following:

- Whole effluent toxicity testing (acute or chronic chemical toxicity)
- Water and sediment physiochemistry (e.g. temperature, pH, nutrients)
- An early detection indicator for water or sediment (e.g. macroinvertebrate community structure)
- A quantitative biodiversity indicator (e.g. fish assemblages)
- A community metabolism indicator (e.g. gross primary production)
- A rapid biological assessment indicator (e.g. macroinvertebrate community structure).

Existing and proposed new sites need to use some (and preferably all) EHMP indicators to meet the ANZECC criteria. These will complement the existing water quality sampling sites that Redland City Council undertake on Native Dog Creek.

4.10.2 Recommendations

Native Dog Creek

To collect data comparable to other sites in south east Queensland, it is recommended that: -

- Native Dog Creek monitoring site ND1 to remain where it is currently located;
- Native Dog Creek monitoring site ND2 to be moved to the west to be located on Reach ND1;
- Native Dog Creek monitoring site ND3 to be moved to the west to be located on Reach ND2 but upstream of development on Sunrise Street;
- Native Dog Creek monitoring site ND4 to remain where it is currently located;
- Native Dog Creek monitoring site ND5 to remain where it is currently located; and
- Native Dog Creek monitoring site ND6 to be relocated to be on Reach ND4 (at approximately the Flindersia Drive roundabout).

The full suite of parameters sampled in the EHMP program are monitored at sites ND1 To ND6 (refer to Table 4.21 below).

Torquay Creek

To collect data comparable to other sites in south east Queensland, it is recommended that:

- Torquay Creek monitoring site TC1 to remain where it is currently located;
- Torquay Creek monitoring site TC2 to remain where it is currently located;
- Torquay Creek monitoring site TC3 to remain where it is currently located;
- Torquay Creek monitoring site to be added in Reach TOR4, possibly adjacent to Talburpin Park; and
- Torquay Creek monitoring site to be added in Reach TOR3, possibly at the end of Kidd Street (alternatively, Unwin Street).

The full suite of parameters sampled in the EHMP program are monitored at the Torquay Creek sites (refer to **Table 4.21**). In addition, the following additional monitoring is recommended for Torquay Creek Site 1 (Refer **Table 4.21**):

- Seagrass extent and depth mapping is undertaken near the mouth of Torquay Creek;
- Event monitoring to investigate stimulatory effects of events on algal growth potential and apparent recovery of parameters including turbidity and total suspended solids. It is suggested that the storm event monitoring in **Table 4.21** is carried out immediately after significant storm events (greater than 40mm) until 2 weeks after the event. Alternatively, if chlorophyll a levels have not decreased by that time, monitoring should continue until this occurs. A longitudinal profile should be analysed over time to monitor the impacts associated with storm events and the apparent recovery. Once a sufficient database has

been gathered on the impacts and recovery from storms and the observed recovery appears adequate, this monitoring could cease;

- Sediment level monitoring to monitor potential increases in sedimentation in the creek; and
- Particle size analysis of surface sediments to investigate potential changes to benthic macroinvertebrate habitat in the case of increasing sedimentation.

Table 4.22 Freshwater Monitoring Parameters

MONITORING LOCATION	PARAMETERS	FREQUENCY
Sites ND1 to ND6 on Native Dog Creek and Site 2 & 3 on Torquay Creek	Chlorophyll a Conductivity Dissolved Oxygen (mg/L and % saturation) **coli** Faecal coliforms pH Temperature Total Nitrogen Total Phosphorus Suspended Solids Turbidity	6 per year
	Biota (fish, macroinvertebrates)	Biannually
	Nutrient cycling N stable isotope signature bioassay of nutrients	Biannually
	Ecosystem processes algal growth carbon stable isotope signature benthic metabolism (respiration and GPP)	Biannually
	Riparian vegetation: cover quality weed cover revegetation	Annually
Storm Event Monitoring at ND1 and ND5 and Site 2 on Torquay Creek	Chlorophyll a Conductivity Dissolved Oxygen (mg/L and % saturation) Faecal coliforms	1 day after event (>40mm rainfall) 1 week after event 2 weeks after event

MONITORING LOCATION	PARAMETERS	FREQUENCY
	Total Nitrogen Total Phosphorus Suspended Solids Turbidity	
Sediment Depth Sampling on ND1 and Site 2 on Torquay Creek	Profiles to monitor sediment level in case of increasing sedimentation Particle size analysis of surface sediments	Annually

Table 4.23 Estuarine Monitoring Parameters

MONITORING LOCATION	PARAMETERS	FREQUENCY
Site 1 on Torquay Creek	Chlorophyll a Conductivity Dissolved Oxygen (mg/L and % saturation) E. coli Faecal coliforms pH Temperature Total Nitrogen Total Phosphorus Suspended Solids Turbidity	Monthly
	Biota (fish)	Biannually
	Seagrass depth range at the lower estuary site (MCC4) Seagrass extent	Biannually (ideally same month each year)
	Intertidal and foreshore vegetation	Annually (cover) Biennially (quality)

4.11 Management Action Plan

4.11.1 Introduction

A set of rehabilitation management principles was developed to guide the management actions for the catchments, to achieve the feasible target conditions. These principles are to:

- Achieve the Feasible Target Conditions (**Section 4.8**);
- Create a waterways network with riparian corridors connecting to bushland and of sufficient width to support wildlife movement;
- Increase natural diversity within the riparian corridors through weed control; and
- Improve water quality by:
- Decreasing channel erosion; and
- Riparian revegetation.

4.11.2 Management Actions

Table 4.24 summarises the management actions recommended in order to achieve the Feasible Target Conditions and their indicative priorities. These priorities were developed with consideration of the following factors:

- The environmental values of the catchments;
- Risks to these values (e.g. weeds, erosion); and
- The degree to which the waterways could be improved (i.e. feasible target condition).

Table 4.24 Management Actions and Priorities

Principle	Action	Priority
Create a waterways network with riparian corridors connecting to bushland and of sufficient width to support wildlife movement	Retain existing riparian vegetation.	High
	Protect and rehabilitate the proposed buffers.	High
	Undertake riparian revegetation in priority areas (including reaches ND1, ND2, ND3, TOR1 and TOR3).	High
	Ensure buffer widths are dedicated for future developments.	High
	Ensure Council planning documents require dedication of buffers, and rehabilitation of those dedicated buffers.	High
	Undertake community awareness programs and/or modify existing extension programs (Rural Support, Land for Wildlife, Waterway Extension) in each catchment on weed management, fertiliser use, stormwater runoff etc. This should focus on properties adjoining proposed buffers.	Moderate
	Enhance longitudinal and latitudinal connectivity to surrounding bushland areas, particularly to the large bushland area west of the Torquay Creek catchment.	Moderate
	Where road crossings require upgrading, integrate fauna movement (both terrestrial, i.e. fauna underpasses, and aquatic, i.e. 'fish-friendly' crossings) in their design.	Moderate
	Exclude stock from riparian areas by fencing creeks in rural areas.	Moderate
Increase natural diversity within the riparian corridors through weed control	Undertake weed control in Reaches ND1,ND2, ND3, TOR1 and TOR3(priority weeds include include Camphor Laurel, Devil's Fig, Lantana, Easter Cassia, Guinea Grass, and Singapore Daisy).	High
	Undertake weed control in Reaches ND4, TOR2, TOR4 (priority weeds include include Camphor Laurel, Devil's Fig, Lantana, Easter Cassia, Guinea Grass, and Singapore Daisy).	Moderate
Improve water quality by: decreasing channel erosion; and riparian	Undertake erosion control works in priority areas (including sites 1, 2, 4 and 5on Native Dog	High

Principle	Action	Priority
revegetation	Creek)	
	Undertake erosion control works in otherareas (including site 3 on Native Dog Creek and sites 6, 7 and 8 on Torquay Creek	Moderate
	Protect and rehabilitate the proposedbuffers	High
	Investigate potential pollution “hot spots”or point sources (such as the poultry farm in Native Dog Creek catchment)	High
	Undertake water quality monitoring asoutlined in Section 8 to develop a set of baseline values for both creeks.	Moderate
	Ensure Water Sensitive Urban Design(WSUD) is included in new developments (e.g. water quality, flow, stormwater capture and re-use).	High
	Ensure that agricultural land management practices are best practices, and carry out education program for rural land owners.	Moderate

4.12 Conclusions and Recommendations

4.12.1 Conclusions

The environmental and waterway assessments undertaken for this study have incorporated a range or approaches and techniques including:

- Desktop assessments comprising:
  - Literature review;
  - Analysis of geology, soils, landscape and Land use spatial information;
  - Assessment of existing water quality data.
- Reach classification of each waterway;
- Waterway health assessments including:
  - Ground-truthing of the spatial information;
  - Geomorphic assessment based on the Index of Stream Condition (ISC) system;
  - Ecological assessments;
  - Evaluating the ecological values of the waterways and risks to those values.
- Setting Water Quality Objectives (WQOs) (for protection of aquatic ecosystems) as benchmarks for Council planning strategies;

- Identification of recommended water quality monitoring requirements;
- Defining current condition and feasible target condition for each reach; and
- Determining management actions and indicative priorities to improve the health of study waterways and achieve the feasible target conditions.

Native Dog Creek and Torquay Creek have been impacted mainly by vegetation clearing, agriculture, urban development and major roads. Riparian and catchment vegetation has been cleared in parts of both catchments for agricultural and urban development. Both catchments contain areas of high habitat value, including remnant terrestrial vegetation, intertidal vegetation (Torquay Creek), freshwater wetlands, and forests, including Eucalypt forest and small areas of rainforest. However, extensive weeds exist throughout the riparian zones of both waterways.

Barriers to connectivity exist in both catchments, including roads and culverts (barriers to both aquatic and terrestrial fauna) and vegetation clearing (fragmenting terrestrial habitat). Rehabilitation works will enhance both the longitudinal connectivity (along the waterways) and latitudinal connectivity to surrounding bushland areas, particularly to the large bushland area west of the Torquay Creek catchment.

Desirable rehabilitation actions include riparian revegetation and weed control, erosion control, and education programs to catchment residents (particularly those adjacent to the riparian buffers) on weed management, fertiliser use and stormwater runoff, and to agricultural land owners on best practices. Retention and rehabilitation of the proposed buffers is essential to protecting and enhancing the ecological health of the waterways. Some clearing and development has already taken place within these buffers.

Water Quality – Native Dog Creek

Water quality data are limited, but preliminary conclusions are that Native Dog Creek contains very high nutrient and sediment concentrations. The highest concentrations were recorded during a period of high rainfall. Due to the particularly high concentrations of nutrients and poor correlation between nutrients and turbidity / suspended solids, it appears that the water quality degradation is primarily caused by a point source of pollution, which may be related to the poultry farm in the upper reaches of this catchment.

While the available datasets are limited, fish and macroinvertebrate monitoring also indicate Native Dog Creek is degraded, with relatively low diversity and no sensitive taxa observed.

In light of the available datasets and limited water quality data, further sampling is likely to be required to more accurately draw conclusions from the data sets as well as better quantifying and assessing the origin of the high nutrient concentrations.

Water Quality – Torquay Creek

Water quality data in Torquay Creek is also limited, but indicates the waterway is close to achieving the WQOs (although dissolved oxygen concentrations were very low). It does contain elevated total nitrogen concentrations, although much lower than Native Dog Creek.

A monitoring program has been recommended to address the limitations of the water quality dataset.

The scope of this Waterway Health Assessment report does not include actions to improve pollutant sources, but some of the proposed actions will impact water quality, such as erosion control. Riparian rehabilitation works are likely to lead to improved overall waterway health, by stabilising the banks, improving vegetation condition and habitat resources, and improving habitat connectivity.

4.12.2 Recommendations

It is recommended that Council:

- Dedicate, maintain and / or rehabilitate the proposed buffers widths (**Table 4.15**) as natural areas to achieve the target conditions outlined in **Section 4.8**;
- Use planning mechanisms to allow dedication of land within the proposed buffer widths and to allow for conservation works to be undertaken within areas that may not be dedicated;
- Adopt the additional monitoring items in the proposed Monitoring Program (**Section 4.10**);
- Retain gullies upstream of the waterways (i.e. confined upper drainage lines) as naturalised channels; and
- Undertake the actions as outlined in the Management Action Plan (**Section 4.11**).

5. WATER QUALITY MODELLING

5.1 Introduction

O2 Environmental was subcontracted by EnGenY on behalf of Redlands City Council to carry out a water quality assessment and prepare a water quality management plan for Native Dog Creek and Torquay Creek Catchments. These catchments are two of 16 major catchments within the Redlands Council area. This assessment and plan forms part of a Redlands Integrated Water Management Plan.

The objectives of this assessment and water quality management plan were to:

- Identify suitable water quality objectives receiving waters.
- Assess impact of likely increase in urbanisation of both catchments on nutrient and suspended solid loads and concentrations.
- Identify stormwater quality improvement devices (SQIDS) (including water sensitive urban design (WSUD)) required to meet adopted objectives for the ultimate catchment (maximum likely urbanisation), and demonstrate compliance using modelling.
- Provide life cycle costing of required SQIDS.

5.2 Need for Assessment

Redlands City Council has made a number of commitments in various policies and planning instruments to manage environmental impacts of urban stormwater runoff on receiving waters, including:

- Planning Scheme Policy 14 (Waterways, Wetlands and Moreton Bay) Section 14.6.1 of this policy states that “all run-off to receiving waters should enhance and protect the water quality of receiving waters, being waterways, wetlands and Moreton Bay”.

Redland’s water policy is consistent with the requirements of Section 42 of the *Environmental Protection (Water) Policy 1997* that requires any local government that has an urban stormwater system to “*develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system*”.

New developments are required to include Water Sensitive Urban Design (WSUD) including SQID measures into layouts and conceptually demonstrate, generally using MUSIC modelling, that the proposed treatment devices will protect receiving environments. Considering this requirement, any increased urbanisation is not expected to significantly increase loads or concentration of nutrients in discharge water. The majority of urban areas in each catchment have been previously developed using traditional stormwater drainage that may or may not incorporate attenuation or treatment of water prior to discharge.

5.3 Water Quality Management Plan Strategy

The design principles that were considered in developing the location and type of and non-built options in MUSIC modeling are outlined in this section. These design principles will be required to be applied again at the constraints and opportunities assessment and detail design stages to ensure that management options implemented are consistent with best management practices.

Design principles for future plans should be uniformly adopted in catchment management plans prepared for other Redland City Council catchments.

5.3.1 Reduce Connectivity of Impervious Areas

The effective impervious area in any catchment is calculated as the percentage of total area comprised of impervious areas that are directly connected to waterways by pipes and channels (Taylor 2005). The effective impervious area in a catchment is a strong predictor of the cumulative impact of altered hydrology, water quality and habitat quality on ecological health of waterways as a result of urbanisation (Walsh et al 2004).

Where possible, impervious areas were separated from receiving water using devices such as filter zones, swales or other vegetated areas.

5.3.2 Integrated Water Treatment Infrastructure throughout the catchment

Collection and treatment of stormwater at source is a key Water Sensitive Urban Design Principle (Wong 2006). Although it was not able to be effectively demonstrated on conceptual drawings or conceptual MUSIC modeling contained in this report, bioretention devices should integrated throughout the catchment and located as closely as possible to the source. It will be important that this is considered at detail engineering calculation and design stage.

Some advantages of integrating devices throughout the catchment at key nodes in preference to 'end of pipe' controls include:

- End of pipe treatment devices are often difficult to install, as stormwater outlets are commonly located in the bed and banks of waterways.
- Integration of stormwater into urban and commercial design allows the re-use of captured water to support growth of landscape design elements, providing a social benefit.
- Increases visual connectivity between human activity (pollution, littering etc.,) and receiving waterways (Wong 2006)

5.3.3 Utilise Rainwater Tanks

Stormwater runoff from roofs contains high levels of nitrogen and contributes significant nitrogenous loads to receiving waters (refer to **Figure 5.5**). With each house having an approximate roof area of 200m^2, and lot sizes in some instance being as small as 600m^2, roof runoff can comprise a high proportion of the effective impervious area in catchments.

Rainwater capture and re-use in toilet flushing and laundry provides a dual function of reducing discharge of nutrient rich water to waterways and reducing in a reduced need and cost of municipal water distribution. For new homes, all owners will effectively be required to install rainwater tanks to comply with legislated water savings targets outlined in Queensland Development Code Part MP4.2.

5.3.4 Achieve load based objectives prior to discharge to any waterway

Environmental Protection (Water) Policy 1997 states that requires any local government that has an urban stormwater system to "develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system". Waters are defined in the EPP Water Policy as all Queensland Waters, excluding only swimming pools, drinking water supplies, waste water storages and aquaculture ponds. To comply with this requirement, all stormwater treatment must be carried out prior to discharge to protect any natural or man made wetlands or ponds in existing waterways to ensure the environmental values of these waters are protected.

Installation of or reliance on any in-line device, whether soft devices such as wetlands or engineered structures such as bioretention basins, does not function to protect these waterways but relies on these waterways to treat waters prior to discharge to ultimate receiving waters, such as Moreton Bay.

5.3.5 Re-establish Riparian Buffer Zones

Riparian buffer zones provide a filter media that effectively captures suspended solids and associated nutrients from diffuse flow from various land uses. Additionally, stabilization of waterways with appropriate selection of riparian habitat results in an increase in aquatic and terrestrial habitat and may reduce risk of bank erosion.

5.4 Water Quality Objectives

Load based targets stipulated in the South East Queensland Regional Plan 2005-2026 Implementation Guideline No. 7 were adopted for discharge targets from urban areas. These targets are:

- 80% reduction in total suspended solids
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen

These targets were adopted after considering load based and concentration based targets, discussion and rationale for the adopted targets is provided below.

5.4.1 Concentration Based Targets

The Department of Environment and Resource Management (DERM) have scheduled concentration based Water Quality Objectives for Redlands Shire, including Torquay and Native Dog Creeks in the document "Redland Creeks Environmental Values and Water Quality Objectives" (EPA 2007). These objectives are concentration based target values for receiving waterways to protect Environmental Values under dry-weather conditions. Concentration based targets have previously been adopted by some as discharge criteria for stormwater, which is contrary to their intended application (EP (Water) Amendment Policy No 30 2006 no.1 p.13). Application of these targets to stormwater discharge is problematic for a number of reasons (SEQ Healthy Waterways 2007, et al):

- Pollutant concentrations in waterways are influenced by a wide range of factors including point source discharges and in-stream pollutant assimilation process that are not considered in MUSIC modeling;
- Application of dry weather targets established by EPA to storm flows considered by numerical monitoring is inappropriate;
- Additional temporal and repeat event based monitoring would be required to develop baseline water quality concentrations.

5.4.2 Load Based Targets

Load based targets represent achievable best practice for stormwater management infrastructure in SEQ climate and pollutant export conditions operating near the limit of its economic performance. Substantial extra cost is required to achieve low concentration based targets, at very small additional water quality benefit.

Load based targets are to be applied at discharge points of overland flow or piped flow to waterways. As agreed with council, Stormwater Quality Improvement Devices (SQIDs) are to be installed off-line from waterways where possible except in the case of degraded first order waterways that may be utilised if required. Locating devices off-line recognises that the waterways in the catchment have ecological importance and ensures that pre-treatment occurs prior to discharge to receiving waterways. Further, receiving waterways should not be relied upon as a treatment device to achieve load targets prior to discharge to Moreton Bay. This methodology is consistent with the requirements South East Queensland Regional Plan (2005-2026) Implementation Guideline No. 7 (Water sensitive urban design: Design objectives for urban stormwater management) (DIP 2008).

DIP (2008) includes quality objectives for (a) frequent flow management that requires capture and release of water from impervious areas and (b) waterway stability management that requires limitation of the post-development peak one year ARI event discharging to any waterway to the pre-development peak. Addressing these objectives effectively requires storage prior to discharge to any waterway (i.e., flood mitigation measures installed in waterways do not address these requirements). Assessment of these quality objectives was beyond the scope of this investigation.

5.5 Water Quality Assessment

Water quality modelling for Native Dog and Torquay Creek catchments was carried out using MUSIC and WaterCAST to assess the performance of Stormwater Quality Improvement Devices (SQIDs). WaterCAST was used to assess the possible water quality improvements by implementing riparian buffer zones (nb. retaining existing as well as implementing buffer zone areas).

All watercourses in rural residential areas were buffered with a 10m (from the top bank) riparian zone on each bank of the waterway. The 10m buffer was adopted purely for conceptual modelling for TP, TN and TSS reduction and does not take into account other ecosystems functions. This is mainly due to larger buffers being so cost restrictive to the community and Council that in our experience no actual implementation is undertaken. The 10m buffer will however: -

- Have a significant improvement on waterway health especially on small waterways (which is the largest % of waterways). Significant waterway health improvements were found to occur in streams “8-10m wide or less” through achieving 75% cover (Bunn et al 1999); and
- Prosser et al (1999) recommends a width of 10 metres for a forest buffer on low gradient land and 5 metres for a dense grass buffer on steeper riparian land for removing sheet flow sediments.

Three different types of SQIDs were used in urban areas as follows:

- Swales were modelled for all rural roads;
- Bio-retention devices were selected for all impervious urban areas. They were sized to 1.5% of the catchment size; and
- Rainwater tanks.

It is noted that while swales may not be suitable for all roads, swales will however be suitable for the majority of the road systems or at least can be retrofitted economically. As such, this approach is appropriate within the context of this study and conceptual model.

The objectives of the water quality assessment were derived from the project proposal, and meeting held with Redland City Council representatives on 1 July 2009. The overall aims of the water quality assessment objectives were to:

1. Assess the affect of increasing urbanisation in catchments on pollutant loads.
2. Assess if proposed SQIDs achieved load based targets for all urban areas.
3. Determine load reductions likely to be achieved by riparian zones in rural residential land uses, to improved end of catchment water quality.
4. Assess what load reductions are achieved by the consideration of rainwater tanks in modelling.
5. To inform priority infrastructure spending by identifying land uses with the greatest pollutant load reduction.

6. Assess if load reductions could be achieved without extensive retrofitting of existing urban areas with SQIDs.

5.6 Methodology

5.6.1 Load Impact of Increasing Urbanisation

Over the next 20 years significant areas of rural residential and forested areas in both of the subject catchments are zoned for urban development. Without treatment, conversion of rural residential and forested areas to urban will result in an increase in nutrient and suspended sediment loads to waterways and Moreton Bay.

Redlands City Council requires through the Planning Scheme that all new developments install stormwater quality improvement devices to meet load based objectives. MUSIC modeling was used to compare the nutrient and suspended sediment loads generated from an urban area with mitigation measures to achieve load based targets to unmitigated forested and rural residential areas. The results of this general analysis are presented in **Section 5.9.1**.

5.6.2 Assess if Proposed SQIDs Achieved Load Based Targets for all Urban Areas

The SQIDs that were adopted in the Stormwater Management Plan were developed in consultation with Redland City Council. Devices were sized using factors relating to catchment areas, and the effectiveness of the proposed devices assessed using MUSIC modeling.

MUSIC models for both Native Dog Creek and Torquay Creek catchments were run using the ultimate land-use. To treat water from all urban areas all urban stormwater was directed to bio-retention basins (sized to 1.5% of catchments) with coarse sediment forebays. Prior to discharge to bio-retention basins, roof water was directed to rainwater tanks for re-uses in houses and road runoff from major roads was conveyed through grass swales. Rainwater tanks were modeled considering likely uptake in new and existing houses (nb - For new homes, all owners will effectively be required to install rainwater tanks to comply with legislated water savings targets outlined in Queensland Development Code Part MP4.2).

MUSIC inputs for all source and treatment nodes for Native Dog Creek Catchment and Torquay Creek Catchments are provided in **Appendix O** and **Appendix P** respectively.

Results of load reductions achieved in urban areas and assessment of compliance with load reduction targets are provided in **Section 5.9**.

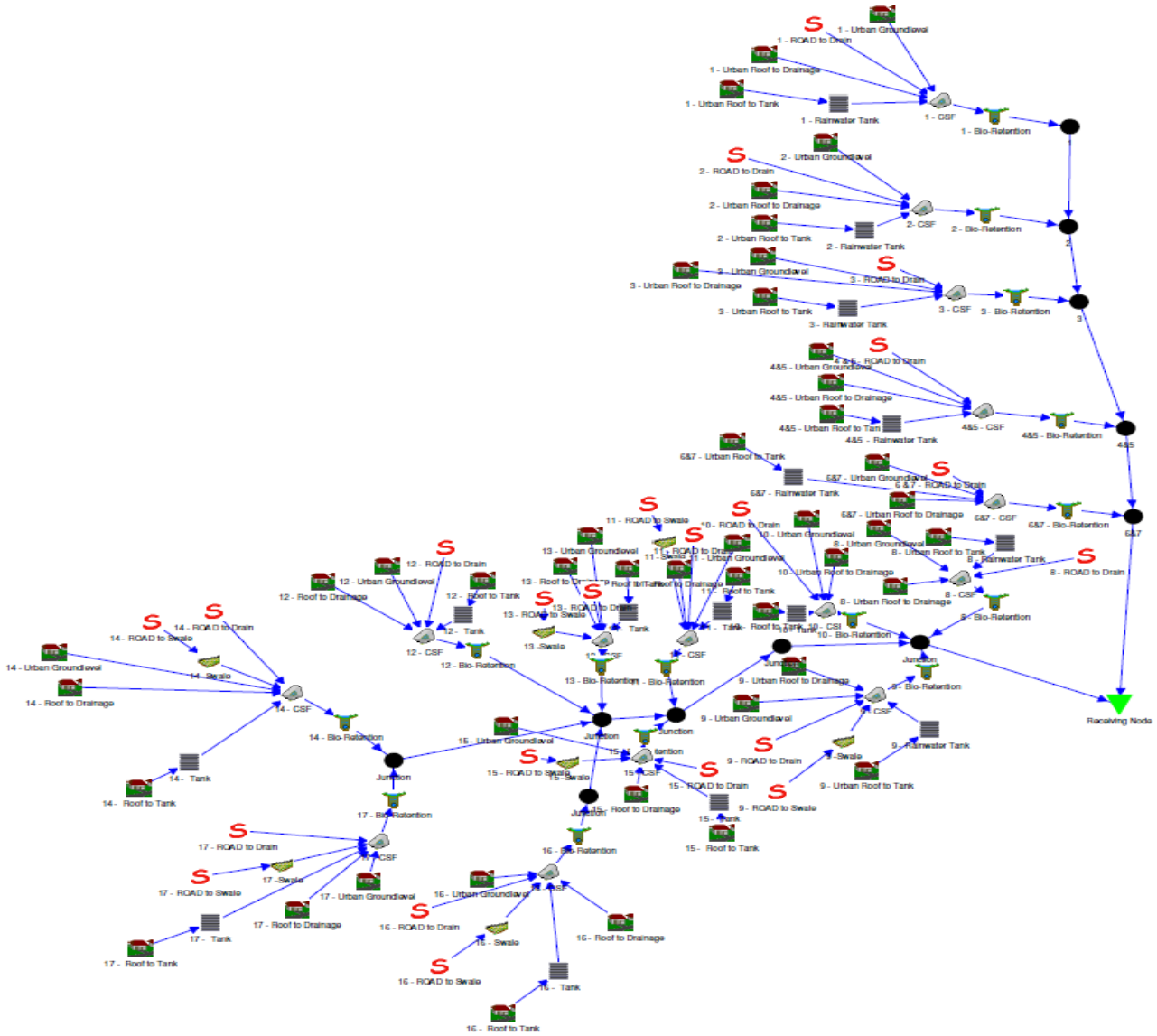


Figure 5.1 Music Model Ultimate Mitigated Torquay Creek Catchment (SC-G00546)

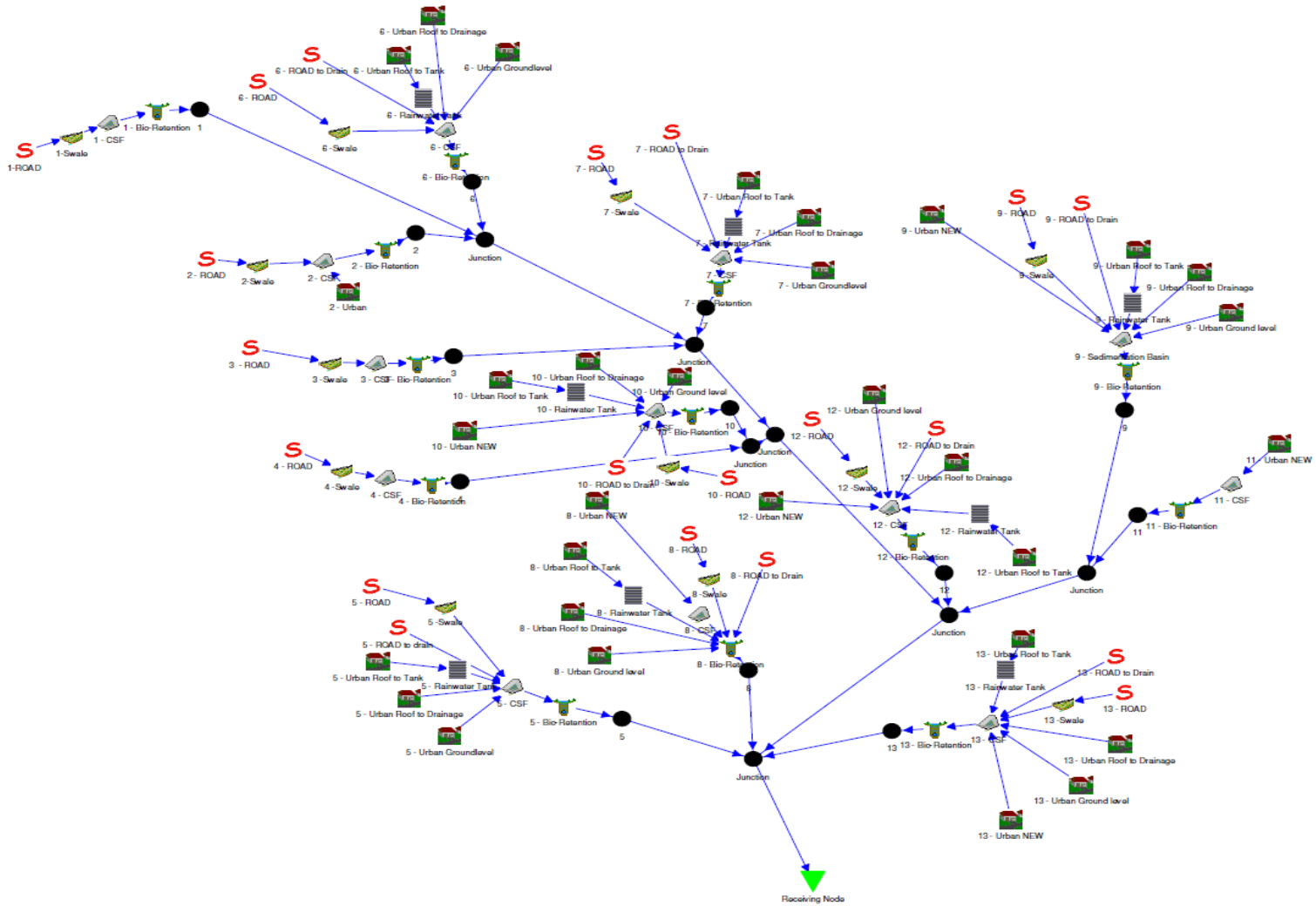


Figure 5.2 **Music Model Ultimate Mitigated Native Dog Creek Catchment (Scenario C SC-G00523)**

5.6.3 Determine load reductions likely to be achieved by riparian buffer zones in rural residential land uses

Ten metre buffers were applied to all mapped waterways occurring in rural residential areas in the ultimate scenario.

Load reductions likely to be achieved by filtering of overland stormwater flows from rural residential areas was modelled using WaterCAST. Details of model set-up to estimate load reductions are provided in **Section 5.8**.

5.6.4 Identify land uses with the greatest pollutant load generation to inform priority infrastructure spending.

Direction was sought by council on which areas infrastructure spending should be targeted to achieve greatest load reductions, at lowest cost. Treatment of stormwater quality from land-uses that produces the greatest sediment and nutrient loads should be prioritised over cleaner land-uses. To determine which land-uses result in production of the greatest load production per unit area, the annual load generation capacity from each land-use was determined by modeling a 1 hectare area of each land-use type in MUSIC. Results of modeling are summarized in **Section 5.9.**

During detail design a number of other factors such as likely adoptions by residents, likely ease of construction considering existing infrastructure and available space should be considered to develop a schedule of installation of measures.

5.6.5 Assess if load reductions could be achieved without extensive retrofitting of existing urban areas with SQIDs

Retrofitting water sensitive urban design measures into existing piped stormwater systems can be expensive, and may in many cases be unfeasible. There can be hydrological limitations preventing installation of devices at inlets and outlets, space restrictions imposed by natural or built structures, sewer and water pipes that prevent excavation required to construct bio-retention basins, and community resistance to works on sidewalks.

To determine if load based reduction objectives could be achieved without retrofitting existing urban areas with WSUD measures a case study was carried out on Native Dog Creek to assess the effectiveness and cost associated with the following less intensive treatment scenarios:

- Treatment Scenario a - Rainwater tanks only (refer to **Figure 5.3** Music Model Scenario A).
- Treatment Scenario b - Rainwater tanks plus bioretention in new developments and swales on all rural roads (Refer to **Figure 5.4**).
- Treatment Scenario c – Rainwater tanks, bioretention in new developments and swales on all rural plus retrofit bioretention on all existing urban areas (refer to **Figure 5.5**).

A secondary outcome of this assessment was to quantify the contribution of non-council controlled infrastructure, such as rainwater tanks, on modelled water quality improvement. To quantify the contribution of these structures to load reductions, a separate scenario for one of the catchments (Native Dog Creek) just modeling rainwater tanks was carried out, and the load reductions achieved by these measures was quantified.

This investigation was undertaken for Native Dog Creek only, as the findings can be readily applied to both catchments. Additionally, in the future Native Dog Creek is subject to a greater increase in urban area.

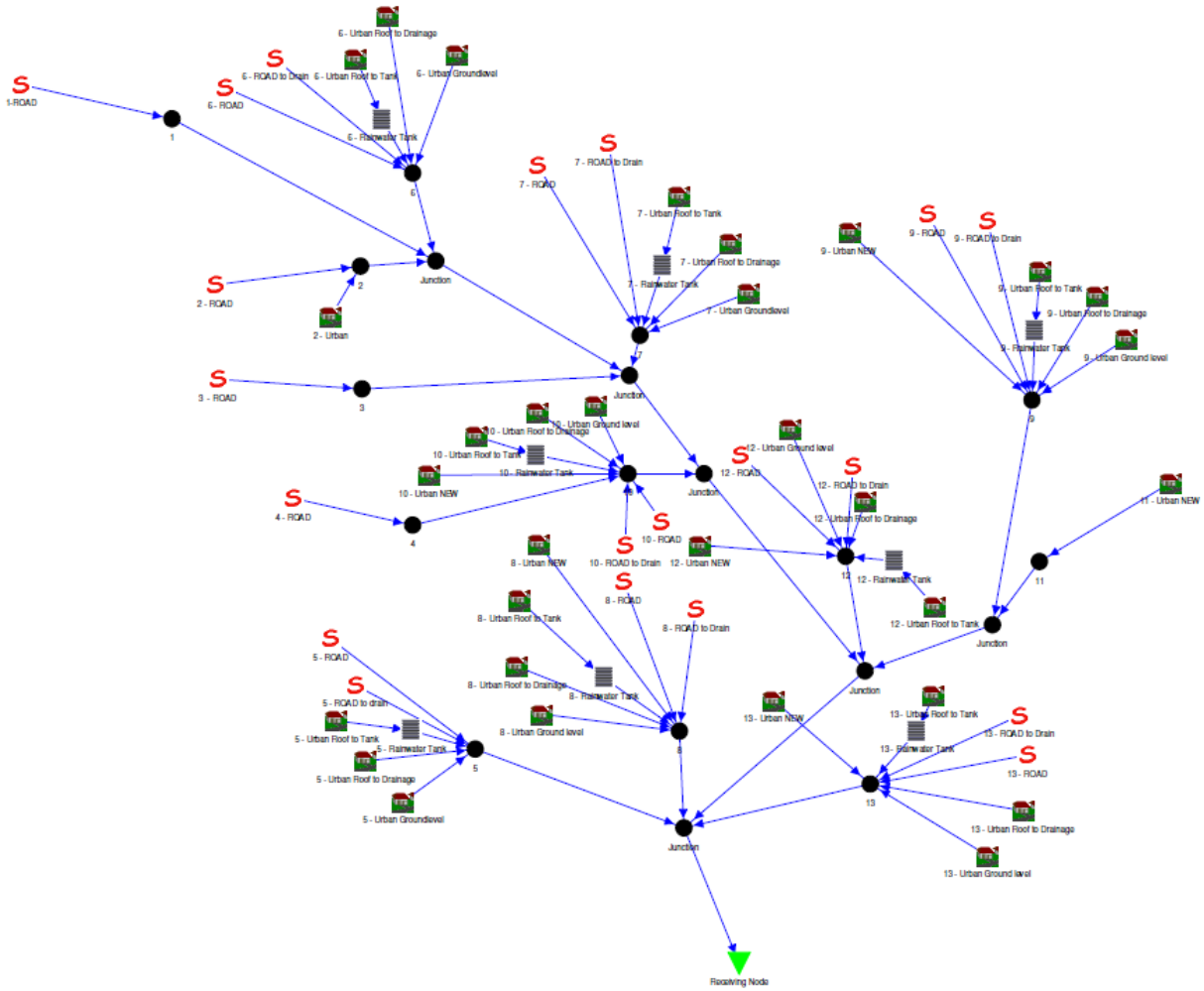


Figure 5.3 Music Model Scenario A (SC-G00517b)

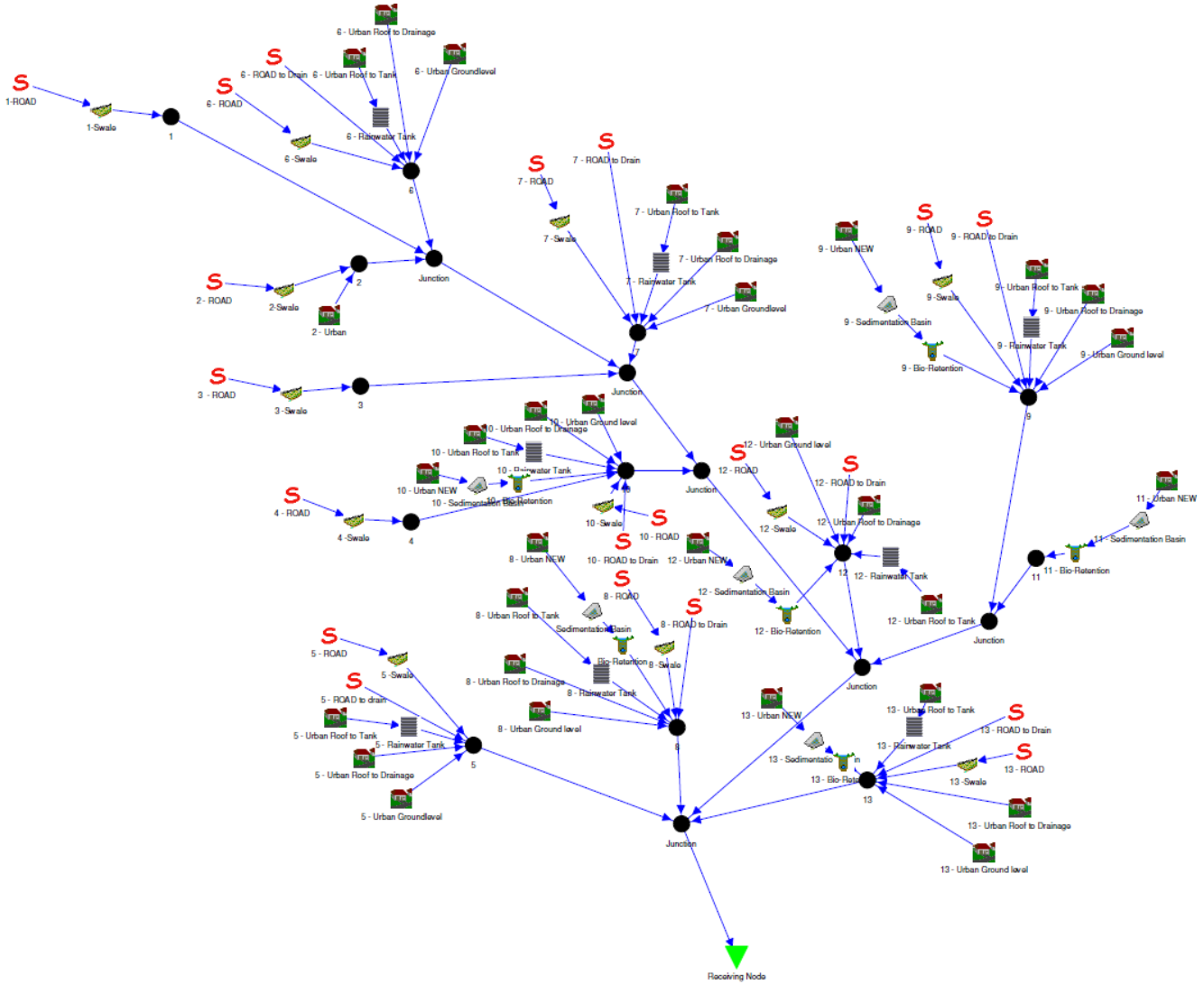


Figure 5.4 Music Model Scenario B (SC-G00522)

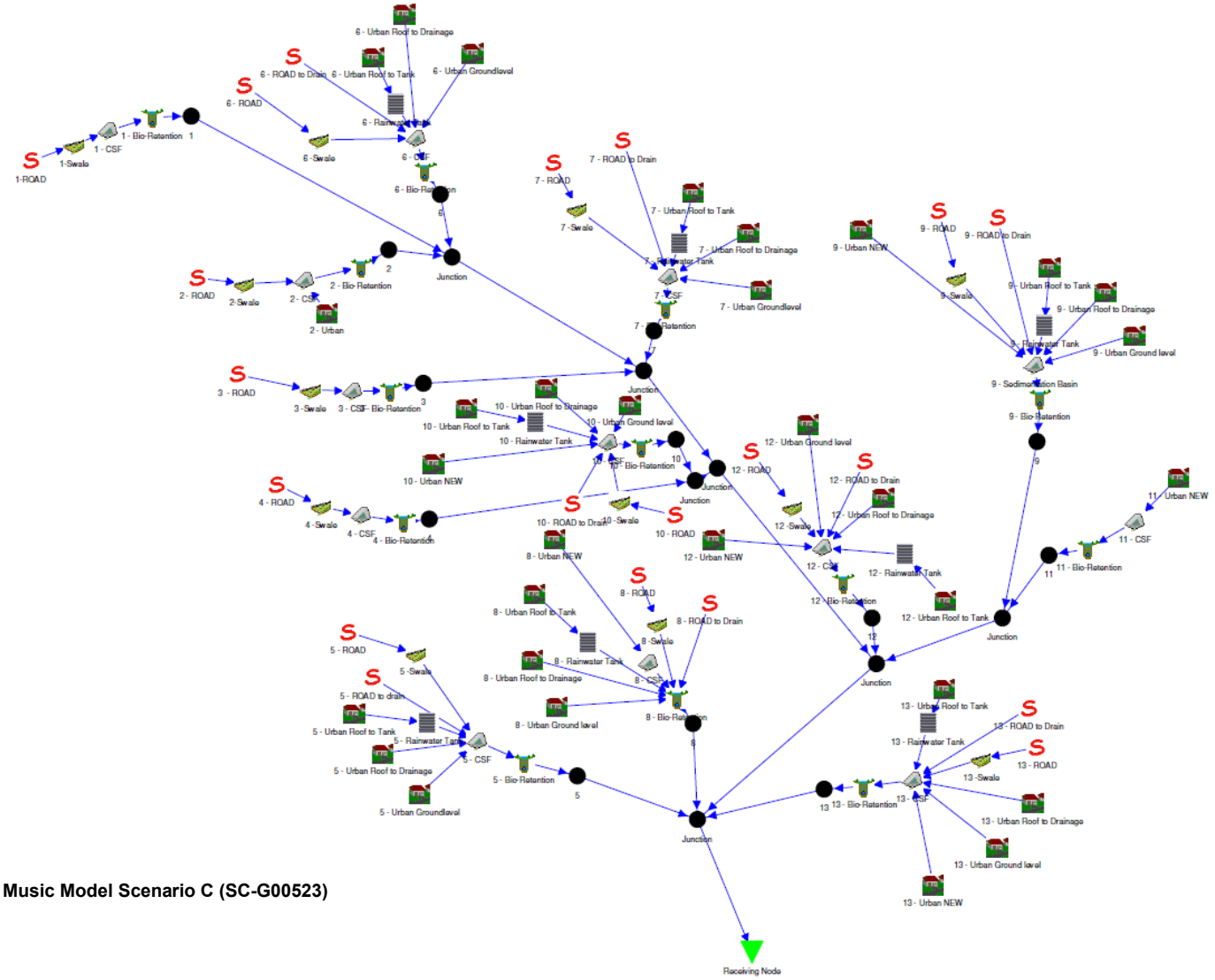


Figure 5.5 Music Model Scenario C (SC-G00523)

5.7 MUSIC Model Parameterisation

This section details the general MUSIC model assumptions and inputs utilsed for all modeling. All input values used for setting up models are detailed in **Appendix O** and **Appendix P** for Native Dog and Torquay Creek catchments respectively. The location of all devices modeled are displayed on **Appendix Q**.

5.7.1 Climate

Six (6) minute data from Redlands BOM station 40265 was adopted for the site. SEQ Healthy Waterways (2007) recommends the use of rainfall data from the period 1980 - 1990 for the Greater Brisbane Area (including Redlands). The rainfall data in this time period from the Redlands HRS station was considered unsuitable due to large periods of missing data. As such the rainfall data was reviewed to identify a period with a complete data record with an average annual rainfall rate over the period that approximated the total average rainfall rate of 1259.2 mm/annum.

Redlands HRS had continuous 6 minute rainfall data between the period 1996 and 2004. Within this complete data range, the average annual rainfall in the period 1996 to 2001 was selected as the most suitable period as it contained 6 complete years of data and had an average annual rainfall rate that closely approximated the annual average rainfall for all records (1227 mm/annum).

Monthly average Pan Evapotranspiration (PET) values were calculated from the average daily PET values reported on the Bureau of Meteorology website for the Redlands HRM station and recorded below in **Table 5.1**.

Table 5.1 Monthly PET

Month	Pan Evaporation (mm /month)
Jan	186
Feb	154
Mar	148
Apr	108
May	81
Jun	66
Jul	68

Month	Pan Evaporation (mm /month)
Aug	93
Sep	120
Oct	152
Nov	168
Dec	186

5.7.2 Source Nodes

Catchments

Catchments established for RAFTS modeling were used to establish catchment boundaries in MUSIC. Due to the land use detail that was modeled, multiple RAFTS catchments were merged to form larger catchment nodes.

The RAFTS catchments that were grouped to form the respective MUSIC catchment are represented in **Figure 5.6** and **Figure 5.7**.

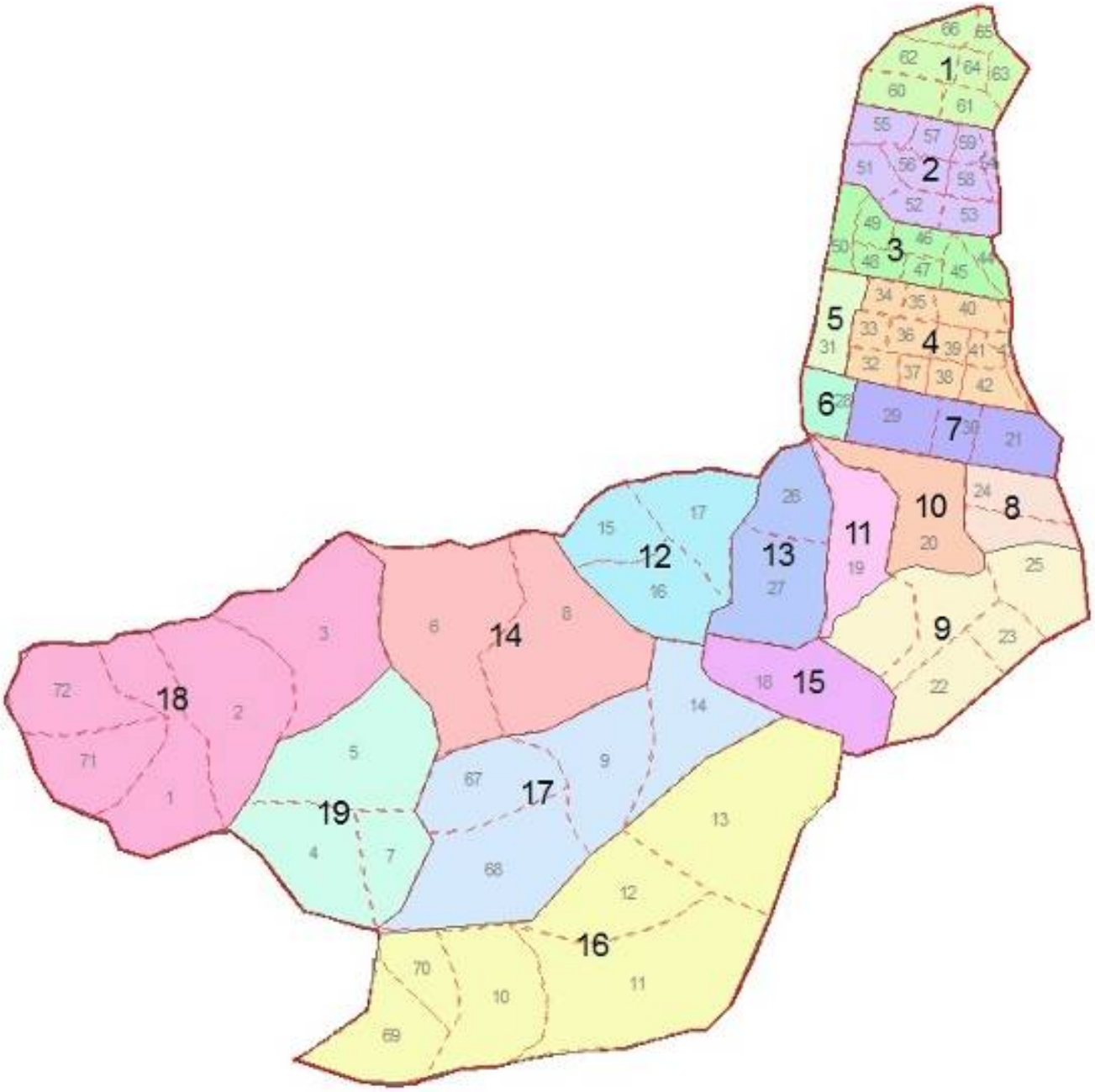


Figure 5.6 Torquay Creek MUSIC Sub-catchments

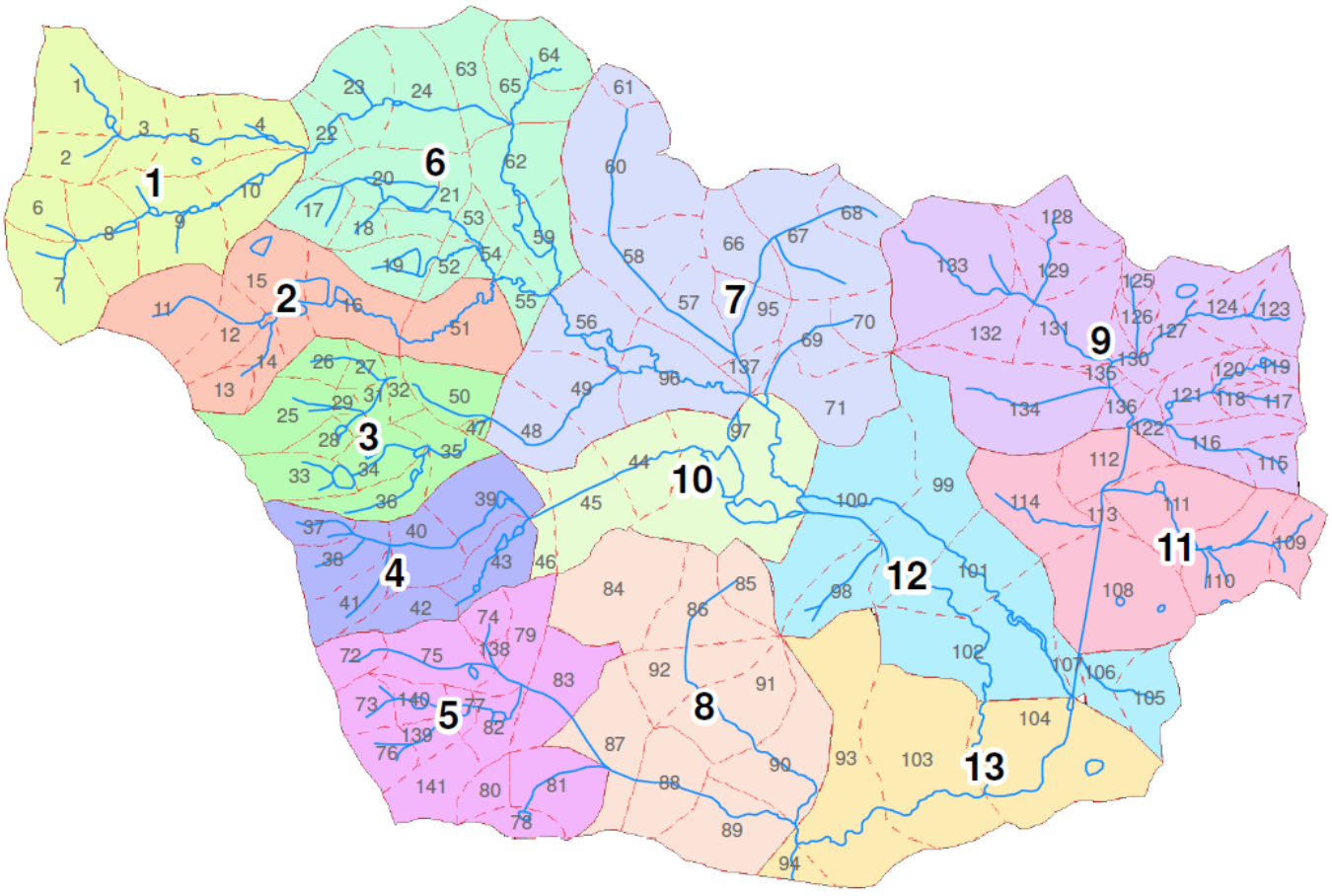


Figure 5.7 Native Dog MUSIC Sub-catchments

Land-use

The Redlands City Council zoning was used to determine the land use in the ultimate land use for each catchment. The equivalent MUSIC node was determined with reference to Table 2.1 of BCC (2003) "Translation of City Plan Area Classifications into MUSIC source nodes". Land use descriptions for each zone were determined from the Redlands City Council planning scheme where land use zones were not included in the BCC list. The council zones occurring in the catchment and corresponding MUSIC source node adopted for the ultimate scenario are summarized below in **Table 5.2**.

The current land use was determined based on analysis of aerial photography. Each of the planning scheme zones was interrogated against recent aerial photography and the MUSIC source node modified to reflect the current observed land use. Land use maps for both catchments are provided in **Figure 5.8** to **Figure 5.11**.

Table 5.2 Redlands Planning Scheme Zones and equivalent MUSIC nodes

Redlands Council Zones	Adopted MUSIC source node.
Conservation	Forested
Environmental Protection	Rural Residential
Investigation Zone	Urban Residential
Local Centre	Urban Residential
Low Density Residential	Urban Residential
Marine Activity	Industrial
Medium Density Residential	Urban Residential
Open Space	Rural Residential
Rural non-urban	Rural Residential
Community Purposes	Urban Residential
Urban residential	Urban Residential
Neighborhood Centre	Urban Residential
Park Residential	Urban Residential

In the absence of runoff and pollution generation parameters provided in any Redlands City Council guidelines. Runoff and pollution generation parameters for catchments stipulated in the Gold Coast City Council MUSIC guidelines (GCCC 2003) were adopted for modeling. The GCCC (2003) methodology divides developed catchments up into road, roof to stormwater tanks, roof to drainage, and other ground nodes, whereas the BCC (2003) methodology models these different components as one node. The GCCC (2003) methodology is a significantly more intensive method of modeling pollutant runoff, but necessary to the account for the significant positive impact rainwater tanks have on stormwater runoff.

Runoff and pollutant generation parameters assigned to land-uses in the GCCC 2003 guidelines are readily applied to modeling carried out in many areas in Queensland, and are applicable to Redland City Council.

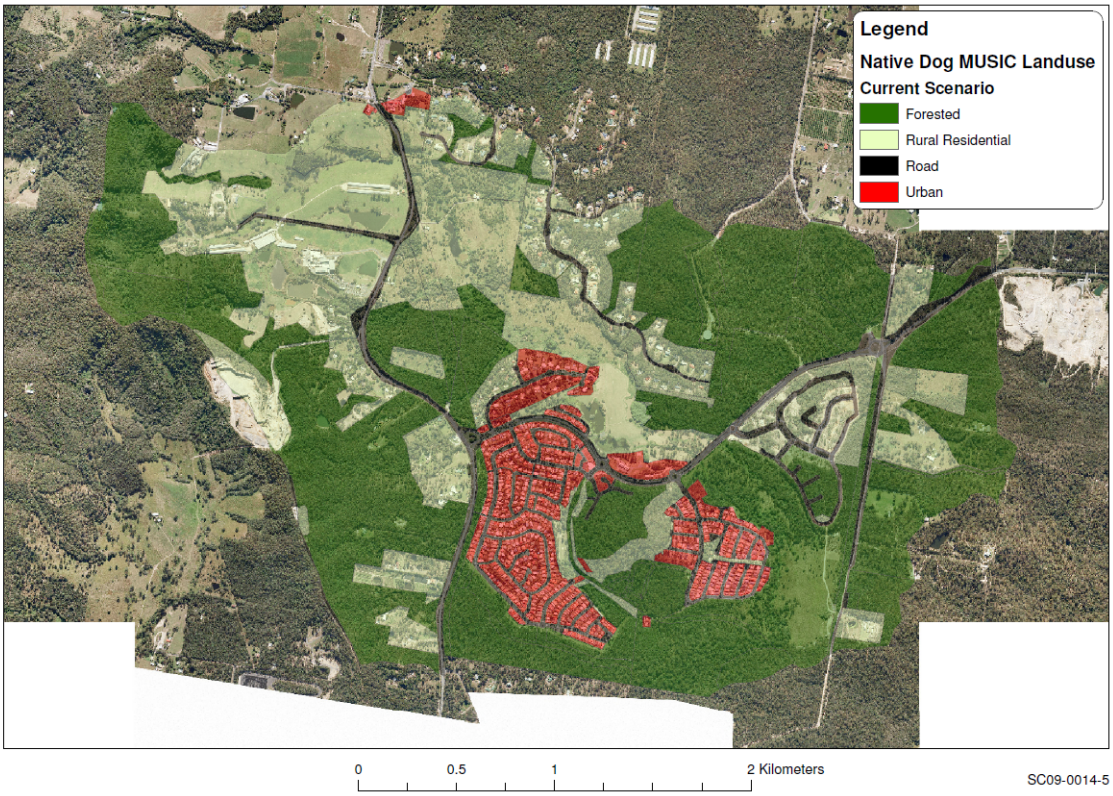


Figure 5.8 **Native Dog Creek catchment landuse – current.**

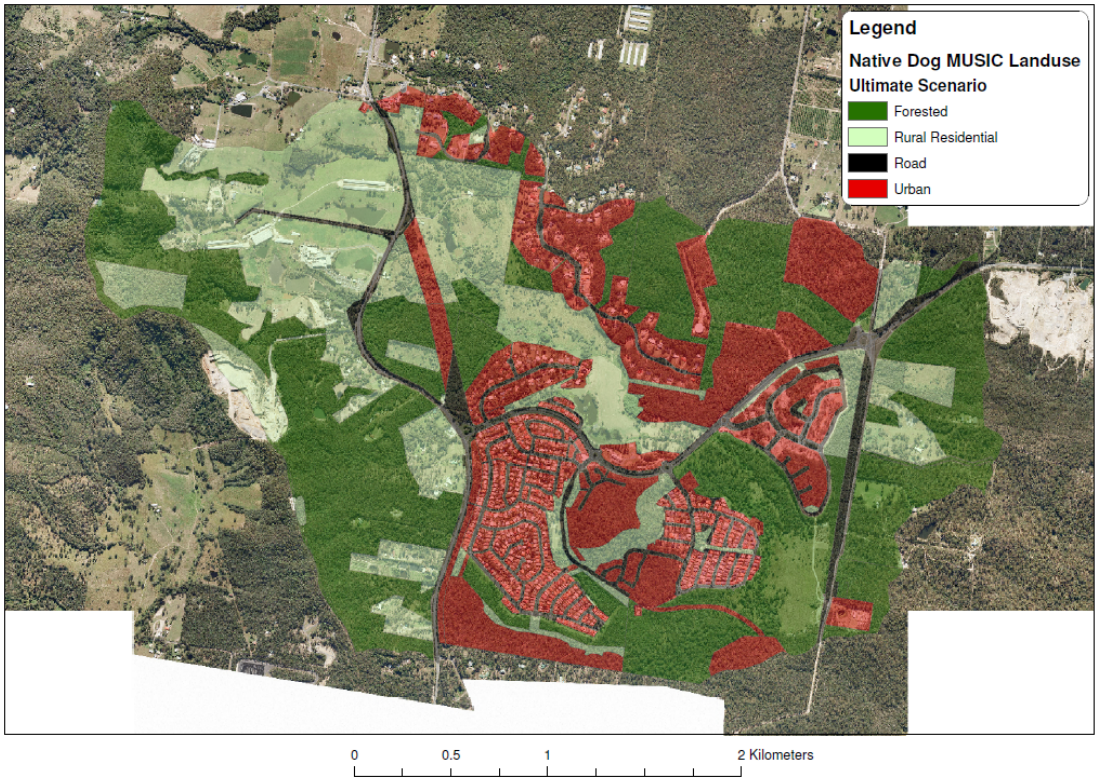


Figure 5.9 **Native Dog Creek catchment landuse – ultimate**

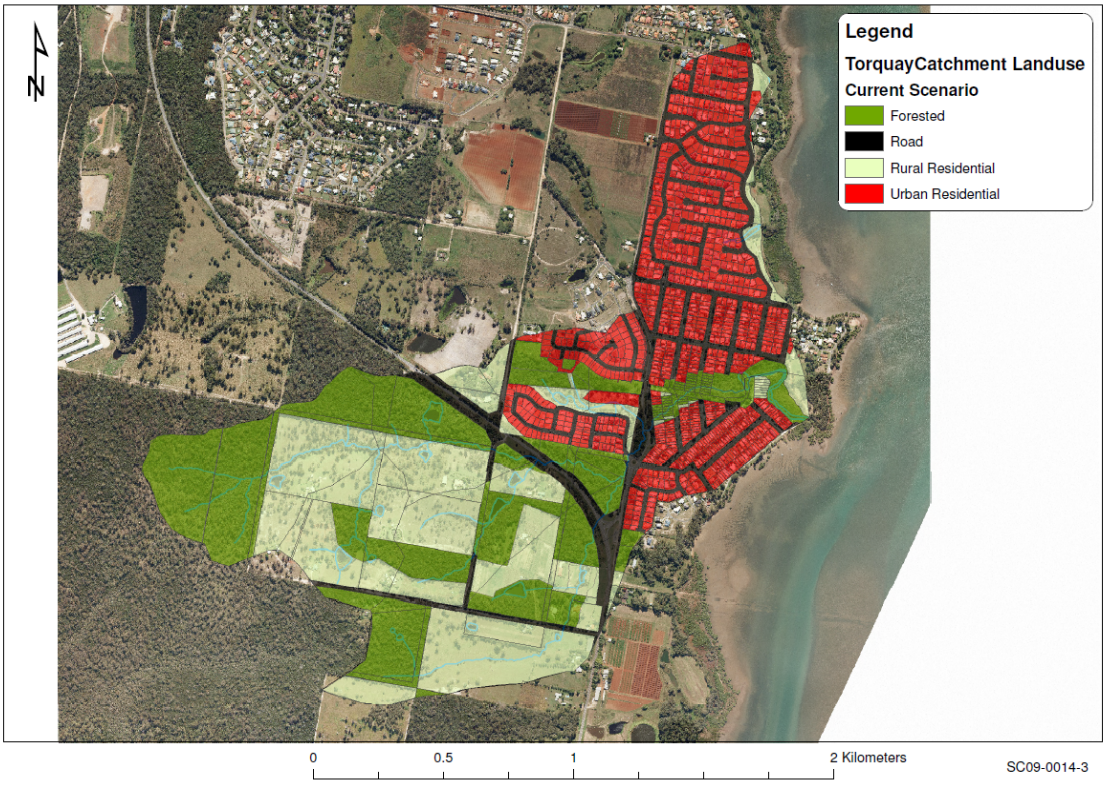


Figure 5.10 Torquay Creek catchment landuse - current

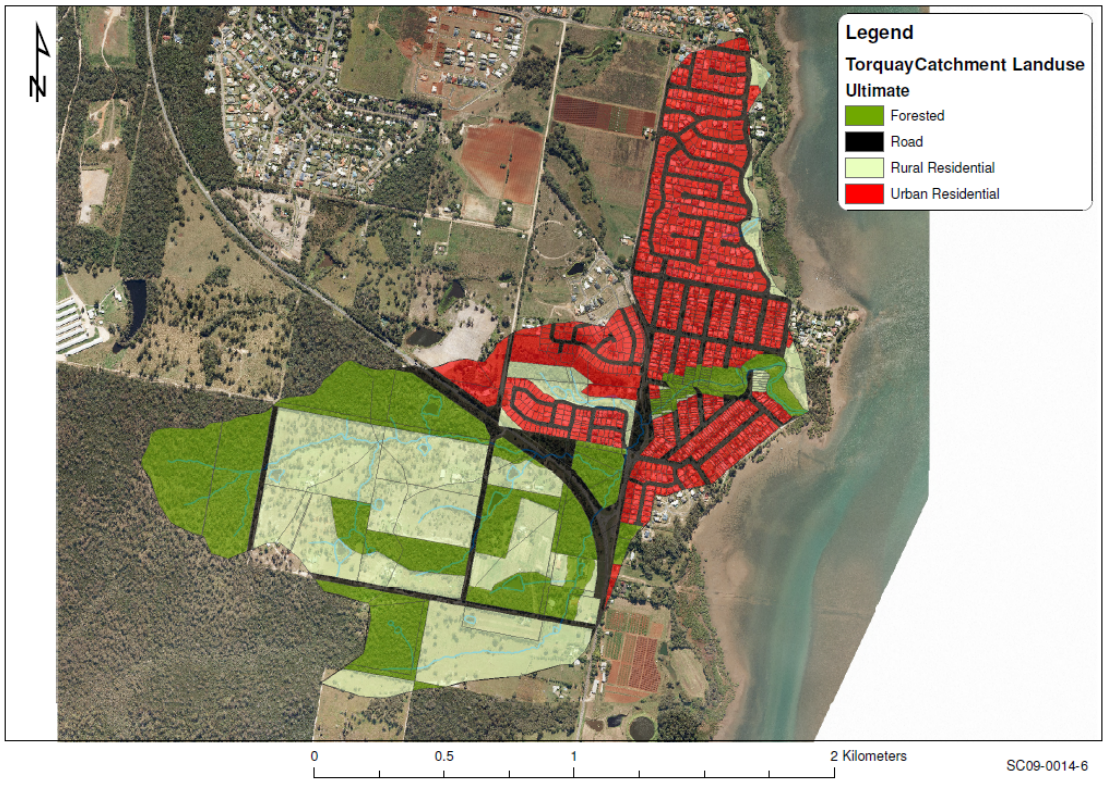


Figure 5.11 Torquay Creek catchment landuse - ultimate

Fractions Impervious

The adopted fraction impervious from Redland Shire Council Planning Scheme Policy 2005 (in GHD 2005) for urban residential areas (including roofs and roads) is 45%. As roads and roofs are being modelled separately, a revised percent impervious for the balance urban areas was required. Representative samples of urban areas in the existing landuse (shown in **Figure 5.8** and **Figure 5.10**) were analysed in GIS to determine the proportion of impervious area are comprised of roads and roofs, and by subtracting what percentage imperviousness should be adopted for the balance area. Results of analysis indicate that roads and roofs comprise 16 and 24% respectively of urban areas, both of these areas are 100% impervious, therefore subtracting these values from 45%, a 10% imperviousness was applied to the ground level urban node. The impervious values for all other land-use zones were adopted from the Weinam Creek Conceptual Stormwater Management Plan (GHD 2006). Effective impervious area modelled in MUSIC was calculated as per the methodology outlined in BCC 2003. Adopted fraction impervious values are summarised in **Table 5.3**.

Table 5.3 Adopted Fraction Impervious

Redlands Council Zones	Adopted MUSIC source node	Fraction Impervious	Conversion Factor	MUSIC Effective impervious (BCC, 2003)
Conservation	Forested	0	0	0
Environmental Protection	Rural Residential	0.05	0.55	0.03
Investigation Zone	Urban Residential	0.1	0.31	0.03
Local Centre	Urban Residential	1	0.31	0.31
Low Density Residential	Urban Residential	0.1	0.31	0.03
Marine Activity	Industrial	0.9	0.76	0.68
Medium Density Residential	Urban Residential	0.1	0.31	0.03
Open Space	Rural Residential	0	0.55	0
Rural non-urban	Rural Residential	0.05	0.55	0.03
Community Purposes	Urban Residential	0.9	0.31	0.28
Urban residential	Urban Residential	0.1	0.31	0.03
Neighbourhood Centre	Urban Residential	0.3	0.31	0.09
Park Residential	Urban Residential	0	0.31	0
Roads	Urban Roads	0.9	1.00	0.9
Roofs	Urban Roofs	1	1.00	1

Point Sources

Redland City Council is serviced by 7 sewage treatment plants (STP), that have a combined average annual discharge of 10 290 ML/yr (GHD 2006). None of these treatment plants fall within the subject catchment boundaries. The closest plant is the Capalaba STP, located approximately 800m east of the eastern boundary of Native Dog Creek Catchment.

5.7.3 Treatment Nodes

Swales

Vegetated or grassed swales reduce the connectivity of impervious areas, and are effective at removing suspended sediments and gross pollutants (refer **Plate 1**). To replicate the treatment efficacy achieved in modeling, swales should be placed on both sides of roads. When defined drainage is not needed, such as roads built on fill above the surrounding ground level equally efficient treatment can be achieved discharging water directly to surrounding vegetation in sheet flow such as shown in **Plate 2**. It is noted that swales generally operate best with longitudinal slopes of between 1 % and 4 %. For longitudinal slopes steeper than 4 %, check banks (e.g. small rock walls) along the invert of the swale, or equivalent measures, can help to distribute flows evenly across the swales, as well as to reduce flow velocities and consequently the potential for scour. In addition to water quality functions, swale drainage systems also aid to provide habitat connectivity through rural areas.



Plate 1 *Swale on a rural road.*



Plate 2 *2 No drainage, stormwater on a rural road filled above surrounding level allowed drains to surrounding environment in sheet flow.*

Rainwater Tanks

Although rainwater tanks do not provide a treatment function, capture of nitrogen rich rainwater and re-use for internal purposes or watering and disposal to either septic or sewage removes significant loads from stormwater systems.

All MUSIC inputs relating to rainwater tanks are detailed in **Appendix O** and **Appendix P** for Native Dog and Torquay Creek catchments respectively

Number of rainwater tanks

In 2007, 22% of houses in Queensland sourced a portion of their water from rainwater tanks (ABS 2007). Marsden Jacaob (2007) reported that approximately 78% of existing houses in SEQ were suitable for retrofit of plumbed rainwater tanks. Based on historic uptake rates all of the 78% of existing houses were likely to be fitted with rainwater tanks by 2019. For new homes, all owners will effectively be required to install rainwater tanks to comply with legislated water savings targets outlined in Queensland Development Code Part MP4.2

The number of new houses yet to be built in the catchment was estimated using GIS based on proposed ultimate landuse. The DCDB layer was overlayed on the current aerial photography and lots that did not have an existing house constructed were manually identified.

The proposed proportion of houses using rainwater tanks is therefore assumed to be:

- Current % of houses using rainwater tanks – 22.1%
- Ultimate % of existing houses using rainwater tanks – 78%
- Ultimate % of new houses using rainwater tanks – 95%

Area of roof draining to tank and stormwater

The Queensland Development Code Part MP4.2 specifies that 100m^2 of half of the roof area (whichever is less) should be directed to rainwater tanks to comply. Average footprint areas of houses constructed in the periods 1984-85, 1993-94, 2002-03 were 162.2, 188.7, 227.6 m^2 respectively (ABS 2005). As existing houses are expected to comprise of buildings constructed in all of these periods, a roof area of 192.8 m^2 was adopted, as such each existing house with a tank was modeled as having 96.4m^2 draining to the tank and 96.4m^2 draining to stormwater. The average footprint of houses constructed in 2002-2003 was 227.6m^2. Consequently, each new house with a tank was modeled with 100m^2 draining to a tank and the balance 127.6 m^2 to stormwater.

Water re-use

The MUSIC model assumes that all tanks are plumbed in and water is used by occupants at a minimum for toilet flushing. A daily demand of 0.326 KL / house / day is adopted as per GCC (2006).

Bioretention Devices

Bioretention devices capture and treat stormwater through plant action and filtration prior to passive discharge through underground drainage. Bioretention devices include linear swales, pods or rain gardens, or larger end of pipe basins.

Bioretention swale devices were sized to 1.5% of the sub-catchment area. A settling depth of 0.3m was applied to all bio-retention devices. Design particle size for filter media was 0.45mm with a permeability of 180mm/hr. As per the recommendations outlined in the Guidelines for Soil Filter Media in Bioretention Systems (Version 2.01) published by the Facility for Advancing Water Biofiltration (FAWB 2008), devices were modelled with a permeability of 90mm/hr to account for reduced permeability that occurs during operation.

Potential locations for bioretention devices have been indicated in **Appendix Q**. Ideally, bioretention devices should be installed at each field or gully pit throughout the catchment (refer to **Figure 5.12**).

All bioretention basins are modelled with coarse sediment forebays (CSF). Installation of a CSF prevents sediment accumulation at the inflow point of bioretention basins that may smother vegetation and reduce infilation to the filter media. Coarse sediment forebays were sized using **Equation 1** (SEQ Healthy Waterways 2006).

Equation 1

$$Vs = Ac \,.\, R \,.\, L_o \times F_c$$

Where:

Vs = volume of forebay sediment storage required (m^3)

A_c = contributing catchment area (ha)

R = capture efficiency (assume 80%)

L_o = sediment loading rate (assume 1.6 m^3/ha/year)

F_c = desired cleanout frequency (2 years)

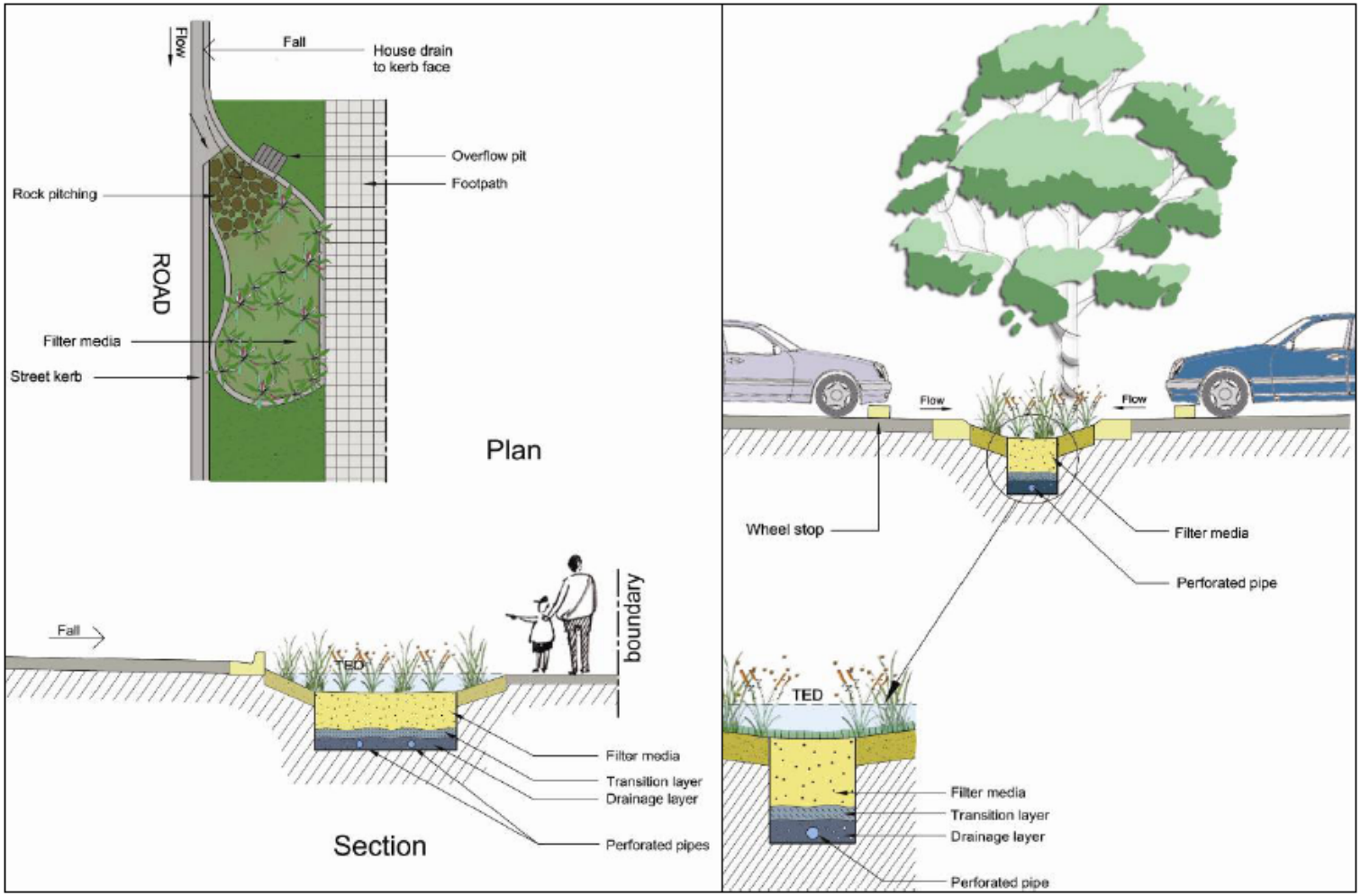


Figure 5.12 Conceptual drawings for bioretention pods and swales (Source unknown)

5.7.4 Costing

Cost for Stormwater Quality Improvement devices were calculated using the Costing functions in MUSIC.

The following Life Cycle Costing Properties were adopted:

- Real Discount Rate 5.5%
- Annual Inflation Rate 2%
- Base Year for Costing (2009)
- Span of Analysis 50 Years

The following provides further details on the costs derived for the various stormwater quality improvement measures.

Bioretention Devices

MUSIC user manual identifies that there is a high level of uncertainty for estimating lifecycle costs of some treatment measures, specifically swales, buffer strips, bioretention systems and infiltration systems. The level of variability between expect cost (median value) and upper cost (84%ile) for any one treatment device can be in the order of 1.4 times the median value. The high level of variability in projected lifecycle costs of modeled treatment trains should be considered by Council when using this data for developing infrastructure charges.

Rainwater Tanks

Default expected costs were adopted for each treatment node, with the exception of rainwater tanks to which a no-cost factor was applied (installation of rainwater tanks will not be a council responsibility).

Buffer and Riparian Zone

Costing for riparian buffer zone implementation was estimated at $\$7.50m^2$. This rate was determined from experience on two of SEQ's largest riparian restoration projects, the Maroochy River Recovery and the SEQ Catchments Echidna Creek project. The figure includes site preparation, purchase of plant, planting and maintenance of plantings for three (3) years to achieve industry standard performance criteria.

5.8 Watercast Modelling

WaterCAST version 1.0 (the Water and Contaminant Analysis and Simulation Tool) has replaced the E2 software, with the aim towards a higher level of adoption across the Australian water industry. WaterCAST has extended the E2 modeling framework by providing more features and greater usability. Previous users of E2 can switch to WaterCAST without any need to convert or re-do existing E2 projects.

eWater CRC provided the following information regarding the model: -

> "*WaterCAST-beta is currently in the final stages of development. The scientific and numeric aspects of the model are accurate, and the documentation and user interface are now being refined. At this point in time the product is only available to eWater Partner organisations and those whose use is directly sponsored and confirmed by a partner*."

As indicated above, E2 software is no longer available and waterCAST has not yet been released to the public. eWater CRC indicated that a public version of WaterCAST is forecast for release later this year in circa November 2009. O2 environmental were granted access to the WaterCAST "beta version" which we have implemented for this project.

Due to the finer scale of the project we were unable to use the WBM E2 model as was previously developed for the Redlands City Council area. Although not part of the initial scope of works, two (2) detailed WaterCAST models have been developed for the Torquay Creek and Native Dog Creek catchments under this study.

5.8.1 Sub-catchment and Landuse Mapping

For consistency of modeling and to allow scenario comparisons of results within the Redland IWMP, subcatchments and landuse within each of the study areas were defined through the RAFTS hydrologic and MUSIC modeling. The GIS layers developed for this model was directly imported into the WaterCAST model.

5.8.2 Rainfall and Evaporation

Torquay and Native Dog Creek sub-catchment WaterCAST model has used the SILO daily rainfall and evaporation data from January 1900 to June 2004. The SILO data was sourced from the Bureau of Meteorology and represents a derived rainfall series applicable to the catchment areas of interest.

5.8.3 Water Quality

The WBM E2 model used detailed information provided by the Redland City ambient water quality monitoring program. The report indicated the following: -

"the wide range of parameters and the duration of the monitoring program provides a data set suitable to derive site-specific DWC values for the Redland E2 model."

Some of the DWC data used in the WBM Redlands E2 model differ substantially from the SEQ EMSS DWC values. The following is noted and has significant implications on future landuse modeling and planning.

- TN from the Redlands E2 DWC for urban landuse (0.75mg/L) is half that of the SEQ model (1.5mg/L).
- TN from the Redlands E2 DWC for Rural Residential landuse (1.37mg/L) is approximately double that of the SEQ model (0.7mg/L).
- TP from the Redlands E2 DWC for urban landuse (0.08mg/L) is two thirds less than of the SEQ model (0.11mg/L).
- TP from the Redlands E2 DWC for Rural Residential landuse (0.13mg/L) is approximately double that of the SEQ model (0.07mg/L).

In effect from the DWC modifications noted urban landuse has become 'cleaner' and rural residential has become 'dirtier'. Torquay Creek sub-catchment will have minor development in the future which will generally consist of rural residential being converted to urban landuse. Initial modeling using the WBM E2 DWC data for Torquay creek found that the catchment loads for TN and TP will improve with urbanisation. It is understood from Council's hot-spot event monitoring program that comparable high nutrient concentrations from non-urban land uses have been found to occur. It is noted however that hot spot analysis taken usually during dry periods may not necessarily provide an accurate understanding or the estimate of loads from a certain land use for the following reasons: -

- Fletcher found that a minimum of fifty (50) event based samples are required to provide an accurate estimate of EMC's;
- Dry weather concentrations (DWC) or loads during low flow events are generally insignificant in the hydrological regime in terms of the total load sum; and
- Consideration of load based versus concentration based water quality results.

In any case, a further review of use of data from the Redlands ambient monitoring program for catchment modeling is recommended and is warranted in order to more accurately classify water quality based on land use types. For the purposes of this project, we have used the DWC and EMC from SEQ EMSS (**Table 5.4**).

Table 5.4 SEQ EMSS EMC/DWC Values

Land Use		TSS (mg/L)		TN (mg/L)		TP (mg/L)	
		DWC	EMC	DWC	EMC	DWC	EMC
Green Space	Lower	3	8	0.3	0.75	0.02	0.015
	Middle	7	20	0.4	1.5	0.03	0.06
	Upper	14	90	0.5	3.75	0.06	0.12
Grazing	Lower	5	110	0.5	1.17	0.03	0.128
	Middle	10	260	0.7	2.08	0.07	0.3
	Upper	23	600	0.9	6.00	0.14	0.77
Broadacre Agriculture	Lower	5	80	0.5	0.91	0.03	0.107
	Middle	10	300	0.7	1.95	0.07	0.321
	Upper	23	700	0.9	5.2	0.14	0.803
Intensive Agriculture	Lower	5	300	0.5	2.08	0.03	0.16
	Middle	10	550	0.7	5.2	0.07	0.449
	Upper	23	800	0.9	12.35	0.14	1.177
Rural Residential	Lower	5	40	0.5	0.9	0.03	0.12
	Middle	10	130	0.7	1.6	0.07	0.28
	Upper	23	380	0.9	4.6	0.14	0.72
Future Urban	Lower	5	40	0.9	0.9	0.05	0.12
	Middle	7	130	1.5	1.6	0.11	0.28
	Upper	27	380	2.8	4.6	0.28	0.72
Suburban	Lower	5	40	0.9	0.9	0.05	0.12
	Middle	7	130	1.5	1.6	0.11	0.28
	Upper	27	380	2.8	4.6	0.28	0.72
Dense Urban	Lower	5	40	0.9	0.9	0.05	0.12
	Middle	7	130	1.5	1.6	0.11	0.28
	Upper	27	380	2.8	4.6	0.28	0.72

5.8.4 Hydrology

As stated in the WBM report (2008) no DNRW stream gauges were identified in mainland regions of Redland City Council. Very limited hydrological records are available for freshwater streams in Redland City Council. This represents a significant gap in the key data sets required to construct a calibrated hydrological model, which underpins the E2/WaterCAST pollutant export model.

The SIMHYD parameters adopted for the region in the SEQ 2002 EMSS have been adopted in the absence of better information. Parameter sets used in the model are provided in **Table 5.5**.

Table 5.5 Hydrological Parameterisation

Parameter	SEQ EMSS Urban	SEQ EMSS Dense Urban	SEQ EMSS Open Space
Baseflow coefficient	0.3	0.3	0.3
Impervious threshold	1	1	1
Infiltration coefficient	200	200	200
Infiltration shape	1.5	1.5	1.5
Interflow coefficient	0.25	0.25	0.25
Pervious fraction	0.8	0.6	1
Rainfall interception storage capacity	1.7	1.7	1.7
Recharge coefficient	0.37	0.37	0.37
Soil moisture storage capacity	94	94	94

No pollutant point sources were included in the modeling.

5.8.5 Model Setup

The layout and final node-link structure of Native Dog and Torquay creek sub-catchments is presented in **Figure 5.13** and **Figure 5.14** respectively.

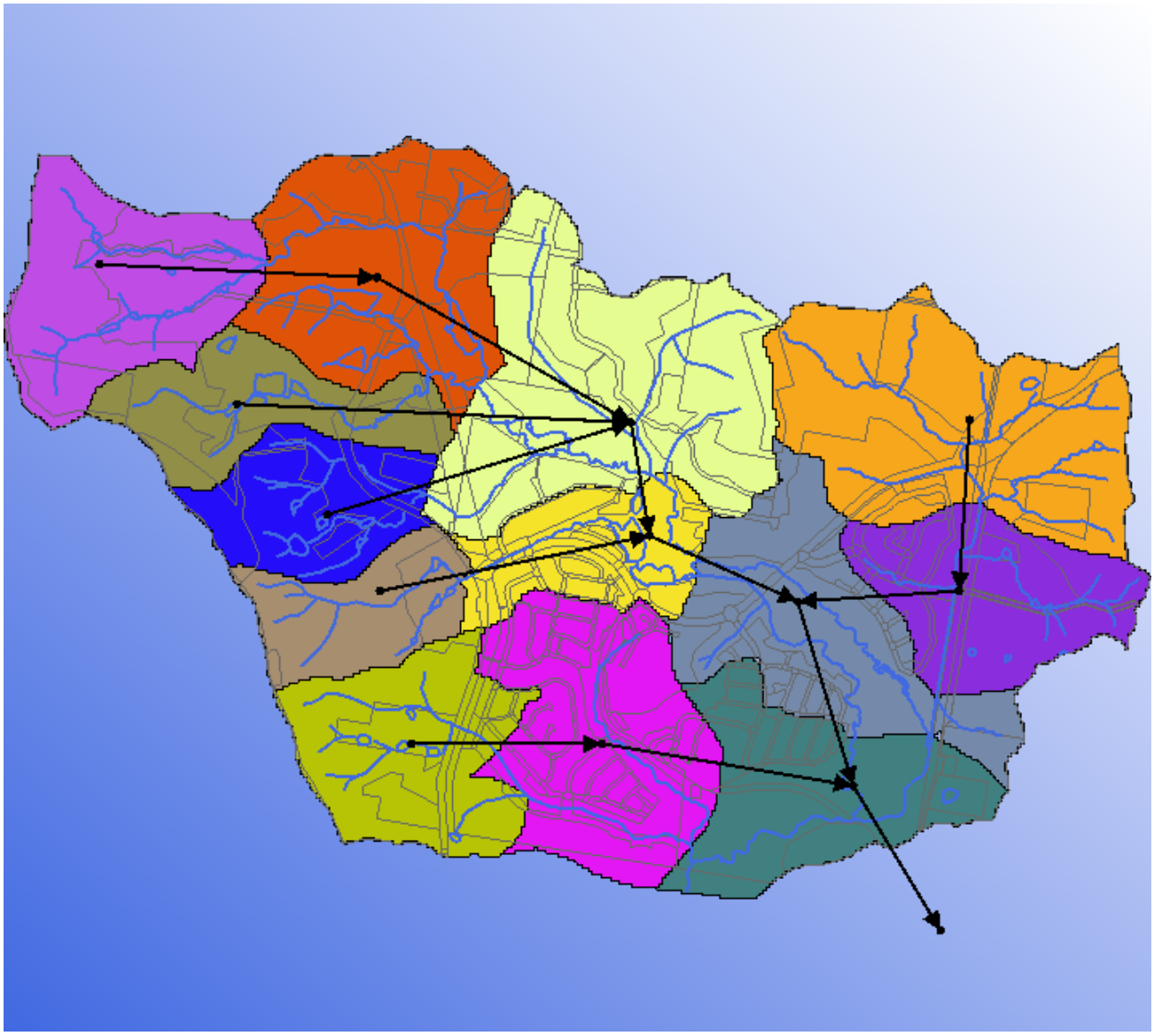


Figure 5.13 Native Dog Creek WaterCAST Model Node Link Structure

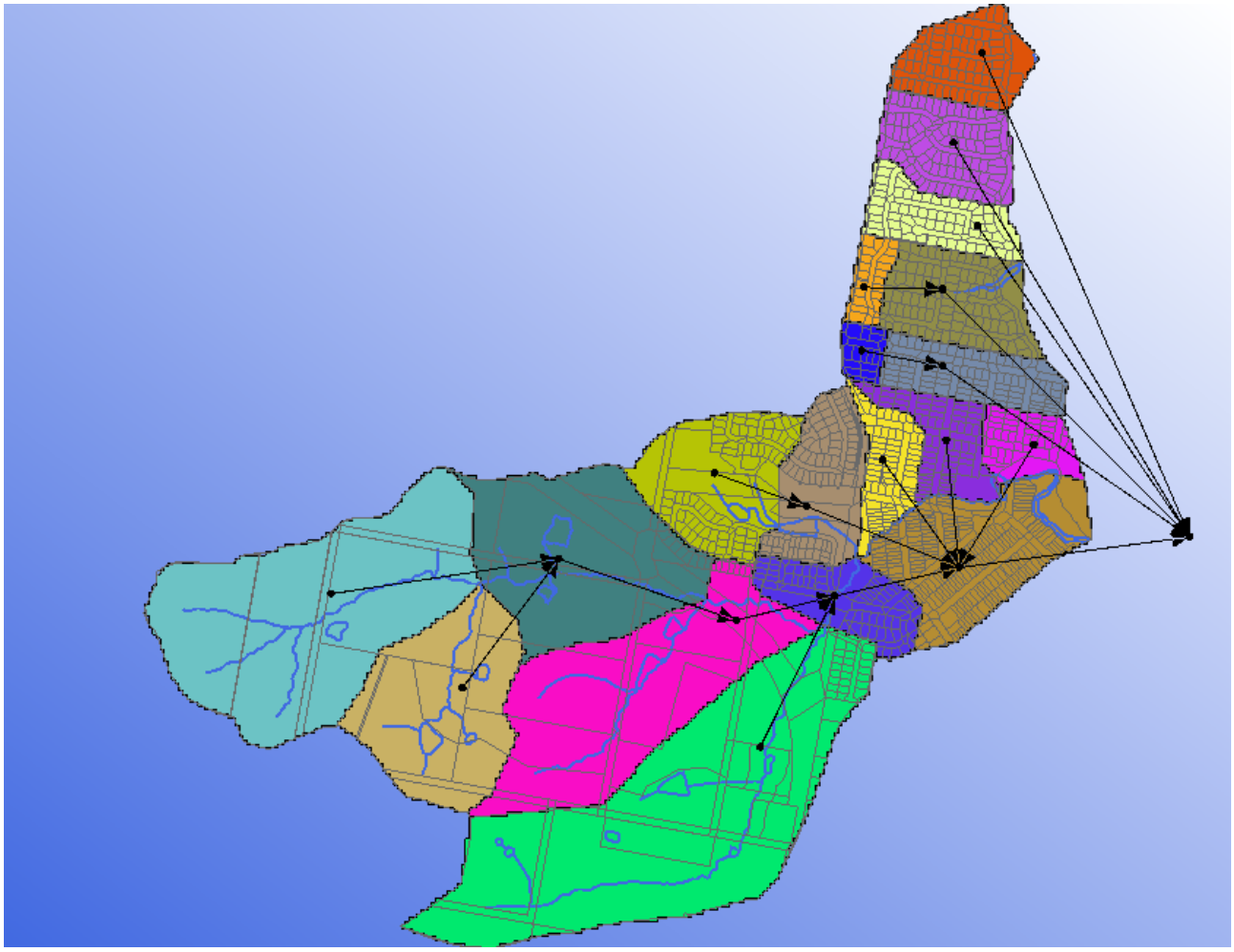


Figure 5.14 Torquay Creek WaterCAST Model Node Link Structure

Two scenarios have been generated from the WaterCAST model for both subcatchments at a discharge outlet or node. The two scenarios include current conditions (2009) and future scenario under planned landuses (2023). Key modeling output includes:

- Pollutant flows and loads from the current condition (2009) and future condition (2023) scenarios at an end of catchment.
- Subcatchment pollutant flows and loads represented spatially
- Comparison of pollutant flows and loads from the two scenarios.

A filter modeling scenario was undertaken to assess the load reductions likely to be achieved in Rural Areas to by re-establishment of 10m riparian filter zones to all waterways within the rural residential landuse using the load-based nutrient and sediment delivery ratio models;

The objective of applying filter models within the framework of an Integrated Water Management Plan is to justify and allow for the investment in 'green infrastructure' to achieve end of catchment load based targets. Riparian zones are a cost effective means of achieving load reductions

compared to more engineered solutions such as WSUD and have many other additional ecosystem service benefits.

One of the advantages of WaterCAST over other catchment management models is that it has the capacity within the model to apply filter models. Filters within WaterCAST reduce the amount of constituents that generate in a Functional Unit (Landuse) and pass this through to a node from a sub-catchment.

There are a number of options for filter modules within WaterCAST varying in complexity and data requirements. For the Redlands IWMP project the CSIRO's Load-based sediment delivery ratio model and the Load based nutrient delivery ratio models were chosen. These models are well accepted scientifically and do not require significant data input of other models i.e. Riparian Particulate Model (RPM) for Riparian Buffers.

The same parameters from the Redland IWMP waterCAST model were used for this project. The default values provided in the WaterCAST references manual were used to parameterise the filter model.

Buffers were applied to all waterways within the rural residential landuse of both subcatchments. Rural Residential landuse was chosen as there is space to apply riparian zones and overland flows are dominant. For both sub-catchment there was a total of 23 sub-catchment modelled.

As input to infrastructure charges schedules, costs have been estimated for a 10 metre wide riparian zone on either side of the creek for each sub-catchment. Ten meter wide riparian zones are appropriate for water quality filtering of overland flows, however this is only one function of a riparian zone and wider zones are recommended to achieve full ecosystem functioning. Costs include land preparation, plant establishment and three years of maintenance. The costs do not include any infrastructure costs such as fencing, crossings or off stream watering or cost of purchasing land.

The sub-catchments modeled length of stream and cost within each sub-catchment and total costs are presented in **Table 5.14** and **Table 5.18**.

5.8.6 Case study - integration of MUSIC and WaterCAST models to examine management options on end of catchment water quality results

WaterCAST has the ability to use different 'filter models' depending on the modeler's requirements and what is best suited to local constraints.

Using WaterCAST a riparian filter zone was implemented to all waterways within the rural residential landuse using the load-based nutrient and sediment delivery ratio models and bio-retention to all roads and urban landuses using the 1st Order Kinetic Model k-C* Filter Model. The k-C* model is a conceptualisation of the reduction in constituent concentration that can be provided by a range of different treatment facilities. The basic equation is a decay function. The k-C* model is the fundamental model used in the Universal Stormwater Treatment Model (USTM) of the MUSIC software

A bio-retention treatment was applied to 2% area of all road and urban landuses within all sub-catchments. The WSUD Technical Design Guidelines for South East Queensland (2006) demonstrated that the optimal sizing for TN removal is approximately 2% (See **Figure 5.15**) and TP and TSS is approximately 1%. Modeling results from WaterCAST demonstrated no differences when treatment area was increased from 2% to 3%.

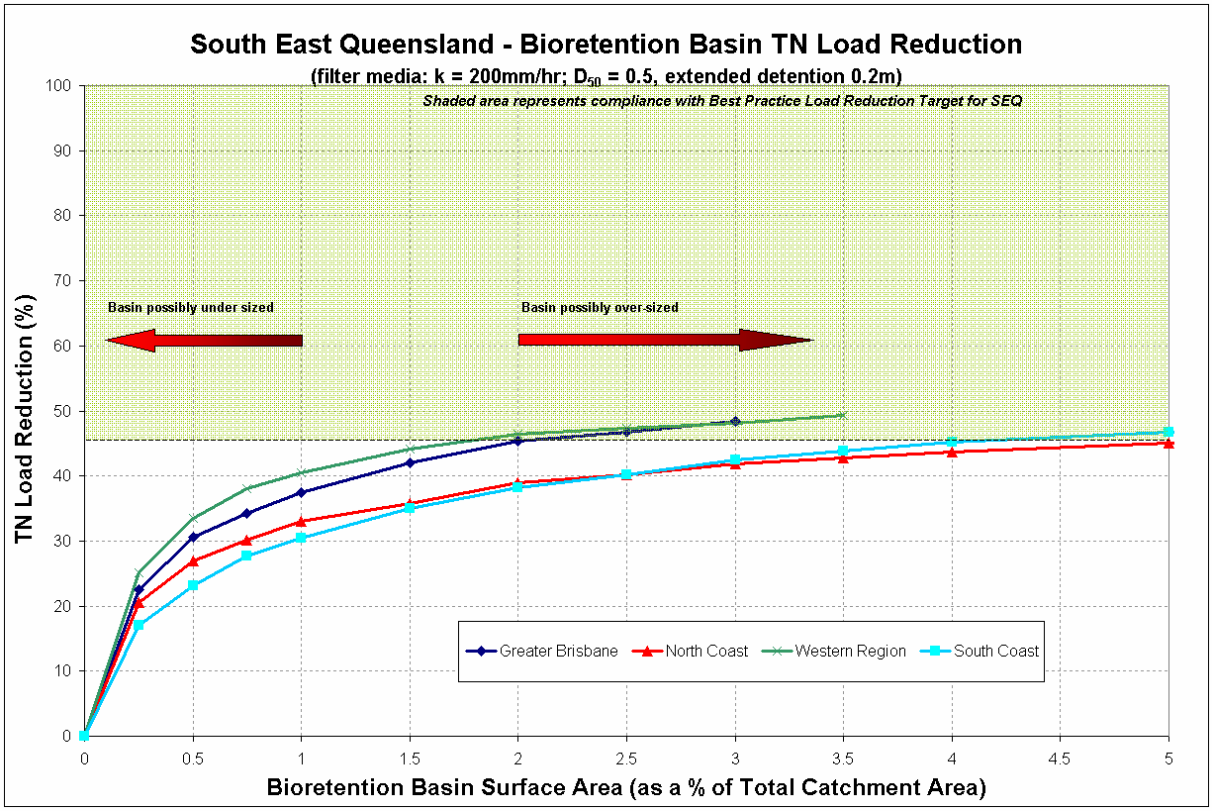


Figure 5.15 Bioretention Basin TN Removal Performance (Healthy Waterways 2006)

Areas of each landuse (roads and urban) in each sub-catchment were imported from ArcGIS and used to calculate bioretention sizing as summarised in **Table 5.6** and **Table 5.7** respectively for Torquay and Native Dog Creek.

Table 5.6 Torquay Creek landuse and treatment area within each sub-catchment

Catchment	Road (m2)	Bio-retention size (2%)	Urban (m2)	Bio-retention size (2%)
1	17,653	353	52,234	1,045
2	24,095	482	61,083	1,222
3	16,392	328	44,821	896
4	19,112	382	68,589	1,372

Catchment	Road (m2)	Bio-retention size (2%)	Urban (m2)	Bio-retention size (2%)
5	5,885	118	16,919	338
6	5,387	108	12,414	248
7	20,327	407	48,780	976
8	9,844	197	21,295	426
9	29,333	587	87,035	1,741
10	11,917	238	33,959	679
11	15,389	308	26,649	533
12	19,119	382	82,997	1,660
13	23,711	474	64,010	1,280
14	32,028	641	29,156	583
15	24,155	483	36,967	739
16	42,181	844	24,393	488
17	26,601	532	3,214	64
Total	**343,130**	**6,863**	**714,515**	**14,290**

Table 5.7 Native Dog Creek landuse and treatment area within each sub-catchment

Catchment	Road (m2)	Bio-retention 2%	Urban (m2)	Bio-retention 2%
1	5,340	107	0	0
2	13,110	262	0	0
3	18,970	379	0	0
4	8,590	172	0	0
5	44,030	881	28,350	567

Catchment	Road (m2)	Bio-retention 2%	Urban (m2)	Bio-retention 2%
6	65,240	1305	22,080	442
7	49,170	983	38,360	767
8	95,680	1914	273,630	5473
9	98,980	1980	90	2
10	86,130	1723	164,170	3283
11	75,970	1519	10	0
12	85,770	1715	88,300	1766
13	38,010	760	83,860	1677
Total	**684,990**	**13,700**	**698,850**	**13,977**

Results indicated significant load reductions and improvements towards achieving WQO's as summarised in **Table 5.8** and **Table 5.9**. Load targets for developed for urban areas do not apply to this scenario as it includes rural landuses and the load reduction targets were developed for urban development only. WQO's were achieved for TSS and TP but not for TN.

Table 5.8 Results from Torquay Creek

Scenario	Loads kg/y	Load Reduction %	Load Reduction targets %	Median Concentrations (mg/L)	Local WQO (mg/L)
Total Suspended Sediments (TSS)					
TSS (2009)	87,670			44.87	15
TSS - Riparian filter model only	80,375	8%	80%	30.83	15
TSS - Riparian Filter and 2% Bio-retention	30,240	66%	80%	14.03	15
Total Phosphorus (TP)					
TP (2009)	216			0.13	0.07
TP - Riparian filter model only	197	9%	60%	0.1	0.07
TP - Riparian Filter and 2% Bioretention	124	43%	60%	0.07	0.07
Total Nitrogen (TN)					
TN (2009)	1,629			1.11	0.65

Scenario	Loads kg/y	Load Reduction %	Load Reduction targets %	Median Concentrations (mg/L)	Local WQO (mg/L)
TN - Riparian filter model only	1,510	7%	45%	0.96	0.65
TN - Riparian Filter and 2% Bioretention	1,360	17%	45%	0.91	0.65

Table 5.9 Results from Native Dog Creek

Scenario	Loads kg/y	Load Reduction %	Load Reduction targets %	Median Concentrations (mg/L)	Local WQO (mg/L)
Total Suspended Sediments (TSS)					
TSS (2009)	222,095			44.04	15
TSS - Riparian filter model only	207,203	7%	80%	36.36	15
TSS - Ripraian Filter and 2% Bioretention	120,326	85%	80%	14.19	15
Total Phosphorus (TP)					
TP (2009)	558			0.13	0.07
TP - Riparian filter model only	484	13%	60%	0.08	0.07
TP - Ripraian Filter and 2% Bioretention	367	52%	60%	0.06	0.07
Total Nitrogen (TN)					
TN (2009)	4,844			1.01	0.65
TN - Riparian filter model only	4,381	10%	45%	0.85	0.65
TN - Ripraian Filter and 2% Bioretention	4,243	12%	45%	0.81	0.65

5.9 Results

5.9.1 Impact of Increasing Urbanisation

As shown in **Table 5.10**, conversion of rural residential or forested areas to urban results in increased nutrient loads, even when best practice load reduction targets are achieved through water sensitive urban design measures. Total Suspended Solids loads from mitigated urban areas modeling results are lower than those produced from rural residential land uses, but higher than forested.

Table 5.10 Indicative Loads per Land-Use

Parameter	Forest	Rural Residential	Mitigated Urban	Unmitigated Urban	Agricultural
TSS (kg/ha/yr)	88.4	437	183	916	398
TP (kg/ha/yr)	0.113	0.469	0.72	1.8	1.09
TN (kg/ha/yr)	1.26	3.96	5.04	9.17	7.54

5.9.2 Load reductions achieved by rainwater tanks

MUSIC modeling indicates that load based targets for Urban areas can only be achieved through retrofit of existing stormwater systems with water sensitive urban design measures.

Although, as shown in **Figure 5.16** significant load reductions will be achieved in Scenario B. Scenario B considers only passive uptake of rainwater tanks by residents and implementation of water sensitive urban design measures by new developments (Greenfield), and establishment of Grass Swales on rural roads which would come at some capital cost.

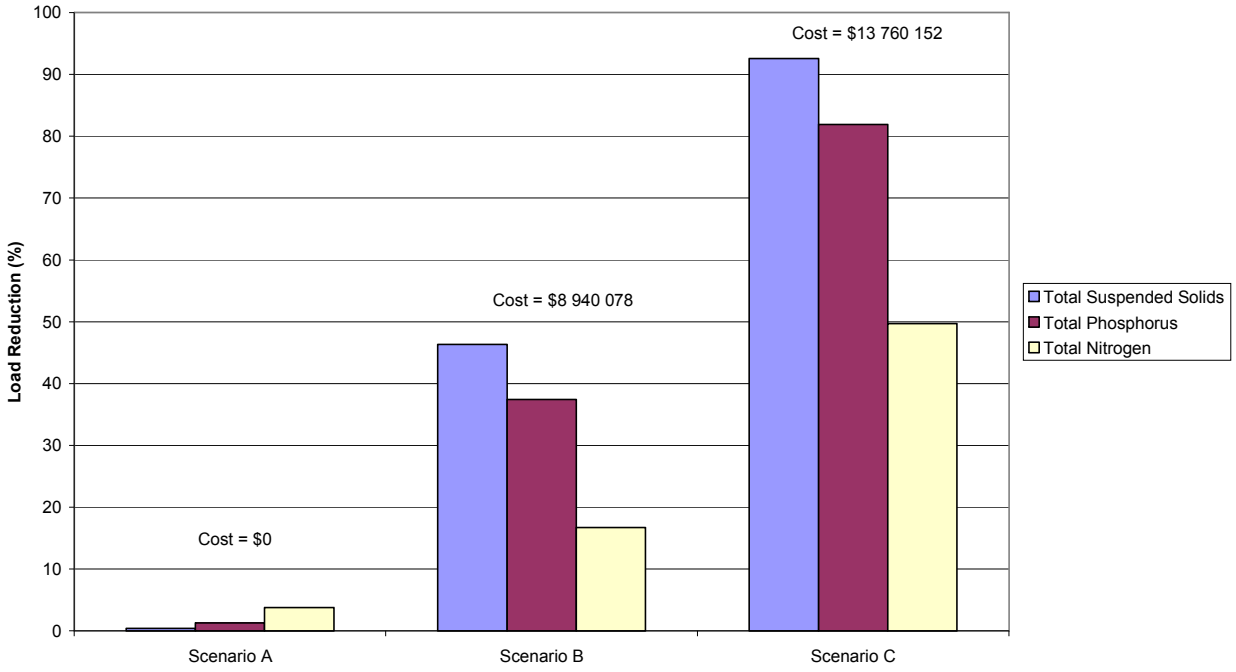


Figure 5.16 Treatment Train Effectiveness and Cost for different treatment scenarios

The consideration of rainwater tanks on load reductions resulted in a 4% reduction in Total Nitrogen Loads and a 1% reduction in phosphorus. The consideration of rainwater tanks and swales with bioretention basins has allowed for bioretention basins to be sized at 1.5% of the contributing catchment area, compared to the 2% that would otherwise be required to achieve load reductions.

The consideration of swales and rainwater tanks in modelling has allowed a 1/4 reduction in total bioretention basin size (1.58ha), equating to a cost saving of $1.34 million (lifecycle cost over 50 years in 2009 $AUD).

5.9.3 Land use pollutant load generation

The average annual loads / hectare of each MUSIC land-use were calculated and are represented graphically below in figures **Figure 5.17** and **Figure 5.18** below. As shown, roads and urban roofs contribute significant loads and discharge per unit area, whereas loads generated from rural residential areas are not substantially increased from forested. Reference is also made to the previous discussions relating to pollutant load generation from various land use types.

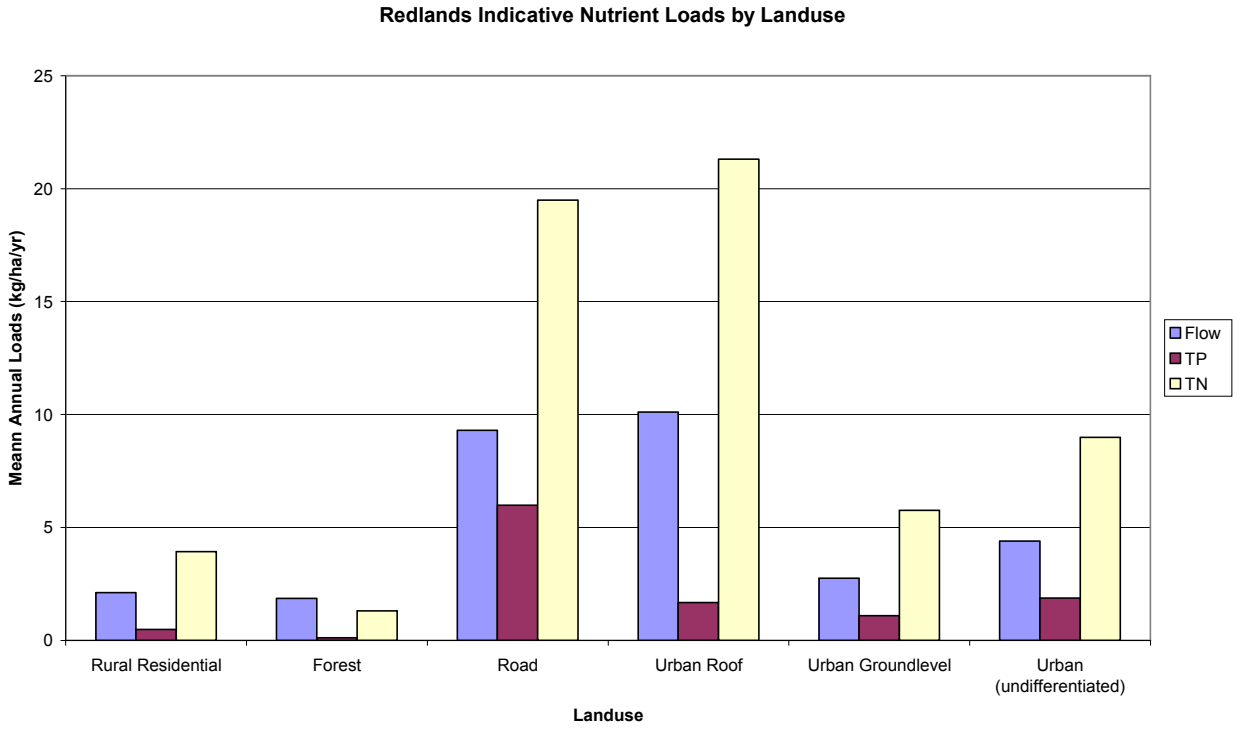


Figure 5.17 Redlands Indicative Nutrient Loads by Landuse

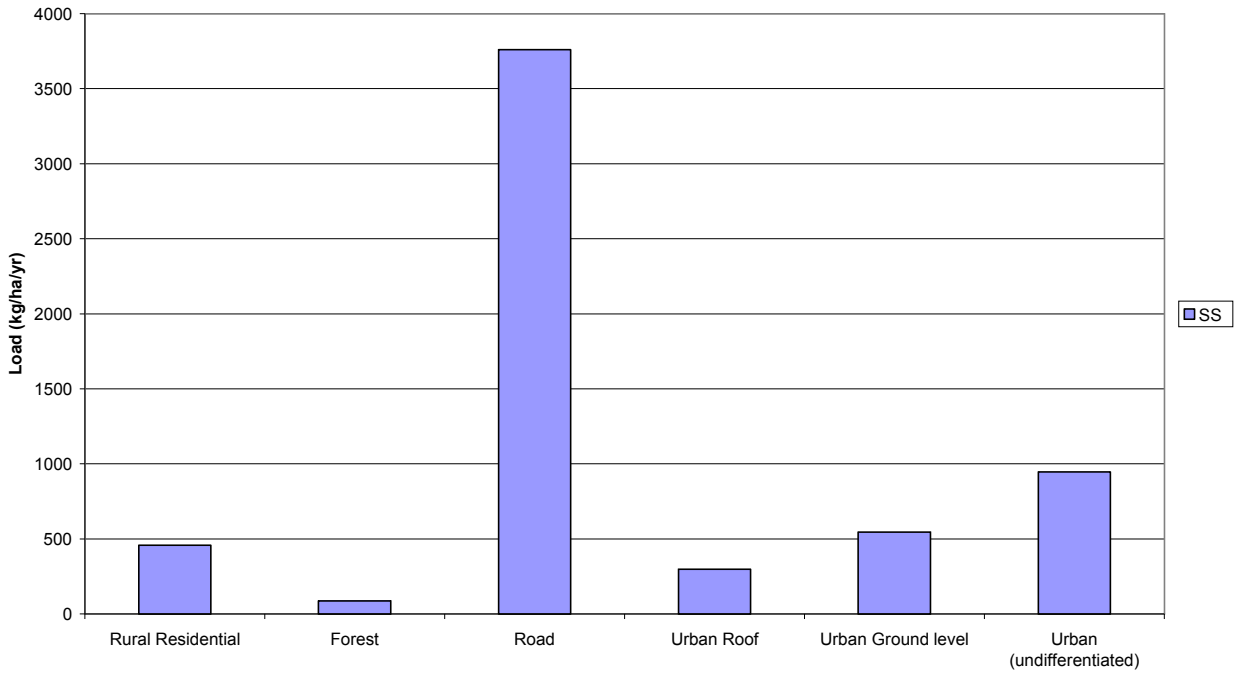


Figure 5.18 Redlands Indicative Suspended Solids Loads by Landuse

5.9.4 Native Dog Creek Catchment – Load Reductions and Costs

Load Reductions

The proposed treatment train of stormwater quality improvement devices (SQIDs) in urban areas resulted in significant reductions in nutrient loads (83% and 51 % for total phosphorus and total nitrogen respectively) and suspended solids loads (94% reduction) from those that would be otherwise discharged from these urban areas.

Implementation of a 10m buffer zones to all creeks in rural areas are also results in reduction in nutrient loads (35% and 33% for total phosphorus and total nitrogen respectively) and suspended solid loads (17% reduction).

After implementation of all recommended design measures, WaterCAST modeling indicates that rural residential areas will be responsible for greater loads of sediment and phosphorus to Native Dog creeks than Urban areas, despite occupying a smaller footprint in the ultimate land-use scenario. This finding is based on the residual loads for nutrients and suspended solids shown in **Table 5.11** and **Table 5.12** for urban and rural residential areas respectively.

Table 5.11 Native Dog Creek - WSUD Treatment Train Effectiveness Urban Areas

Catchment	TSS (kg/yr)			TP (kg/yr)			TN (kg/yr)		
	Source	Residual	% Reduction	Source	Residual	% Reduction	Source	Residual	% Reduction
1	1,980	27	99	3	0	91	11	5	55
2	7,220	311	96	12	2	86	47	24	48
3	7,230	114	98	12	1	91	37	17	54
4	1,760	24	99	3	0	91	9	4	55
5	20,800	1,060	95	37	6	85	152	74	51
6	31,000	1,000	97	53	6	88	203	94	54
7	53,900	3,090	94	98	17	83	445	226	49
8	64,100	4,150	94	119	22	82	571	268	53
9	51,500	2,210	96	90	12	86	372	182	51
10	42,900	2,110	95	76	12	85	319	152	52
11	15,000	1,770	88	30	7	76	147	78	47
12	42,000	3,080	93	76	14	82	344	175	49
13	27,800	2,380	92	51	10	80	238	124	48
Total	367,190	21,326	94	658	109	83	2,894	1,423	51

Table 5.12 Native Dog Creek – Riparian Buffer Filtering Treatment Train Effectiveness Rural Residential Areas

Catchment	TSS (kg/yr)			TP (kg/yr)			TN (kg/yr)		
	Source	Residual	% Reduction	Source	Residual	% Reduction	Source	Residual	% Reduction
1	8130	7070	13	20	10	50	140	90	36
2	7040	6050	14	20	10	50	120	80	33
3	4790	4330	10	10	10	0	80	50	38
4	2720	1330	51	10	0	100	50	30	40
5	3550	2950	17	10	10	0	60	40	33
6	21880	19220	12	60	40	33	360	250	31
7	19120	17190	10	50	30	40	320	220	31
8	2130	1860	13	10	0	100	40	20	50
9	5340	4600	14	10	10	0	90	60	33
10	4580	3690	19	10	10	0	80	50	38
11	5070	2810	45	10	10	0	80	60	25
12	3310	1680	49	10	10	0	60	40	33
13	0	0	0	0	0	0	0	0	0
Total	87,660	72,780	17	230	150	35	1,480	990	33

Costing

The estimated cost of all SQIDs in Urban areas required to meet load based water quality objectives in Native Dog Creek Catchment in 2009 $AUD is $14 072 288. This value includes establishment, operation and maintenance and decommissioning over a 50 year period. And equates to an annual equivalent annual payment cost of $281 446 over this period.

Re-establishing 10m riparian habitat on all drainage lines in rural residential areas is estimated to cost $2.987 mil in 2009 $AUD. However, this is likely to be an overestimate as it was assumed for modeling purposes that all drainage lines required full restoration. More accurate cost estimates can be derived from a detailed riparian survey.

The total cost of establishing SQIDs in urban areas and re-establishing 10m riparian habitat on all waterways is estimated to be $17.060 mil in 2009 $AUD. This equates to an average annualized cost of $341 202 per year over the expected lifespan of structures (50 years), or a cost of $29 163 per hectare.

The equivalent annual cost/kg for each contaminant is summarized below in

Table 5.13 and cost for infrastructure in each catchment is summarized below in **Table 5.14.**

Table 5.13 Cost Benefit Analysis Native Dog Creek

Item	Urban (SQIDs)	Rural (Riparian Restoration)	Total
Lifecycle Cost ($AUD 2009)	14,072,288	2,987,834	17,060,122
Lifecycle Period (years)	50	50	50
Equivalent Annual Payment ($AUD 2009)	281,446	59,757	341,202
Area Controls Applied to (ha)	316	269	585
Cost per hectare ($AUD 2009)	44,533	11,107	29,163
Load Suspended solids removed per year (kg/year)	345,864	14,880	170,072
Cost to remove kg Suspended Solids per year ($AUD 2009)	0.81	4.02	2.01
Load Total Phosphorus removed per year (kg/year)	549	80	629
Cost to remove kg Total Phosphorus per year ($AUD 2009)	513	747	542
Load of Total Nitrogen removed per year (kg/year)	1,471	490	1,961
Cost to remove kg Total Nitrogen per year ($AUD 2009)	191	122	174

Table 5.14 Infrastructure Costs Native Dog Creek Catchment by sub catchment

	WSUD Infrastructure				Riparian Habitat	Grand Total
Item	Total Acquisition Cost	Sum of Annual Maintenance Costs	Sum of Renewal Costs	Decommissioning Cost	Total	
1	127,527	218,011	46,055	3,986	299,944	695,523
2	149,861	259,865	53,871	4,681	274,803	743,081
3	226,611	292,190	81,765	7,082	81,516	689,164
4	115,534	208,457	41,728	3,611	139,957	509,287
5	496,572	445,699	178,384	15,511	195,343	1,331,509
6	744,632	524,303	267,967	23,264	675,288	2,235,454

	WSUD Infrastructure				Riparian Habitat	Grand Total
Item	Total Acquisition Cost	Sum of Annual Maintenance Costs	Sum of Renewal Costs	Decommissioning Cost	Total	
7	951,522	601,658	340,798	29,711	342,472	2,266,161
8	864,633	572,597	309,187	26,993	90,898	1,864,308
9	882,433	581,105	316,494	27,558	211,233	2,018,823
10	620,999	496,416	222,696	19,393	390,376	1,749,880
11	212,552	216,776	75,408	6,629	146,637	658,002
12	676,074	516,841	242,148	21,110	139,367	1,595,540
13	362,902	239,746	92,529	8,213	0	703,390
TOTAL	6,431,852	5,173,664	2,269,030	197,742	2,987,834	17,060,122

5.9.5 Torquay Creek Catchment – Load Reductions and Costs

Loads and Treatment Train Effectiveness

The proposed treatment train of stormwater quality improvement devices (SQIDs) in urban areas resulted in significant reductions in nutrient loads (81% and 51% for total phosphorus and total nitrogen respectively) and suspended solids loads (92% reduction).

Implementation of a 10m buffer zones to all waterways in rural areas also results in reduction in nutrient loads (33% and 44% for total phosphorus and total nitrogen respectively) and suspended solid loads (33% reduction).

After implementation of all recommended design measures, modeling indicates that rural residential areas and urban areas will contribute similar loads to receiving waters, despite the rural areas occupying a smaller footprint than urban in the ultimate land-use scenario.

Table 5.15 Treatment Train Effectiveness Urban Areas by Catchment – Torquay Creek Catchment

	TSS			TP			TN		
Catchment	Source t/yr	Residual t/yr	% Reduction	Source t/yr	Residual t/yr	% Reduction	Source t/yr	Residual t/yr	% Reduction
1	9520	856	91	16.5	3.31	80	64.4	32.9	49
2	12000	1050	91	20.9	4.15	80	82.4	42.8	48
3	8800	793	91	15.1	2.96	80	58.2	30	48
4&5	15000	1350	91	25.1	5.05	80	99.1	50.8	49
6&7	13000	1280	90	22.3	4.52	80	85.6	44.4	48
8	4740	463	90	8.72	1.82	79	41.2	19.8	52
9	14600	1400	90	28.9	5.95	79	162	72.6	55
10	6000	628	90	11.3	2.42	79	58.7	27.2	54
11	7010	551	92	12.9	2.41	81	62.3	30.6	51
12	11300	1280	89	22.5	4.9	78	122	54.8	55
13	11500	900	92	22.1	4.24	81	120	56.3	53
14	17200	867	95	28.4	3.93	86	102	50.7	50
15	10800	785	93	19.5	3.47	82	85.4	42.6	50
16	21200	1010	95	35.1	4.89	86	125	63.1	50
17	14700	1380	91	24.3	4.68	81	82.5	46	44
TOTAL	**177370**	**14593**	**92**	**313.62**	**58.7**	**81**	**1350.8**	**664.6**	**51**

Table 5.16 Treatment Train Effectiveness Rural Areas by Catchment – Torquay Creek Catchment

	TSS			TP			TN		
Catchment	Source t/yr	Residual t/yr	% Reduction	Source t/yr	Residual t/yr	% Reduction	Source t/yr	Residual t/yr	% Reduction
1	151	140	8	0.38	0.25	34	2.52	1.72	32
2	0	0	0	0	0	0	0	0	0
3	97	90	8	0.24	0.16	33	1.62	1.1	32
4&5	262	201	23	0.66	0.44	33	4.37	2.99	32
6&7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	414	382	8	1.04	0.69	34	6.89	4.71	32
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	682	526	23	1.72	1.14	34	11.36	7.76	32
13	277	214	0	0.7	0.46	34	4.61	3.15	32
14	2755	2437	12	6.94	4.62	33	45.92	31.35	32
15	0	0	0	0	0	0	0	0	0
16	6777	3959	42	17.08	11.37	33	112.95	77.1	32
17	3748	3358	10	9.44	6.29	33	62.46	42.64	32
18	3400	1741	49	8.57	5.7	33	56.66	38.68	32
19	3722	1940	48	9.38	6.24	33	62.04	42.35	32
TOTAL	**22283**	**14988**	**33**	**56.15**	**37.36**	**33**	**371.4**	**253.55**	**44.3**

Costing

Cost benefit analysis results are summarized below in **Table 5.17**. As indicated by the table, investment in Water Sensitive Urban Design measures in urban areas is a more cost effective method of removing Suspended Solids (2.3 times more cost effective) and Total Phosphorus (1.4 times more cost effective) than using riparian restoration from rural areas. Whereas riparian buffer zones results in a more cost effective method of removing Nitrogen loads from stormwater (1.5 times more cost effective).

The equivalent annual cost/kg for each contaminant is summarized below in **Table 5.17** and cost for infrastructure in each catchment is summarized below in **Table 5.18.**

Table 5.17 Cost Benefit analysis Torquay Creek Catchment

Item	Urban (SQIDs)	Rural (Riparian Restoration)	Total
Lifecycle Cost ($AUD 2009)	6 493 740	667 361	7161101
Lifecycle Period (years)	50	50	50
Equivalent Annual Payment ($AUD 2009)	129 875	13 347	143222
Area Controls Applied to (ha)	111	80	191
Cost per hectare ($AUD 2009)	58 502	8 342	37493
Load Suspended solids removed per year (kg/year)	162 777	7 295	170072
Cost to remove kg Suspended Solids per year ($AUD 2009)	0.80	1.83	0.84
Load Total Phosphorus removed per year (kg/year)	254	18.8	273
Cost to remove kg Total Phosphorus per year ($AUD 2009)	509	710	525
Load of Total Nitrogen removed per year (kg/year)	686	117	803
Cost to remove kg Total Nitrogen per year ($AUD 2009)	189	113	178

Table 5.18 Infrastructure Costs in Torquay Creek Catchment by Sub-catchment

	WSUD Infrastructure				Riparian Habitat	Grand Total
Catchment	Total Acquisition Cost	Sum of Annual Maintenance Costs	Sum of Renewal Costs	Decommissioning Cost	Total	
1	100,914	154,334	35,810	3,148	3,743	297,949
2	112,387	162,090	39,880	3,505	0	317,862
3	89,731	146,295	31,844	2,799	365	271,034
4&5	144,329	181,673	51,208	4,502	27,767	409,479
6&7	114,335	163,346	40,574	3,566	0	321,821
8	51,374	113,525	18,240	1,602	0	184,741
9	148,460	225,500	52,728	4,631	1,892	433,211
10	69,017	129,813	24,501	2,153	0	225,484
11	139,346	253,643	49,981	4,352	0	447,322
12	127,358	171,589	45,191	3,972	80,057	428,167
13	235,430	321,274	84,397	7,352	34,210	682,663

	WSUD Infrastructure				Riparian Habitat	Grand Total
Catchment	Total Acquisition Cost	Sum of Annual Maintenance Costs	Sum of Renewal Costs	Decommissioning Cost	Total	
14	280,735	341,173	100,918	8,770	71,323	802,919
15	173,469	280,349	62,174	5,417	0	521,409
16	355,241	374,515	127,816	11,098	130,104	998,774
17	164,698	271,377	59,147	5,144	83,712	584,078
18	0	0	0	0	109,310	109,310
19	0	0	0	0	124,878	124,878
TOTAL	**2,306,824**	**3,290,496**	**824,409**	**72,011**	**667,361**	**7,161,101**

5.10 Conclusion and Recommendations

The water quality analysis works completed in this study have improved on previous IWMP by:

- Including water tanks as part of our MUSIC model resulting in a cost saving.
- Focusing our analysis on protection of local waterways as well as Moreton Bay. This was completed by using treatments at a more local scale and not within waterways. Waterways have an inherent environmental value and should also be protected not used as a treatment device.
- Integrated broader catchment management actions and WSUD into one modeling package to demonstrate achievable water quality objectives using WaterCAST.

MUSIC modeling indicates that total load pollutant reduction targets can be achieved for urban areas in both Torquay Creek Catchment and Native Dog Creek catchment in the ultimate development scenario. Targets were achieved by utilizing rainwater tanks on houses, swales on rural roads and bio-retention devices sized to 1.5% of the contributing catchment, with coarse sediment forebays.

The application of filtering modules within WaterCAST provides justification to allow for the investment in 'green infrastructure' in a treatment train approach with WSUD to achieve end of catchment water quality targets. Riparian zones are a cost effective means of achieving load reductions compared to more engineered solutions such as WSUD and have many other additional ecosystem service benefits.

The case study presented indicates that a multi-mitigation approach incorporating both riparian rehabilitation and WSUD can achieve water quality objectives at end of catchment. This approach achieves better Triple Bottom Line outcomes i.e. financial, social and ecological than WSUD

implementation alone. The modeling approach taken for the Redland IWMP in applying MUSIC and WaterCAST modeling in unison is unique and through this project is proven successful.

The Environmental Protection (Water) Policy 1997 requires councils with urban stormwater systems "develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system" Reliance on water any water treatment that may occur in natural wetlands or ponds to in-stream 'treatment' that may occur through the action of natural wetlands or in-stream devices does not serve to protect these waters and therefore does not comply with the section of the EPP provided above. The stormwater quality management plan proposed in this report relies only on treatment by off-line devices, and requires that load reduction targets are met prior to discharge to waterways. This results in load reduction targets being achieved not only at discharge to Moreton Bay, but at every discharge point to all waterways within the catchment.

Although modeled as single devices in MUSIC, bioretention devices should be dispersed throughout each sub-catchment as close as possible to each source, ideally at each field or gully inlet. In situations where installation at field or gully pits is not possible due to site constraints (i.e. existing infrastructure, hydraulic gradient, underground services), bioretention devices may be located at discharge points including the potential locations identified on **Appendix Q.** Locating and sizing of each bioretention device throughout sub-catchments will be required at detail design.

Achieving load based reductions may not result in concentration based water quality objectives being achieved at the discharge point to each waterway. Load based targets represent achievable best practice for stormwater management infrastructure in SEQ climate and pollutant export conditions operating near the limit of its economic performance. Substantial extra cost required to achieve low concentration based targets, at very small additional water quality benefit.

5.10.1 Recommendations

The following recommendations relating to water quality are made: -

- Recommendations from WBM (2008) regarding improving catchment modeling and reducing uncertainty are equally valid for this report.
- That WaterCAST should be used as a first run conceptual design tool for IWMP and initial costing, allowing for the inclusion of green infrastructure in infrastructure charges.
- MUSIC is adapted at the detailed planning stage and undertaken at a finer streetscape scale allowing for the protection of waterways and the bay.
- MUSIC modeling include the modeling of rain water tanks and roads

5.10.2 Action Plan

The following action plan is recommended: -

1. Detail design and construction of swales on all rural roads (ref **Appendix Q**).

2. Continue requirement for all new developments to install SQIDs to achieve load based reduction targets.
3. Riparian buffer zone implementation
    a. Council to prepare rehabilitation plan for all waterways in rural residential area
    b. Carry out rehabilitation works
4. Council to develop policy to encourage uptake of rainwater tanks on existing houses.
5. Detailed design of treatments
    a. Constraints and Opportunity analysis at each field inlet to identify if bioretention can be effectively installed, and if not to identify suitable alternative locations.
    b. Detail design of all bio-retention devices.
    c. Construction of bioretention devices.

6. FLOOD ASSESSMENT

6.1 Introduction

EnGenY in association with Sargent Consulting were subcontracted by Redlands City Council to undertake a comprehensive hydrological and hydraulic assessment for the Native Dog Creek and Torquay Creek – Southern Redland Bay (Part 22) Catchments. These catchments comprise two (2) of the 16 major catchments within the Redlands City Council area and are illustrated previously in **Figure 1**. The catchment boundaries and associated waterway networks for the respective catchments are illustrated in **Figure 2** and **Figure 3** previously for Native Dog Creek and Torquay Creek catchment respectfully. The hydrological and hydraulic assessment works undertaken represents one component of the overall larger study for the Integrated Water Management Plan for these catchments.

This section of the report provides a detailed description of the works undertaken for the hydrological and hydraulic analysis works for the Native Dog and Torquay Creek catchments.

6.2 Scope of Works

The Scope of work for the hydrological component of the study included the following tasks:

- Establish XP-RAFTS models for both the Native Dog and Torquay Creek catchments;
- In the absence of hydrological calibration data, undertake model validation tasks in order to prepare a representive hydrological model for both catchments;
- Analyse both XP-RAFTS hydrological models in order to quantify catchment flows for the 1 in 10, 20, 50 and 100 year average recurrence interval (ARI) design events based on ultimate catchment conditions;
- Provide a summary tabulation of all flows as well as extracting both local and total flow hydrographs for inclusion in the hydraulic model; and
- Prepare a report to document all works undertaken for the preparation of the XP-RAFTS hydrological models including all model parameters and details as appropriate.

6.3 Study Area and Catchment Description

The study area for this investigation includes two (2) discrete catchments within the Redlands City Council Local Government Area (LGA) that comprise:

- The Native Dog Creek catchment; and
- The Torquay Creek Catchment (Southern Redland Bay (Part 22).

The following provides a brief description of the two catchment areas.

6.3.1 Native Dog Creek Catchment

This catchment includes a large portion of the Mount Cotton suburb with the Native Dog Creek branch following the eastern side of the catchment. The catchment is traversed by Mount Cotton Road in the west as well as both Heinemann and German Church Roads in the east. The catchment includes the Mount Cotton Village and Community Park on the northern side. The main channel branch originates in three (3) separate tributaries within the catchment before flowing in a southerly direction to converge to form the larger main creek branch. The catchment discharge is in a southerly direction to ultimately discharge to the Logan River within the Logan City Council Local Government Area. The discharge point for this study resides at the Local Government Administration Boundary between Redland City Council and Logan City Council and is not subject to tidal influences at this point. The total catchment area subject to this study is approximately 957.35 Hectares. The catchment is typified by runoff slopes which range from steep (approx. 25% in the upper reaches) to a flatter slope of only 0.1% in the lower tributary reaches.

6.3.2 Torquay Creek Catchment

The Torquay Creek catchment includes a portion of the Redland Bay suburb. The catchment extends from the upper reaches to the west of Cleveland Redland Bay Road through to Moreton Bay downstream of Serpentine Road. There are three (3) discrete tributaries in the upstream reaches which combine immediately upstream of Serpentine Road to form the single Torquay Creek waterway which flows in an eastern direction before discharging to Moreton Bay near Point Talburpin. The waterway is subject to tidal influences in the lower reaches. The total catchment area is approximately 261.17 Hectares. The runoff slope for this catchment ranges from approximately 6.8% in the upper reaches of the catchment to a flat 0.1% slope in the lower reaches at the catchment outlet.

6.4 Catchment Hydrology

6.4.1 Introduction

A hydrological model of the Native Dog Creek and Torquay Creek catchments has been developed using an XP-RAFTS model. The XP-RAFTS model is a non-linear runoff routing program. Rainfall runoff is routed through a series of sub catchment storages and along channel links to produce hydrographs throughout the catchment.

The preparation of the XP-RAFTS models in this study has included the division of the catchment into an extensive number of sub catchments, derivation of various physical catchment properties and assembly of the catchment into a nodal network. Routing of flow along the various waterways is performed using a series of discrete and representative waterway cross sections based upon the physical catchment properties in order to enable representative channel routing to be assessed. The individual sub catchments are added in sequence to the routed flows based on location within the nodal network.

The following sections of this report provide a summary of the various data and parameters used in the development of the new XP-RAFTS models for both catchments under this study.

6.4.2 Base Data Sets

Aerial Photography

Aerial photography of the catchment area was provided by Redland City Council for this study. The photography is believed to be captured in circa 2004 and is spatially corrected to the MGA94 Zone 56 co-ordinate system. Aerial photograph images were available for both catchment areas and provided a fairly recent picture of the level of development throughout the catchment. The aerial photographs have been utilised for the purposes of illustration and more importantly the land use and development characteristics of the catchment for the purposes of hydrological modelling.

Topographic Survey Data

Topographic survey information for both catchments was provided by Redland City Council in the form of 1 metre contour intervals along with Airborne Laser Survey (ALS) data in the form of text files containing Reduced Level (RL) height data to the Australian Height Datum (AHD) against spatially corrected points to the MGA94 Zone 56 co-ordinate system. The latter represented a more detailed and comprehensive set of topography data and was subsequently utilised for the purposes of preparing a Digital Terrain Model (DTM) for both catchments. It is understood that the ALS data was captured in circa 2004 and at the same time as the capture of the aerial photography across the catchment.

GIS Data

Electronic GIS data for both study areas was also supplied by Council at the commencement of the works. A range of electronic GIS data was provided which included land use layers, cadastre layers, planning layers, waterway lines, stormwater, sewer, etc. All GIS data was provided as a series of layers and was spatially corrected based on the MGA94 Zone 56 co-ordinate system. The GIS data has been used as a basis for this study.

Land Use

Catchment land use information was provided as part of the GIS data. The land use data represented Council's Strategic Land Use Planning information for the various catchments and included a number of land use zones throughout the catchments to define the intent for future land use development. The strategic plan land use information has been used as a basis on which the catchment hydrology has been prepared.

6.4.3 Site Inspection

A site inspection of the catchment areas was undertaken by the project team in May 2009. The purpose of the site inspection was to verify the catchment conditions and to assist in the preparation of the various technical work elements associated with the development of the Integrated Water Management Plan for the catchments. The site inspection aided in the development of the XP-RAFTS hydrological model including confirming sub-catchment definition, waterway and drainage paths as well as catchment watershed limits.

6.5 XP-RAFTS Model Parameters

6.5.1 Catchment Definition

The analysis of runoff from the catchment was performed using the non-linear runoff routing program XP-RAFTS. The XP-RAFTS analysis involved division of the catchment into approximately one hundred and forty (140) separate sub-catchments for the Native Dog Catchment and some seventy two (72) separate sub-catchments for the Torquay Creek catchment. The sub-catchments were delineated using the digital terrain model to identify the overall catchment boundary as well as internal sub-catchment water shed lines. The XP-RAFTS model sub-catchment derivations for the Native Dog and Torquay Creek catchments are illustrated in **Appendix R**.

6.5.2 Sub-Catchment Parameters

The various physical catchment model parameters for the various sub-catchments within the XP-RAFTS model have been determined based upon the supplied GIS data and digital terrain model. Catchment parameters were selected based on recommended design values for various categories of vegetation types and land use categories as detailed in the Queensland Urban Drainage Manual (QUDM, 2007). A brief summary of the parameters and data sources are summarised below:

Impervious and pervious areas - Strategic plan land use information for the catchments as supplied by Council in GIS format;

Sub-catchment slopes – Slopes have been determined using contour and topographic data including the digital terrain model prepared for both catchments;

Catchment roughness values - Aerial photography spatially corrected in addition with validation of roughness zones using detailed site inspections; and

Design rainfall Intensity-Frequency-Duration (IFD) values - Determined in accordance with the procedures detailed in Australian Rainfall and Runoff (AR&R, 2001) and discussed in further detail below.

6.5.3 Design Rainfall

The Design Rainfall Intensity Frequency Duration (IFD) data for storm events up to and including the 100 year Average Recurrence Interval (ARI) flood event have been derived based upon the procedures outlined in Book 2 of the Australian Rainfall and Runoff (AR&R) 2001 edition. The design IFD parameter data for the catchment is presented in **Table 6.1** below.

Table 6.1 IFD data

2-yr ARI Intensities	50-yr ARI Intensities	Skewness and Geographical Factors
$^{2}I_{1}$ = 48 mm/hr	$^{50}I_{1}$ = 88.5 mm/hr	Skewness, G = 0.15
$^{2}I_{12}$ = 9.2 mm/hr	$^{50}I_{12}$ = 18.4 mm/hr	Geographical Factor, F_2 = 4.00
$^{2}I_{72}$ = 3.0 mm/hr	$^{50}I_{72}$ = 7.0 mm/hr	Geographical Factor, F_{50} = 16.90

The above design IFD parameters have been used to define design rainfall event data for both catchments including the derivation of various storm durations for each design event. The analysis has been prepared based on the procedures outlined in Australian Rainfall and Runoff (AR&R) 2001 edition.

6.5.4 Catchment Land Use

As noted previously, catchment land use was adopted based on Council Strategic Plan which included various planning zones throughout both catchments. The adopted percentage impervious and corresponding pervious area roughness parameters (PERN values) for use in the XP-RAFTS model are summarised in **Table 6.2** below. The fraction impervious values have been defined using the land use zoning information and in accordance with the recommended values as defined in the QUDM. For all sub-catchment areas, two (2) separate catchment areas were defined in the XP-RAFTS model for the impervious and pervious land use types for runoff determination. The catchment splits between impervious and pervious land use types has been performed using an area average technique based on the resulting land use for each individual sub-catchment. All impervious areas (i.e. hardstand areas) were allocated a PERN value of 0.015. The strategic land use information for the Native Dog and Torquay Creek catchments are presented in **Appendix R**.

Table 6.2 Catchment Land use Parameters

Land Use Zone Description (as per Strategic Plan)	% Impervious Fraction	Manning's "n" PERN Number
Community Purposes	0.6	0.100
Conservation	0.0	0.020
Environmental Protection	0.0	0.090
Low Density Residential	0.6	0.100
Neighbourhood Centre	0.9	0.100
Open Space	0.0	0.040
Park Residential	0.2	0.070
Rural Non-Urban	0.1	0.040
Urban Residential	0.8	0.100
Road	0.9	0.015
Investigation Zone	0.6	0.100

6.5.5 Rainfall Loss Model

Rainfall loss on each sub-catchment in the XP-RAFTS model has been applied using an initial and continuing rainfall loss model. Design loss parameters for the hydrological model were based on guideline values as recommended by ARR (Table 3, Book 6) and QUDM recommendations. In addition, rainfall loss parameters from previous studies including adjacent investigations were also considered for comparative purposes. The adopted rainfall loss parameters applied for the XP-RAFTS model are summarised in **Table 6.3** below.

Table 6.3 Adopted Rainfall Loss Parameters Used in the XP-RAFTS Model

Loss Type	Pervious Area	Impervious Area
Initial Loss (mm)	15	0
Continuing Loss (mm)	2.5	1

6.5.6 Storages

There was no major storage dams located in either the Native Dog or Torquay Creek catchments. Given the rural nature of the catchments and especially in the upper reaches, there was however several smaller storages primarily associated with the rural land use pursuits. These storages can be classified as primarily farm dams for the purposes of stock and domestic uses.

As part of this project these dams were further investigated by way of seeking Council advice on the development status and previous approvals. In all cases, none of the storages were identified as having development approval nor had a development application for the dam been granted by Council. As such, for the purposes of the XP-RAFTS model, none of these storages were prescriptively included in the model. This approach is considered to be appropriate in this instance as many of the dams were small and would therefore be likely to be at full supply level at the onset of the major storm event. This approach is also justified on the basis that the subsequent flows determined using the XP-RAFTS model are conservative and are therefore appropriate within the context of this study.

6.6 XP-RAFTS Model Validation

Model calibration of the XP-RAFTS model could not be undertaken for this study given the absence of stream flow gauging records in the catchments. As such, model validation tasks were undertaken in order to ensure that the resulting design flood hydrographs for both the Torquay and Native Dog Creek catchments were appropriate and representative. Model validation for the XP-RAFTS models prepared as part of this study has been undertaken using on the following techniques:

- Comparison of catchment flows from the models to that determined as part of previous studies undertaken within the same catchments (where available);
- Comparison of flows using a catchment discharge average to that determined for other locally based and adjacent catchments; and
- Flow calculations via Rational Methods at several locations throughout both catchments.

The comparison of catchment discharges for the 100 year ARI flood event at various locations throughout the catchments are summarised in **Table 6.4** and **Table 6.5** below. A map illustrating the locations for which the discharges have been compared is attached in **Appendix R**.

Table 6.4 Native Dog Creek Catchment Flow Comparisons

Location ID (1)	XP-RAFTS Node Name	XP-RAFTS Peak Flow (m3/s)	Peak Flow from Previous Reports (m3/s)	Rational Method Peak Flow (m3/s)
1	N8	11.4	n/a	14.1
2	N144	31.5	n/a	38.3
3	N77	68.8	n/a	63.2
4	N63	46.6	52.5	46.9
5	N65	116.0	n/a	118.4

Note: Refer Appendix R for Reporting Locations

Table 6.5 Torquay Creek Catchment Flow Comparisons

Location ID (1)	XP-RAFTS Node Name	XP-RAFTS Peak Flow (m3/s)	Peak Flow from Previous Reports (m3/s)	Rational Method Peak Flow (m3/s)
1	N19	5.2	n/a	7.9
2	N9	8.0	n/a	11.5
3	N16	24.5	n/a	29.5
4	N31	46.5	n/a	40.2

Note: Refer Appendix R for Reporting Locations

On the basis of the results presented above, the new XP-RAFTS models prepared as part of this study have produced model discharges close to that determined from the previous studies during a 1 in 100 year ARI event. The model discharges also compare favourably to that determined using the Rational Method approach at the majority of locations. The rational method calculations prepared are based upon the Bransby-Williams formula for time of concentration as both catchments were typically of a rural nature.

As a further check on the XP-RAFTS model, a comparison has also been made against a Area/Flow ratio using reported flows from other catchment studies located close by or adjacent to the subject catchments. A summary of the Area/Flow ratios are presented in **Table 6.7** and **Table 6.8**.

Table 6.6 Q100/Area from Previous Studies

Catchment Name	Area (Ha)	Reported Q100 Flow (m3/s)	Ratio (Q100/Area)
Moogurrapum Creek	1449	108.7	0.08
Hilliards Creek	2593	233.0	0.09
Weinam Creek	304	64.1	0.21
Tarradarrapin Creek	528	123.2	0.23

Table 6.7 Q100/Area for Native Dog Creek

Location ID	Area (ha)	Q100 Flow (m3/s)	Ratio (Q100/Area)
1	77	11.4	0.15
2	216	31.5	0.15
3	484	68.8	0.14
4	151	46.6	0.31
5	957	116.0	0.12

Table 6.8 Q100/Area for Torquay Creek

Location ID	Area (ha)	Q100 Flow (m3/s)	Ratio (Q100/Area)
1	35	5.2	0.15
2	68	8.0	0.12
3	156	24.5	0.16
4	218	46.5	0.21

The comparison of the flows determined for the Native Dog and Torquay Creek catchments using the current XP-RAFTS model is generally very similar to that reported in previous studies when compared on a flow versus area basis. The flows from the current XP-RAFTS model were found to generally lie within the middle of the flow versus area ratios for the adjacent catchments.

The model validation tasks undertaken as part of this study have shown that the current XP-RAFTS model flows are appropriate and representative based on the various checks undertaken. As such, the XP-RAFTS prepared in this study are considered to be appropriately validated and have been subsequently adopted for this study.

6.7 Critical Duration Analysis

Storm durations ranging from 10 minutes through to 360 minutes were simulated in the XP-RAFTS model to determine design flow estimates for the ultimate case 1 in 10, 20, 50 and 100 year ARI flood events. This approach was performed for both catchments and in order to identify the critical storm durations and associated peak flows at all locations throughout the systems. The results of the XP-RAFTS model indicated that the dominant storm duration for the catchment was the 60 minute storm event as this resulted in the largest peak flow at the majority of locations throughout the model.

Although the 60 minute critical duration storm event resulted in the largest peak flows throughout the majority of the catchment, it is noted that this event may not necessarily translate into the highest flood levels throughout the waterways. This is a result of the available storage within the waterway systems and in the case of both the Native Dog and Torquay Creek systems a significant amount of storage was available especially in the lower catchment reaches. The storage effects were found to have a dramatic effect on the routing of the flows within the hydraulic model. It was subsequent found as part of the hydraulic modelling works undertaken in this study that the peak flood levels throughout the catchment did not occur for the XP-RAFTS 60 minute critical storm event and additional storm duration events were required to be simulated owing to the storage effects. This aspect is discussed in further detail as part of the section on the hydraulic modelling works.

6.8 XP-RAFTS Catchment Flow Summary

The XP-RAFTS models developed for the Native Dog and Torquay Creek catchments have been analysed for all durations and design rainfall events to prepare a summary of peak flows throughout the catchments. The model has been analysed for the design events using a storage coefficient (beta) of unity within the XP-RAFTS model in order to obtain a comprehensive flow summary. A copy of the total flow summary for both catchments is resented in **Appendix S** and includes peak flows for all design events and storm durations. It should be noted that this summary represents the total flow hydrograph summary which is a cumulative flow summary. A set of local inflow hydrographs has been prepared separately for inclusion directly into the hydraulic model.

6.9 Flood Hydraulics

6.9.1 Introduction

This section of the report describes the hydrodynamic modelling component of the Integrated Waterway Management Plan (IWMP) for Native Dog Creek and Torquay Creek. This component has been undertaken by Sargent Consulting as a Sub-Consultant to lead Consultant EnGenY Management & Resourcing.

The section of the report outlines: the scope of work; study area; the model used; structure of the model for each of the catchments; input data; parameter estimation; model runs and results; sensitivity tests; flood immunity of existing culverts; identification of residential areas subject to flooding; flood mitigation options; hydraulic impacts of proposed waterway management measures; conclusions and recommendations.

6.9.2 Scope of Work

The scope of works for this component of the study for development of the IWMP is summarised below:

For each catchment:

- Establish a 2-d hydrodynamic model of the catchment's waterways;
- In the absence of sufficient data for model calibration, select appropriate model parameters;
- Run the model with critical duration streamflow hydrographs for design events of 10, 20, 50 and 100 year average recurrence interval (ARI) for ultimate catchment conditions as derived from the hydrologic models established for the study (it having been agreed that there was virtually no difference between existing and ultimate catchment conditions);
- Tabulate the peak flows and water levels at each of the culvert crossings for each design flood and determine the existing flood immunity of each road crossing;
- Prepare maps of flood inundation extent for each of the design floods (this component was undertaken by EnGenY based on the results from the modelling described herein);
- Identify any developed areas subject to flood inundation up to 100 year ARI;
- Undertake appropriate sensitivity testing of model results;
- Investigate and report on options to improve road flood immunity to current standards where required (to be included in the Final Report);
- Investigate and report on options to improve flood immunity of built infrastructure to current standards where required;
- Evaluate the impact on flood levels of proposed waterway management measures; and
- Prepare a report on the above including recommendations.

6.9.3 Study Areas

The Study Areas comprise the waterways of Native Dog Creek and its tributaries and of Torquay Creek and its tributaries as shown in **Figure 6.1** and **Figure 6.2**.

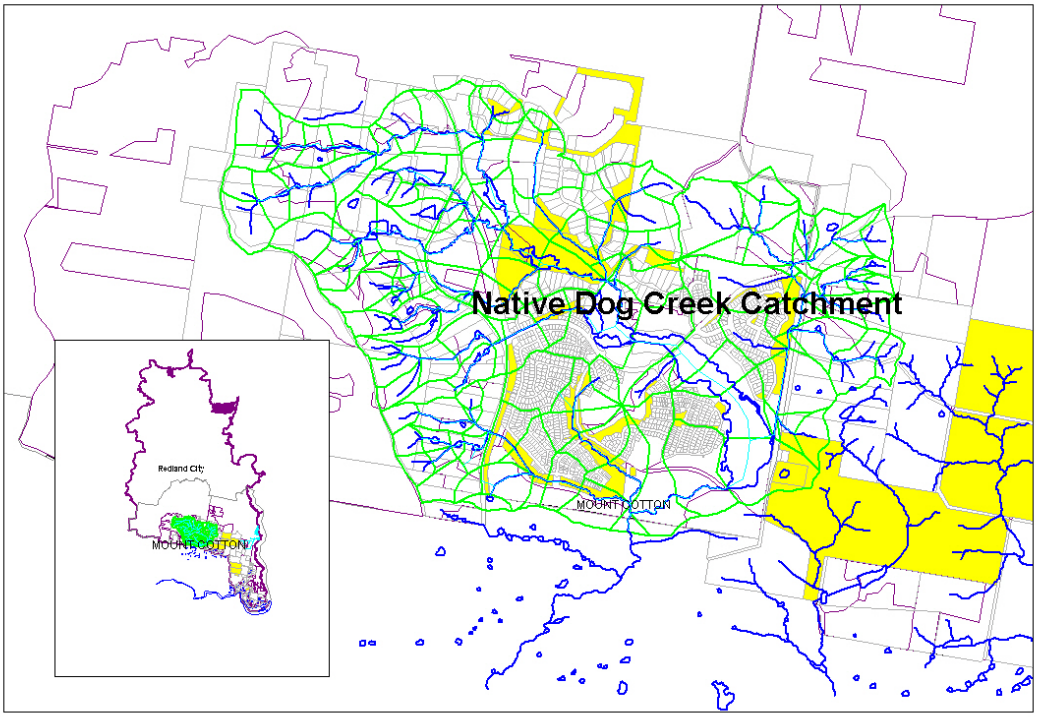


Figure 6.1 Native Dog Creek Catchment

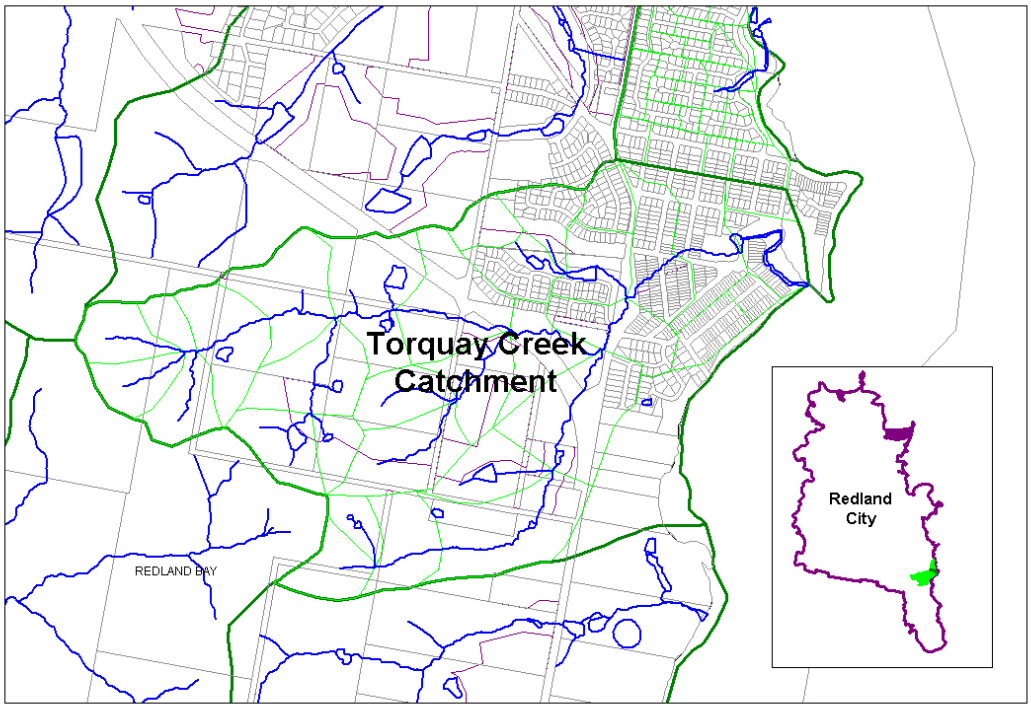


Figure 6.2 Torquay Creek Catchment

6.10 Hydrodynamic Model

6.10.1 Models Used

The hydrodynamic model used in this Study was XP-SWMM which couples together the SWMM one-dimensional (1D) model and two dimensional (2D) finite difference model TUFLOW, and provides a graphical user interface (GUI) for both models. These models are industry accepted, Australian owned, commercial software packages highly suited to the investigation of flood behaviour in complex flow scenarios.

The models for both catchments were set up as 2-D models using a 5m x 5m rectangular grid. The culverts were set up as 1-D elements integrated with the 2-D grid, using information provided by Council and the Department of Main Roads.

6.10.2 Boundary Conditions

The model boundary conditions comprised local inflow hydrographs for all sub-catchments derived from the XP-RAFTS model as described in the Hydrology Report, together with a water level boundary condition at the downstream end of the model.

In the case of Native Dog Creek, the downstream boundary was set to its normal (uniform) flow level as computed from the model. The model was extended downstream of the Redlands City /Logan City boundary (as a 1-d model) in order to eliminate the sensitivity of the model outcomes to this boundary condition.

In the case of Torquay Creek, the downstream boundary condition was set as follows, as agreed with RCC:

- Highest Astronomical Tide (HWT) of 1.52m AHD for ARI of 100 years and 50 years: and
- Mena High Water Spring Tide (MHWS) of 0.96m AHD for ARI of 20 years and 10 years.

As the relative timing of design flood and tide is not known, the tide boundary was set at a constant elevation.

6.10.3 Model Parameters

In the absence of historical flow and flood level data from which to calibrate the hydrodynamic model, it was necessary to adopt appropriate values based on values given in Chow (1973), on aerial photography and from experience. Hydraulic roughness elements were assigned to each grid cell on this basis using the values given in **Table 6.9.**

Table 6.9 Adopted Hydraulic Roughness Values

Conditions/Landuse	Hydraulic Roughness Parameter (Manning's n)
Channel	0.03
Floodplain	0.05
Urban Residential	0.08
Rural Residential	0.06
Dense vegetation	0.08

The eddy viscosity coefficient was set at its default value of 1.0 throughout.

6.11 Native Dog Creek

6.11.1 Model Setup

The area covered by the Native Dog Creek model and the 5m by 5m grid is shown in **Figure 6.3**.

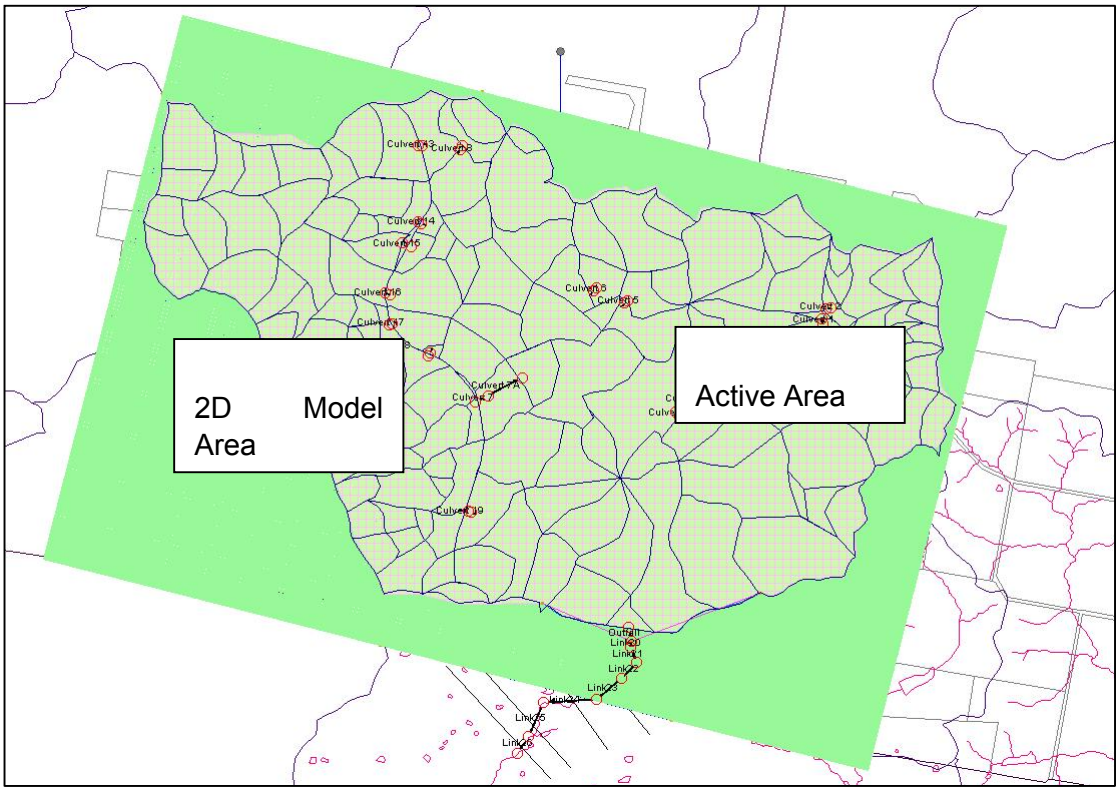


Figure 6.3 2-D Model Area – Native Dog Creek

The model was extended downstream into Logan City as a 1-d model in order to minimise the sensitivity of model results to the downstream boundary condition.

6.11.2 Existing Conditions

The model was run firstly for existing conditions.

The critical storm duration for all ARI was determined from the hydrologic modelling to be 1 hour, with very little difference for 2 hour flows. However, it was evident from running the hydraulic model that temporary storage of floodwaters was an important aspect of the creek hydraulics, not only in the natural floodplain, but also against road embankments.

In order to determine the critical duration for peak water levels rather than peak flows, the hydraulic model was run with inflows from storms of duration 1, 2 and 3 hours for 10 year and 100 year ARI and additionally for 4.5 hour duration for 100 year ARI only. The result of this was that there was little difference in peak levels between those resulting from 2 hour, 3 hour and 4.5 hour storms but that these were all significantly higher than those from the 1 hour storms. The 3 hour storm was selected, therefore, as the critical duration storm and used for the production of flood inundation maps.

Although the hydrologic model contains channel routing, this is rudimentary in nature, and it is typical that the discharges in the lower reaches of 2-D models are lower than those from the corresponding hydrologic model, as a result of the far more detailed flood routing in the hydraulic model. This effect was very noticeable in this instance, due to the high degree of temporary storage in the system as commented upon in the previous paragraph.

The locations of the culverts and the identification numbers assigned to them are shown in **Figure 6.4.** The peak discharge and peak water level data from the Native Dog Creek model are given in **Table 6.1**.

The following culverts have flood immunity levels (with no over road flow) of 10 year ARI or less:

- Culverts 2, 13, 14, 15, 17, 18, 7a and 19.
- The following culverts have flood immunity levels of 100 year ARI or greater:
- Culverts 3, 4, 5, 6, 7and 16.

No property flooding was evident at 100 year ARI.

6.11.3 Sensitivity Testing

The initial modelling terminated at the Redland City boundary, with a normal flow boundary condition. The model results were found to be sensitive to the assumed boundary condition. This sensitivity was removed by extending the model further downstream into Logan City as can be seen from **Figure 6.3**.

6.11.4 Flood Mitigation Options

Flood mitigation options were considered for road crossings, based on the following design criteria:

- Main roads – 50 year ARI flood immunity; and
- Local roads – 10 year ARI flood immunity.

Provision of the required level of flood immunity for those road crossings currently deficient in this regard was firstly investigated on the basis of increasing waterway area alone. This was done by increasing the number of culvert cells (of the same size as the existing cells) until the over road flow was eliminated.

In some instances, this strategy was found to be unsuccessful, and it was found to be necessary to raise road sag points to eliminate the over road flow. Some of these instances required both an increase in waterway area and raising of the roadway.

In some instances it was found that construction of a table drain along the roadway reduced or eliminated the over road flow in conjunction with an increase in waterway area.

The results from the flood mitigation modelling are given in **Table 6.11.** Detailed hydraulic model results are also attached in **Appendix T.**

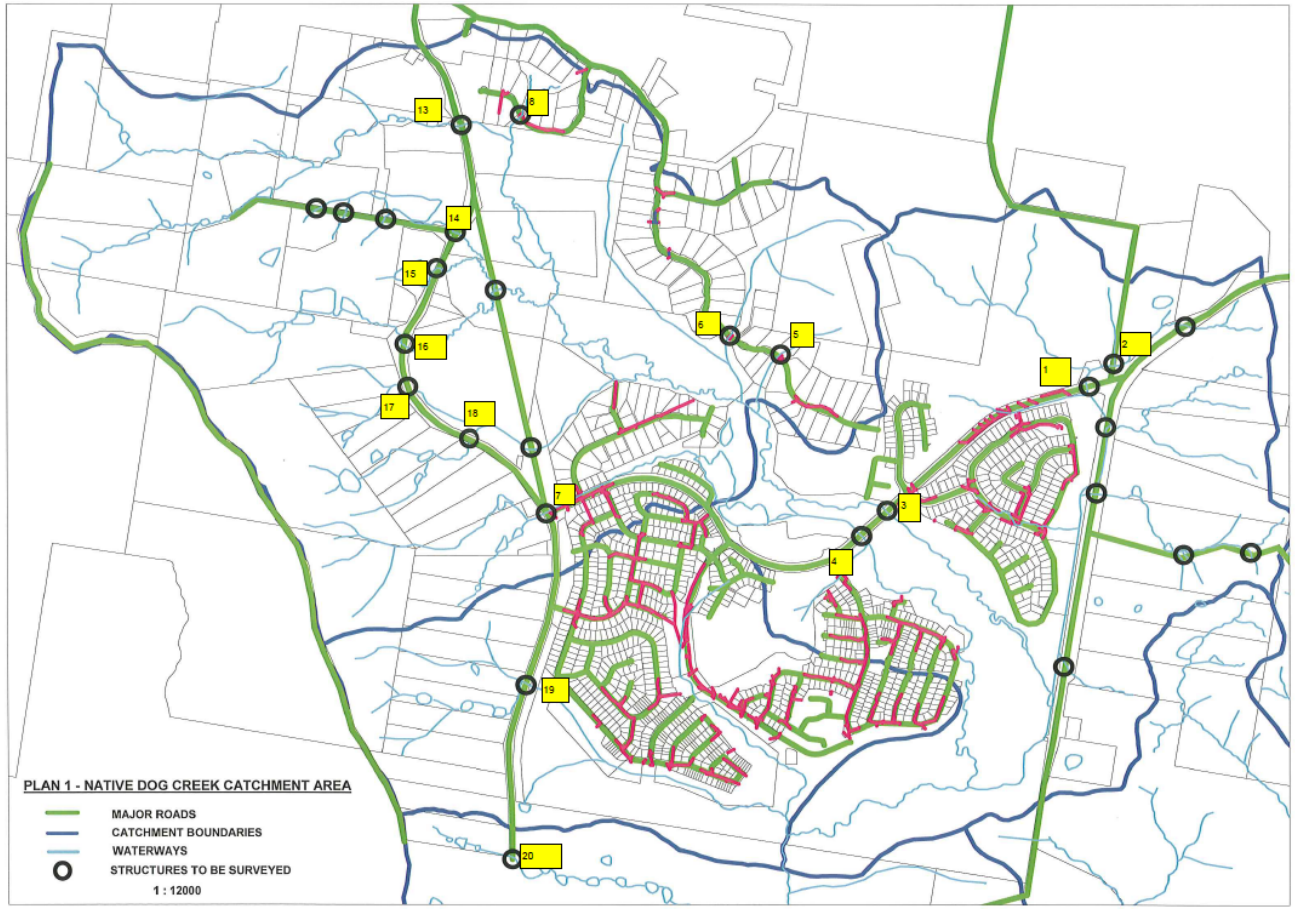


Figure 6.4 Native Dog Creek Culvert Location and Numbering

Table 6.10 Summary of Model Results Existing Conditions– Native Dog Creek

Location	Culvert No	10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
		Peak Flow cumecs	Max Water Depth Road C/L m	Peak Flow cumecs	Max Water Depth at Road C/L m	Peak Flow cumecs	Max Water Depth at Road C/L m	Peak Flow cumecs	Max Water Depth at Road C/L m
Mt Cotton Road	13	3.0	0.23	4.0	0.26	5.3	0.29	6.5	0.34
Mt Cotton Road	14	0.7	0.13	1.0	0.13	1.2	0.14	1.4	0.14
Mt Cotton Road	15	0.1	0.19	0.1	0.20	0.1	0.20	0.2	0.20
Mt Cotton Road	16	2.4	not flooded	2.9	not flooded	3.6	not flooded	4.2	not flooded
Mt Cotton Road	17	1.5	0.13	1.6	0.13	2.2	0.14	2.4	0.20
Mt Cotton Road	18	1.2	0.12	1.3	0.13	1.8	0.13	2.0	0.19
Mt Cotton Road	7	1.8	not flooded	2.6	not flooded	3.0	not flooded	3.5	not flooded
Mt Cotton Road	7a	2.5	0.28	3.1	0.32	3.9	0.37	4.8	0.40
Mt Cotton Road	19	1.0	0.15	1.3	0.28	1.6	0.29	1.8	0.30
Valley Way	3 & 4	20.0	not flooded	26.0	not flooded	33.0	not flooded	40.0	not flooded
Valley Way	1	4.0	not flooded	5.0	0.11	6.2	0.14	7.4	0.31
Heinemann Rd	2	1.2	0.40	1.4	0.47	1.8	0.52	2.0	0.69
Santuary Drive	5	0.7	not flooded	1.0	not flooded	1.1	not flooded	1.2	not flooded
Santuary Drive	6	1.2	not flooded	1.6	not flooded	2.0	not flooded	2.2	not flooded
Wrights Place	8	0.5	not flooded	0.7	not flooded	0.7	0.12	0.8	0.13
total flow d/s Valley Way	-	21.0	not applicable	27.0	not applicable	35.0	not applicable	41.0	not applicable
total flow main branch	-	28.0	not applicable	32.0	not applicable	34.0	not applicable	35.0	not applicable
total flow north branch	-	7.5	not applicable	8.7	not applicable	9.5	not applicable	11.0	not applicable
total flow west branch	-	5.2	not applicable	6.4	not applicable	6.8	not applicable	8.0	not applicable
total flow outfall	-	33.0	not applicable	42.5	not applicable	53.0	not applicable	65.0	not applicable

Table 6.11 Summary of Model Results - Flood Mitigation Measures– Native Dog Creek

Location	Culvert No	Road Ownership	Current Flood Immunity Years ARI	Design Flood Immunity Years ARI	Existing Culvert Details	Additional Culverts required to provide design immunity	Comments/ additional works
Mt Cotton Road	13	DMR	<10	50	3 no 1800mm dia RCP	2 no 1800mm dia RCP	Raising road at sag south of culvert required to 50.75m (0.65m max) over length of 50m
Mt Cotton Road	14	DMR	<10	50	2 no 1800mm dia RCP	none	Included in requirements for culvert 15
Mt Cotton Road	15	DMR	<10	50	1 no 675mm dia RCP	1 no 675mm dia RCP	Approx 1m deep table drain between culvert 15 and culvert 14 inlets required to prevent over road flow (length approx 100m)
Mt Cotton Road	16	DMR	>100	50	1 no 1600mm dia RCP	none	
Mt Cotton Road	17	DMR	<10	50	2 no 1200 x 1200mm dia RCBC	1 no 1200 x 1200mm dia RCBC	Approx 1m deep table drain from north to culvert 17 inlet required to prevent over road flow (length approx 45m)
Mt Cotton Road	18	DMR	<10	50	3 no 1500mm dia RCP	2 no 1500mm dia RCP	Approx 1m deep table drain both east and west of culvert 18 inlet required to prevent over road flow (total length approx 110m)
Mt Cotton Road	7	DMR	>100	50	3 no 1200mm dia RCP	none	
Mt Cotton Road	7a	RCC	10	10	1 no 1675mm dia RCP	none	
Mt Cotton Road	19	DMR	<10	50	4 no 1050mm dia RCP	9 no 1050mm dia RCP	Raising road at sag required to 27.25m (0.6m max) over length of approx 90m Approx 1m deep table drain from south of culvert 19a inlet through existing drainage path required to prevent over road flow (length approx 100m)
Valley Way	3	RCC	>100	10	3 no 3000 x 3000mm dia RCBC	none	
Valley Way	4	RCC	>100	10	3 no 3000 x 3000mm dia RCBC	none	
Valley Way	1	RCC	10-20	10	3 no 1800mm dia RCP	none	
Heinemann Rd	2	RCC	<10	10	2 no 2700 x 900 mm dia RCBC	none	Increasing culvert capacity ineffective. Raise road to 25m (0.5m max) over 30m to remove sag
Santuary Drive	5	RCC	>100	10	1 no 1350mm dia RCP	none	
Santuary Drive	6	RCC	>100	10	3 no 1200mm dia RCP	none	
Wrights Place	8	RCC	20-50	10	1 no 1500mm dia RCP	none	

NOTE: Culvert upgrades have been based on the same pipe or box culvert dimensions as the existing structures. Other combinations are possible
NOTE: Raising of road sags has been included only where increase in waterway area alone is ineffectual

6.11.5 Impact of Waterway Management Works

The waterway management strategy component of the study has recommended 50m wide buffer strips along both banks of the major creek reaches. It has been assumed that the revegetation of these buffers will increase the hydraulic roughness to 0.08.

The flood mitigation models were modified to account for this roughness increase and re-run. It was found that these measures did not adversely impact on any of the road flood immunity proposed works, or result in any property flooding up to 100 year ARI.

6.12 Torquay Creek

6.12.1 Model Setup

The area covered by the Torquay Creek model and the 5m by 5m grid is shown in **Figure 6.5.**

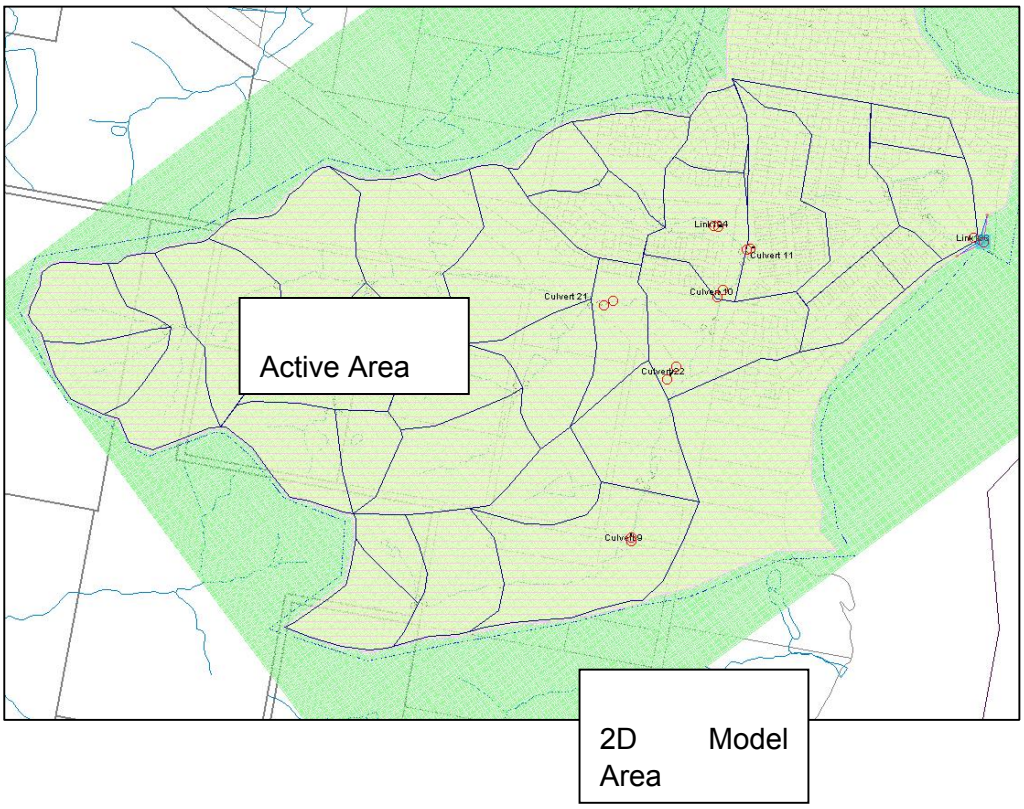


Figure 6.5 2-D Model Area – Torquay Creek

6.12.2 Existing Conditions

The critical storm duration for all ARI was determined from the hydrologic modelling to be 1 hour, with very little difference for 2 hour flows. However, it was evident from running the hydraulic model that temporary storage of floodwaters was an important aspect of the creek hydraulics, not only in the natural floodplain, but also against road embankments.

In order to determine the critical duration for peak water levels rather than peak flows, the hydraulic model was run with inflows from storms of duration 1, 2 and 3 hours for 10 year and 100 year ARI and additionally for 4.5 hour duration for 100 year ARI only. The result of this was that there was little difference in peak levels between those resulting from 2 hour, 3 hour and 4.5 hour storms but that these were all significantly higher than those from the 1 hour storms. The 3 hour storm was selected, therefore, as the critical duration storm and used for the production of flood inundation maps.

Although the hydrologic model contains channel routing, this is rudimentary in nature, and it is typical that the discharges in the lower reaches of 2-D models are lower than those from the corresponding hydrologic model, as a result of the far more detailed flood routing in the hydraulic model. This effect was very noticeable in this instance, due to the high degree of temporary storage in the system as commented upon in the previous paragraph.

The locations of the culverts and the identification numbers assigned to them are shown in **Figure 6.6**.

The peak discharge and peak water level data from the Native Dog Creek model are given in **Table 6.12**.

Serpentine Creek Road (culvert 11) and Oakland Avenue (culvert 10) have a flood immunity of less than ten years10 year ARI. Cleveland - Redland Bay Road (culverts 21 and 22), and Kidd St (culvert 9) have a flood immunity of 100 year ARI.

6.12.3 Flood Mitigation Options

Flood mitigation options were considered for road crossings, based on the following design criteria:

- Main roads – 50 year ARI flood immunity; and
- Local roads – 10 year ARI flood immunity.

Provision of the required level of flood immunity for those road crossings currently deficient in this regard was firstly investigated on the basis of increasing waterway area alone. This was done by increasing the number of culvert cells (of the same size as the existing cells) until the over road flow was eliminated.

In some instances, this strategy was found to be unsuccessful, and it was found to be necessary to raise road sag points to eliminate the over road flow, Some of these instances required both an increase in waterway area and raising of the roadway.

In some instances it was found that construction of a table drain along the roadway reduced or eliminated the over road flow in conjunction with an increase in waterway area.

The results from the flood mitigation modelling are given in **Table 6.3**. Detailed hydraulic model results are attached in **Appendix U**.

6.12.4 Impact of Waterway Management Works

The waterway management strategy component of the study has recommended 50m wide buffer strips along both banks of the major creek reaches. It has been assumed that the revegetation of these buffers will increase the hydraulic roughness to 0.08.

The flood mitigation models were modified to account for this roughness increase and re-run. It was found that these measures did not adversely impact on any of the road flood immunity proposed works, or result in any property flooding up to 100 year ARI.

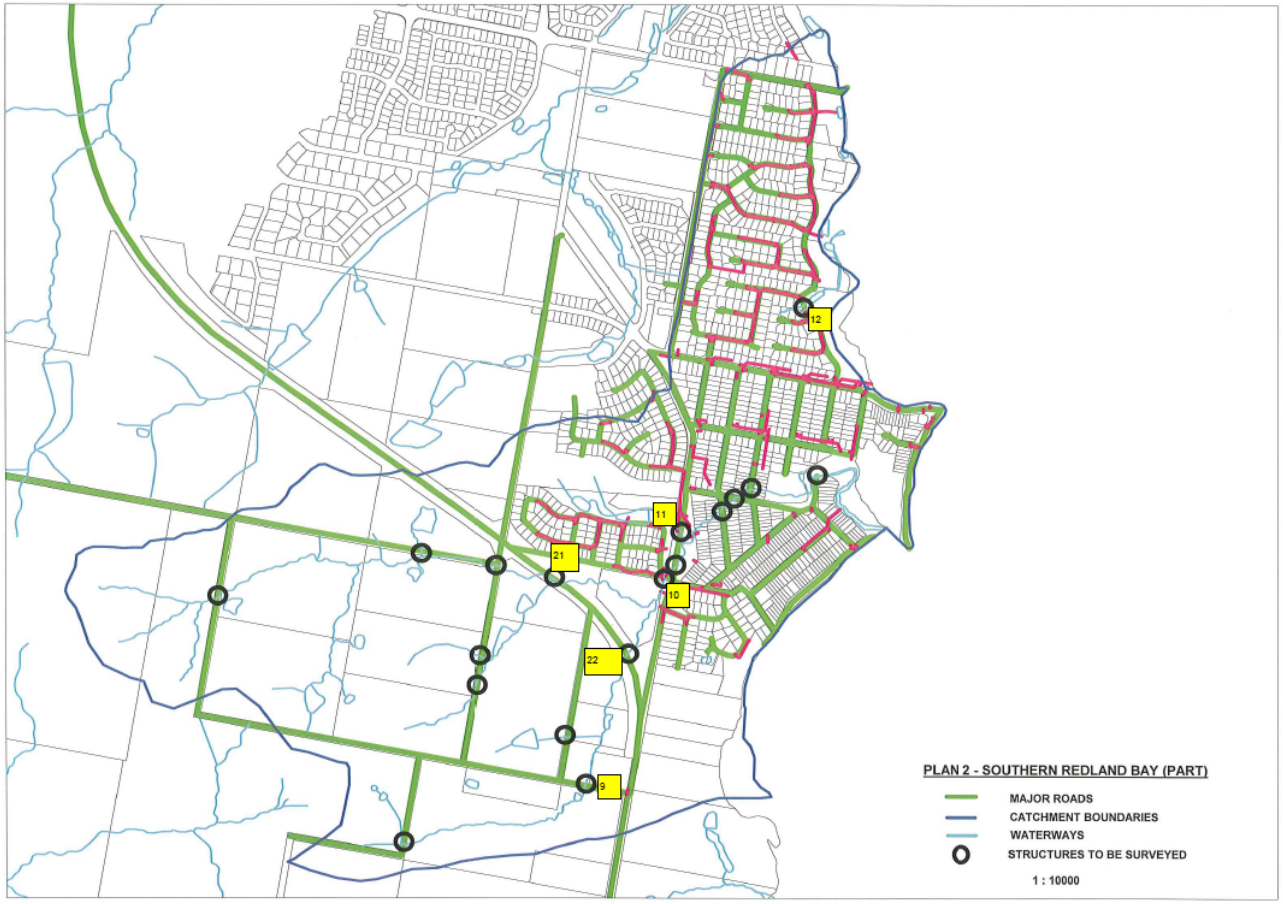


Figure 6.6 Torquay Creek Culvert Location and Numbering

Table 6.12 Summary of Model Results - Existing Conditions - Torquay Creek

Location	Culvert No	10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
		Peak Flow cumecs	Max Water Depth Road C/L m	Peak Flow cumecs	Max Water Depth at Road C/L m	Peak Flow cumecs	Max Water Depth at Road C/L m	Peak Flow cumecs	Max Water Depth at Road C/L m
Kidd St	9	0.7	not flooded	1.0	not flooded	1.2	not flooded	1.5	not flooded
Oakland Ave	10	5.8	0.4	7.0	0.5	9.8	0.6	12	0.7
Cleveland-Redland Bay Rd	21	3.8	not flooded	4.8	not flooded	7.0	not flooded	7.8	not flooded
Cleveland-Redland Bay Rd	22	1.6	not flooded	2.0	not flooded	2.7	not flooded	3.2	not flooded
Serpentine Ck Rd	11	6.6	0.26	8.1	0.39	11.2	0.44	14	0.47
Creek Mouth	-	6.5	N/A	8.5	N/A	12	N/A	17	N/A

Table 6.13 Summary of Model Results – Flood Mitigation Measures - Torquay Creek

Location	Culvert No	Road Ownership	Current Flood Immunity Years ARI	Design Flood Immunity Years ARI	Existing Culvert Details	Additional Culverts required to provide design immunity	Comments/ additional works
Kidd St	9	RCC	>100	10	3 no 900mm dia RCP	none	
Oakland Ave	10	RCC	<10	10	7 no 2400 x 900 mm RCBC	none	raising road at sag east-west required to 5.0m (1.25m max) over length of approx 35m
Serpentine Ck Rd	11	RCC	<10	10	3 no 750mm dia RCP	7 no 750mm dia RCP	raising road at sag to 4.0m (0.5m max) required over length of approx 60m approx 1m deep table drain from north to creek required to prevent over road flow causing flooding of steep area to east of Seprentine Creek Rd (length approx 110m)
Cleveland-Redland Bay Rd	21	DMR	>100	50	2 no1800mm dia RCP	none	
Cleveland-Redland Bay Rd	22	DMR	>100	50	2 no 1350mm dia RCP	none	

NOTE: Culvert upgrades have been based on the same pipe or box culvert dimensions as the existing structures. Other combinations are possible
NOTE: Raising of road sags has been included only where increase in waterway area alone is ineffectual

6.13 Flood Mapping and GIS

Flood inundation mapping for both the Native Dog and Torquay Creek systems have been prepared as part of this study. The flood extent maps have been prepared Mapping has been prepared using a Digital Terrain Model (DTM) which has been prepared as part of this study using Council supplied Airborne Laser Survey (ALS) data. It is understood that Council's ALS information was collected in circa 2004. The flood extents that have been prepared and illustrated in this study are therefore reflective of topographical conditions that predominated in 2004. The flood maps have been overlaid with aerial photography information in order to assist in locating various catchment features. The aerial photography as illustrated is understood to be collected in 2008 and is therefore recent imagery throughout the catchments.

A summary of the flood extent and GIS mapping prepared as part of this study is summarised in **Table 6.14** below. All flood extent plans are attached in **Appendix V** of this report.

It should be noted that flood mitigation options were not analysed for the 100 year ARI event as no residential properties were identified to be flooded to above floor level in either catchment system. As such, no flood mitigation maps have been prepared for the 100 year ARI event.

Table 6.14 Summary of Flood Extent and GIS Mapping

CATCHMENT	MAP TITLE	SCENARIO
Native Dog Creek	H007 – 1 in 10 Year ARI Flood Extent – Existing Case	Existing Case
Native Dog Creek	H007 – 1 in 20 Year ARI Flood Extent – Existing Case	Existing Case
Native Dog Creek	H007 – 1 in 50 Year ARI Flood Extent – Existing Case	Existing Case
Native Dog Creek	H007 – 1 in 100 Year ARI Flood Extent – Existing Case	Existing Case
Torquay Creek	H009 – 1 in 10 Year ARI Flood Extent – Existing Case	Existing Case
Torquay Creek	H009 – 1 in 20 Year ARI Flood Extent – Existing Case	Existing Case
Torquay Creek	H009 – 1 in 50 Year ARI Flood Extent – Existing Case	Existing Case
Torquay Creek	H009 – 1 in 100 Year ARI Flood Extent – Existing Case	Existing Case

CATCHMENT	MAP TITLE	SCENARIO
Native Dog Creek	H007 – 1 in 10 Year ARI Flood Extent – Mitigated Case	Mitigated Case
Native Dog Creek	H007 – 1 in 50 Year ARI Flood Extent – Mitigated Case	Mitigated Case
Torquay Creek	H009 – 1 in 10 Year ARI Flood Extent – Mitigated Case	Mitigated Case
Torquay Creek	H009 – 1 in 20 Year ARI Flood Extent – Mitigated Case	Mitigated Case

6.14 Conclusions

The hydraulic modelling has provided good information regarding the current flood immunity of road crossings and properties within the Native Dog Creek and Torquay Creek catchments.

Overland sheet flows were found to affect a discrete number of property allotments with depths of flow generally less than 200mm. In the absence of floor level survey data and based on the limited sheet flow depths, no flood inundation of existing properties to above floor level was found to occur in the 100 year ARI event for both Native Dog and Torquay Creek catchments. As such, no flood mitigation measures to alleviate or mitigate property flooding were required.

The flood immunity for a number of road crossings were found to be deficient and upgrades to improve these immunities to meet the normal design criteria were investigated and have been listed in the relevant sections of the report. The principle adopted was to provide the required flood immunity by increasing the waterway area only wherever this was possible, and only to incorporate raising of the road pavement level in situations in which waterway area increases were ineffective or only partially effective.

The hydraulic modelling confirmed that the proposed waterway management measures do not adversely impact on flood levels at key locations in either catchment.

No allowance for potential climate change impacts (either in the form of sea level rise, or increased rainfall intensity) has been made in the work presented in this report, as this was outside of the agreed Scope of Work. Additional modelling could be undertaken to quantify these effects, should Council so wish.

6.15 Recommendations

The following recommendations are made in respect of upgrading of the flood immunity of road crossings to meet design standards. Further details of these recommendations are contained in Table 6.11 and Table 6.13 for Native Dog Creek and Torquay Creek respectively.

6.15.1 Native Dog Creek

Local Roads

- Heinemann Road – design criterion – not overtopped in 10 year ARI event
- Raising of roadway to eliminate sag

Main Roads

- Mount Cotton Road – design criterion – not overtopped in 50 year ARI event
- Increase in waterway area at 5 culvert crossings (nos. 13, 15, 17, 18 and 19);
- Raising of road level to eliminate sags at 2 culvert crossings (nos. 13 and 19);
- Construction of table drains of up to 1m deep adjacent to 4 culvert crossings (between culverts nos. 14 and15, 17, 18, and 19).

6.15.2 Torquay Creek

Local Roads

- Design criterion – not overtopped in 10 year ARI event
- Serpentine Creek Road
- Increase in waterway area at culvert crossings (no. 11);
- Raising of roadway to eliminate sag; and
- Construction of open channel drain to the west of Serpentine Creek Road to eliminate over road flow in the relatively steep are north of the crossing.

Oakland Avenue

- Raising of roadway to eliminate sag.

Consideration of undertaking additional model runs to quantify the impact of currently perceived levels of sea level rise and increase in rainfall intensity due to climate change is also recommended.

7. INFRASTRUCTURE ASSESSMENT AND COST ESTIMATES

7.1 Introduction and Basis

The section of the report provides a summary of the infrastructure related work items which have been identified and recommended as part of the various technical elements of the larger IWMP.

7.2 Estimation of Regional Flooding Mitigation Works

Infrastructure works associated with regional flood mitigation items of works have been readily quantified through the assessment of a variety of flood mitigation options for both Native Dog Creek and Torquay Creek catchments. The infrastructure items relate specifically to culvert and road upgrade works in order to cater for current road design and flood immunity requirements for both minor and major road types. No flood mitigation works have been identified for protection of above floor level property inundation as no properties within the study areas of Native Dog Creek and Torquay Creek were identified as being flood affected.

The cost estimtes prepared for regional flood mitigation works comprising road and culvert upgrades represent budget costs which have been estimated using unit rates based on Cordell's e-Costing system for Queensland, Sept 2009 wherever possible. The exception to this is in relation to unit rates for standard concrete box and pipe culvert products which are based on suppliers current price lists current as at the time of this report. The following allowances to the cost estimates have also been made:

- Overheads – 10%;
- Preliminaries – 10%;
- Contingency – 20%;
- Engineering (design) – 12%; and
- Supervision – 6%.

A summary of the infrastructure costs for culvert and road upgrade works is presented in **Table 7.1** below against culvert number and location. A series of maps have also been prepared as part of this study to illustrate the various culvert locations and flood extents which are included in **Appendix T** and **Appendix U** for Native Dog Creek and Torquay Creek, respectively, of this report. A more detailed cost estimate breakdown for the works is presented in **Appendix W**.

Table 7.1 Cost Estimates for Culvert and Road Upgrade Works

Catchment Name	Location	Culvert ID	Asset Owner	Works Required	Cost Estimate ($)
Native Dog Creek	Mount Cotton Road	13	DMR	2 no 1800mm dia RCP raising road at sag south of culvert to 50.75m (0.65m max) over length of 50m	$293,600
Native Dog Creek	Mount Cotton Road	15	DMR	1 no 675mm dia RCP approx 1m deep table drain between culvert 15 and culvert 14 inlets (length approx 100m)	$103,100
Native Dog Creek	Mount Cotton Road	17	DMR	1 no 1200 x 1200mm dia RCBC approx 1m deep table drain from north to culvert 17 inlet (length approx 45m)	$133,200
Native Dog Creek	Mount Cotton Road	18	DMR	2 no 1500mm dia RCP approx 1m deep table drain both east and west of culvert 10 inlet (total length approx 110m)	$247,500
Native Dog Creek	Mount Cotton Road	19	DMR	9 no 1050mm dia RCP raising road at sag required to 27.25m (0.6m max) over length of approx 90m	$493,400
Native Dog Creek	Heinemann Road	2	RCC	Increasing culvert capacity ineffective raise road to 25m (0.5m max) over 30m to remove sag	$43,100
Torquay Creek	Oakland Avenue	10	RCC	raising road at sag east-west required to 5.0m (1.25m max) over length of approx 35m	$87,400
Torquay Creek	Serpentine Creek Road	11	RCC	7 no 750mm dia RCP raising road at sag to 4.0m (0.5m max) required over length of approx 60m approx 1m deep table drain from north to creek (length approx 110m)	$265,300
				TOTAL (Excl. GST)	**$1,666,600**

7.3 Estimation of Stormwater Quality Management Works

The fundamental approach applied to stormwater quality as part of this IWMP is different to that traditionally employed as part of previous studies and has resulted in a difference of thinking within the boarder context of integrated water management.

The *Environmental Protection (Water) Policy 1997* requires councils with urban stormwater systems to "*develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system*". Under these provisions, reliance on any water treatment that may occur within natural wetlands or ponds to in-stream 'treatment' that may occur through the action of natural wetlands or in-stream devices does not serve to protect these waters and therefore does not comply with the section of the EPP provided above. The stormwater quality management plan proposed in this report relies only on treatment by off-line devices, and requires that load reduction targets are met prior to discharge to waterways. This results in load reduction targets being achieved not only at discharge to Moreton Bay, but at every discharge point to all waterways within the catchment. Specifically, targets have been achieved by utilizing rainwater tanks on houses, swales on rural roads and bio-retention devices sized to 1.5% of the contributing catchment with coarse sediment forebays.

The estimated costs of stormwater quality infrastructure identified in this study is summarised as follows:

7.3.1 Native Dog Creek

- **Option 1** - The estimated cost of all SQIDs in Urban areas required to meet load based water quality objectives in Native Dog Creek Catchment in 2009 $AUD is $14 072 288. This value includes establishment, operation and maintenance and decommissioning over a 50 year period.
- **Option 2** - The total cost of establishing SQIDs in urban areas and re-establishing 10m riparian habitat on all waterways is estimated to be $17 060 000 in 2009 $AUD. This equates to an average annualized cost of $341 202 per year over the expected lifespan of structures (50 years).

7.3.2 Torquay Creek

- **Option 1** - The estimated cost of all SQIDs in Urban areas required to meet load based water quality objectives in Torquay Creek Catchment in 2009 $AUD is $6 493 740. This value includes establishment, operation and maintenance and decommissioning over a 50 year period.

The following aspects should be noted in relation to the infrastructure costs provided for stormwater quality measures:

- Improved stormwater quality outcomes are generally achieved in combination with the provision of buffers to waterways. While an element of the infrastructure cost is related

to land acquisition for buffer protection purposes, the provision of waterway buffers may be better achieved through planning instruments including a Planning Scheme Policy amendment;

- The Queensland Development Code Part MP4.2 now requires legislated water savings targets to be met which in the majority of instances will effectively mean that all new homes are required to install rainwater tanks. The capital, operational and ongoing maintenance costs of the rain water tanks will be met by individual owners;
- Bioretention devices have been identified to be dispersed throughout each sub-catchment and as close as possible to each source ideally at each field or gully inlet. To a large degree, a significant number of bioretention devices will be provided by way of private development under the traditional development assessment and planning scheme policy instruments and these approaches should be continued.

The associated infrastructure cost to be applied as part of any future Infrastructure Charges Schedule should be prepared having regard to the above and in order to prevent double counting of infrastructure provisions. Disregarding stormwater quality infrastructure to be provided by private development as is currently a planning scheme requirement, a number of other bioretention facilities will be required for retrofitting throughout the catchments as has been detailed in this report. The specific sizes, locations and arrangements for these measures are subject to more detailed investigations including site inspections and ground truthing based on the various sub-catchment allocations. These further works are supported via the new strategic approach that is proposed for Integrated Water Management Plans and specifically including the proposed works identified under the Stormwater and Waterways Infrastructure Planning Process.

7.4 Estimation of Waterway Rehabilitation and Buffer Provisions

Retention and rehabilitation of the proposed waterway buffers is essential to protecting and enhancing the ecological health of the waterways. As such, this study has identified a number of areas for waterway buffer retention and protection. The retention of waterway buffers throughout both the Native Dog and Torquay Creek catchments has also been identified as providing beneficial outcomes for water quality purposes and has been assessed as providing no adverse flood effects. The retention and protection of waterway buffers is an integrated catchment and waterways management approach.

The associated costs for re-establishing a 10 metre wide riparian habitat on all drainage lines in rural residential areas has been estimated as part of the water quality assessment component of this project and is estimated to cost the following:

- Native Dog Creek - A total of approximately $2.987M (in 2009 $AUD); and
- Torquay Creek - A total of approximately $667,000 (in 2009 $AUD).

These costs are indicative estimates only and are based on a base rate of $7.50 per square metre for riparian buffer zone implementation. This rate was determined from experience on two of SEQ's largest riparian restoration projects, the Maroochy River Recovery and the SEQ Catchments Echidna Creek project. The rate includes site preparation, purchase of plant,

planting and maintenance of plantings for three (3) years to achieve industry standard performance criteria.

The identified costs above are indicative only and do not take into account the varying waterway buffer widths as have been identified and recommended as part of this study. However, the provision of waterway buffers is likely to be better achieved through a variety of planning and development instruments including a Planning Scheme Policy amendment. This approach will likely have economical, environmental and overall improved sustainability outcomes and is the recommended approach for preservation of waterway buffers. As such, no infrastructure costs as per say have been allocated against waterway buffer measures.

8. STUDY CONCLUSIONS

The findings from this study in terms of each of the technical elements of works are summarised as follows:

8.1 Waterway and Environmental Assessment

Native Dog Creek and Torquay Creek have been impacted mainly by vegetation clearing, agriculture, urban development and major roads. Riparian and catchment vegetation has been cleared in parts of both catchments for agricultural and urban development. Extensive weeds exist throughout the riparian zones of both waterways. However, both catchments contain areas of high habitat value, including remnant terrestrial vegetation, intertidal vegetation (Torquay Creek), freshwater wetlands, and forests, including Eucalypt forest and small areas of rainforest.

Barriers to connectivity exist in both catchments, including roads and culverts (barriers to both aquatic and terrestrial fauna) and vegetation clearing (fragmenting terrestrial habitat). Rehabilitation works will enhance both the longitudinal connectivity (along the waterways) and latitudinal connectivity to surrounding bushland areas, particularly to the large bushland area west of the Torquay Creek catchment.

Desirable rehabilitation actions include riparian revegetation and weed control, erosion control, and education programs to catchment residents (particularly those adjacent to the riparian buffers) on weed management, fertiliser use and stormwater runoff, and to agricultural land owners on best practices. Retention and rehabilitation of the proposed buffers is essential to protecting and enhancing the ecological health of the waterways. Some clearing and development has already taken place within these buffers.

Water quality data are limited, but preliminary conclusions are that Native Dog Creek contains very high nutrient and sediment concentrations. The highest concentrations were recorded during a period of high rainfall. Due to the particularly high concentrations of nutrients and poor correlation between nutrients and turbidity / suspended solids, it appears that the water quality degradation is primarily caused by a point source of pollution, which may be related to the poultry farm in the upper reaches of this catchment.

While the available datasets are limited, fish and macroinvertebrate monitoring also indicate Native Dog Creek is degraded, with relatively low diversity and no sensitive taxa observed.

Water quality data in Torquay Creek is also limited, but indicates the waterway is close to achieving the WQOs (although dissolved oxygen concentrations were very low). It does contain elevated total nitrogen concentrations, although much lower than Native Dog Creek.

A monitoring program has been recommended to address the limitations of the water quality dataset.

The scope of this Waterway Health Assessment report does not include actions to improve pollutant sources, but some of the proposed actions will impact water quality, such as erosion control. Riparian rehabilitation works are likely to lead to improved overall waterway health, by stabilising the banks, improving vegetation condition and habitat resources, and improving habitat connectivity.

8.2 Water Quality Assessment

The water quality analysis works undertaken for this study has incorporated approaches and techniques not traditionally used previously including:

- The inclusion of water tanks as part of the MUSIC model to result in a cost saving;
- Focusing the water quality analysis on protection of local waterways as well as Moreton Bay. This was completed by using treatments at a more local scale and not within waterways. Waterways have an inherent environmental value and should also be protected in preference to be used as a treatment device; and
- Integrated broader catchment management actions and Water Sensitive Urban Design (WSUD) into one modeling package to demonstrate achievable water quality objectives using WaterCAST.

MUSIC modeling indicates that total load pollutant reduction targets can be achieved for urban areas in both the Torquay Creek and Native Dog Creek catchments in the ultimate development scenario. Targets have been achieved by utilizing rainwater tanks on houses, swales on rural roads and bio-retention devices sized to 1.5% of the contributing catchment with coarse sediment forebays.

The application of filtering modules within WaterCAST provides justification to allow for the investment in 'green infrastructure' in a treatment train approach with WSUD to achieve end of catchment water quality targets. Riparian zones are a cost effective means of achieving load reductions compared to more engineered solutions such as WSUD and have many other additional ecosystem service benefits.

The case study presented indicates that a multi-mitigation approach incorporating both riparian rehabilitation and WSUD can achieve water quality objectives at the end of the catchment. This approach achieves better Triple Bottom Line outcomes i.e. financial, social and ecological than WSUD implementation alone. The modeling approach taken for this study in applying MUSIC and WaterCAST modeling in unison is unique and through this project has proven successful.

The *Environmental Protection (Water) Policy 1997* requires councils with urban stormwater systems "*develop and implement an environmental plan about urban stormwater quality management that improves the quality of stormwater in a way that is consistent with the water quality objectives for waters affected by the system*" Reliance on water any water treatment that may occur in natural wetlands or ponds to in-stream 'treatment' that may occur through the action of natural wetlands or in-stream devices does not serve to protect these waters and therefore does not comply with the section of the EPP provided above.

The stormwater quality management plan proposed in this report relies only on treatment by off-line devices, and requires that load reduction targets are met prior to discharge to waterways. This results in load reduction targets being achieved not only at discharge to Moreton Bay, but at every discharge point to all waterways within the catchment.

Although modeled as single devices in MUSIC, bioretention devices should be dispersed throughout each sub-catchment as close as possible to each source, ideally at each field or gully inlet. In situations where installation at field or gully pits is not possible due to site constraints (i.e. existing infrastructure, hydraulic gradient, underground services), bioretention devices may be located at discharge points including the potential locations as have been identified within this study. Locating and sizing of each bioretention devices throughout sub-catchments will be required at the detail design stage.

Achieving load based reductions may not result in concentration based water quality objectives being achieved at the discharge point to each waterway. Load based targets represent achievable best practice for stormwater management infrastructure in South East Queensland (SEQ) climate and pollutant export conditions operating near the limit of its economic performance. Substantial extra cost is required to achieve low concentration based targets at a very small additional water quality benefit.

8.3 Regional Flooding

Regional flooding works undertaken for this study are based on a rainfall-runoff XP-RAFTS hydrological model in combination with a 2 dimensional (2D) TUFLOW model. The technical elements of the regional flooding works have been performed in line with industry practice and have made use of commercially available software packages.

Hydrological modelling of the catchment has culminated in the quantification of design flood estimates for a range of design storm events for the 1 in 10, 20, 50 and 100 year Average Recurrence Interval (ARI) storm events under a range of critical storm durations. The catchment hydrology undertaken for both Native Dog and Torquay Creek catchments has quantified the various catchment inflow hydrographs which have been incorporated directly into the hydraulic model.

The regional hydraulic modelling performed using a 2 dimensional TUFLOW model has been successful in quantifying flooding throughout the various catchment areas. The flood assessment works have facilitated in the assessment of flood levels, flood depths and flood extents within the various waterway systems throughout Native Dog Creek and Torquay Creek catchments. The flood modelling works have been successful in identifying the following flooding issues in the catchments:

- Overland sheet flows were found to affect a discrete number of property allotments with depths of flow generally less than 200mm. In the absence of floor level survey data and based on the limited sheet flow depths, no flood inundation of existing properties to above floor level was found to occur in the 1 in 100 year ARI event for both Native Dog and Torquay Creek catchments. As such, no flood mitigation measures to alleviate or mitigate property flooding were required.

- The flood immunity for a number of road crossings were found to be deficient and upgrades to improve the level of road immunity to meet the normal design criteria were investigated and have been listed in the relevant sections of this report. The principle adopted for road immunity upgrade works was to provide the required flood conveyance capacity by increasing the waterway area only wherever this was possible and only to incorporate raising of the road pavement level in situations in which waterway area increases were ineffective or only partially effective;
- The hydraulic modelling confirmed that the proposed waterway management measures which comprise the establishment of waterway buffers and the associated increase in channel roughness parameters which would result do not adversely impact on flood levels at key locations throughout either catchment area. The proposed establishment of waterway buffers recommended as part of the waterway management measures in addition to the similar recommendations provided as part of the water quality assessment works are therefore appropriate within the context of being supported by the regional flood assessment works.

No allowance for potential climate change impacts (either in the form of sea level rise, or increased rainfall intensity) has been made in the work presented in this report. The flood models prepared as part of this study can be readily applied for any future climate change assessments as may be required. It is recommended that these works be undertaken in due course and following formal advice and recommendations from either the Federal or State Governments by way of a policy stance in this regard. To pre-empt these outcomes, it is also possible that Council look to undertake the assessment of a range of climate change scenarios in order to proactively quantify any potential flood related impacts throughout the catchments for future Local Government policy direction and code revisions.

9. RECOMMENDATIONS

In light of the above outcomes and subsequent findings made from this study, the following recommendations are made: -

9.1 Waterway and Environmental Assessment

- Dedicate, maintain and / or rehabilitate the proposed waterway buffer widths as natural areas to achieve the target conditions;
- Use planning mechanisms to allow dedication of land within the proposed buffer widths and to allow for conservation works to be undertaken within areas that may not be dedicated;
- Adopt the additional water quality monitoring items identified in the proposed Water Quality Monitoring Program;
- Retain gullies upstream of the waterways (i.e. confined upper drainage lines) as naturalised channels;
- Undertake the actions as outlined in the Management Action Plan as detailed.

9.2 Water Quality Assessment

- The previous recommendations from WBM (2008) regarding improving catchment modelling and reducing uncertainty are equally valid for this study;
- That WaterCAST model should be used as a first run conceptual design tool for IWMP and initial costing, allowing for the inclusion of green infrastructure in infrastructure charges;
- The MUSIC model be adapted at the detailed planning stage and undertaken at a finer streetscape scale allowing for the protection of waterways and the bay;
- Any future MUSIC modelling to include the modelling of rain water tanks and roads.

9.3 Regional Flood Assessment

- A property floor level survey be undertaken to quantify the existing floor levels for selected residential properties in Native Dog and Torquay Creek catchments. Further, the floor level surveys be used in conjunction with the flood levels defined in this study to quantify if properties are subject to flooding to above floor level flooding.
- The following road and drainage infrastructure items be upgraded to comply with current design standards: -

9.3.1 Native Dog Creek

- Heinemann Road – Raising of roadway to eliminate sag.
- Although under the jurisdiction and ownership of the Department of Main Roads (DMR), Mount Cotton Road was found to be deficient in various locations and required upgrading as follows:
  - Increase in waterway area at 5 culvert crossings (nos. 13, 15, 17, 18 and 19);
  - Raising of road level to eliminate sags at 2 culvert crossings (nos. 13 and 19);
  - Construction of table drains of up to 1m deep adjacent to 4 culvert crossings (between culverts nos. 14 and15, 17, 18, and 19).

9.3.2 Torquay Creek

- Serpentine Creek Road to be upgraded as follows:
  - Increase in waterway area at culvert crossings (no. 11);
  - Raising of roadway to eliminate sag; and
  - Construction of open channel drain to the west of Serpentine Creek Road to eliminate over road flow in the relatively steep are north of the crossing.
- Oakland Avenue to be upgraded as follows:
  - Raising of roadway to eliminate sag.
  - It is also recommended from the regional flood assessment works that additional model runs be undertaken in order to quantify the impact of currently perceived levels of sea level rise and increases in rainfall intensity due to climate change. These assessments will assist in quantifying the various climate change impacts in the respective catchments and therefore provide Council with base information under which policy revisions and code amendments can be formulated as may be required.

10. REFERENCES

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APPENDIX A
Overview Map of Catchments

APPENDIX B
Field Data

APPENDIX C

Survey Site Locations

APPENDIX D
Council Overlay Maps

APPENDIX E

Council Vegetation Mapping

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Regional Ecosystem Mapping

APPENDIX G

Waterway Reaches

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Council Water Quality Monitoring Sites

APPENDIX I

Water Quality Graphs

APPENDIX J

Buffers

APPENDIX K

Environmental Regulatory Context and Planning Considerations

APPENDIX L

Coastal Management District Map

APPENDIX M

Moreton Bay Marine Park Map

APPENDIX N

EPP (Water) Maps

APPENDIX O

MUSIC Inputs – Native Dog Creek

APPENDIX P

MUSIC Inputs – Torquay Creek Catchment

APPENDIX Q

Indicative location of SQIDs and Riparian Habitat Restoration

APPENDIX R

XP – RAFTS Land Use Plans

APPENDIX S

XP – RAFTS Detailed Results

APPENDIX T

Hydraulic Model Detailed Results – Native Dog Creek

APPENDIX U

Hydraulic Model Detailed Results – Torquay Creek

APPENDIX V

Flood Inundation and GIS Maps

APPENDIX W

Flood Mitigation Works Construction Cost Estimates