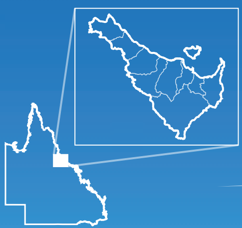
creektocoral
our waterways - our responsibility



Black Ross (Townsville)
Water Quality Improvement Plan

Improving Water Quality from Creek to Coral

enter

contents

February 2010

Australian Government

Queensland Government

Townsville

TOWNSVILLE CITY COUNCIL

This publication was funded by the Australian Government's Coastal Catchments Initiative through the Department of Environment, Water, Heritage and the Arts.

Australian Government

Published by Townsville City Council
PO Box 1268, Townsville
Queensland 4810

Published May 2010

ISBN 978-0-9807305-1-7

DOCUMENT DISCLAIMER STATEMENT

Townsville

Townsville City Council advises that this publication contains information based on scientific research, knowledge and understanding as well as perceptions and interpretations by the authors. The reader is advised that such information may be incomplete or unsuitable to be used in certain situations. While all care has been taken in the preparation of this document, Townsville City Council accepts no liability for any decisions or actions taken on the basis of the information contained in this document, or from conclusions drawn from interpreting the information. Readers should also be aware that some information might be superseded as a result of further scientific studies and evolving technology and industry practices.

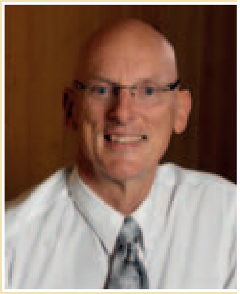
This document can be cited as:

Gunn, J. and Manning, C. 2010, *Black Ross (Townsville) Water Quality Improvement Plan: Improving Water Quality from Creek to Coral*, Townsville City Council - Creek to Coral, Townsville.

Design: Andreas Wagner, www.coolplanetdesign.com.au

FOREWORD

Cr Les Tyrell, OAM
Mayor, Townsville City Council



Ray Burton
CEO, Townsville City Council

With a population of more than 180,000 (as per 2008 projections), Townsville is the largest city in northern Australia and one of the country's fastest growing communities. This popularity is due to our lifestyle, climate, diverse economy and abundant natural resources, including our local waterways and the Great Barrier Reef.

Townsville's City Council's Creek to Coral partnership, an initiative of all levels of government and our community, is committed to protecting our waterways and wetlands, and the Great Barrier Reef from the effects of land based activities. The city's proactive approach has been recognised with Townsville named one of the first Reef Guardian Councils.

The Black Ross (Townsville) Water Quality Improvement Plan (WQIP) is intended as a guidance document for all levels of government and the community. It was developed by council in partnership with our local stakeholders and was funded by the Australian Department of Environment, Water, Heritage and the Arts' Coastal Catchments Initiative. The Plan is supported by many background reports and individual catchment summary sheets to meet the needs of a wide range of users.

The Plan provides a comprehensive assessment of our catchments using available water quality data and identifies where water quality could be improved. Population growth is driving urban area expansion, which is impacting our local waterways and the Great Barrier Reef. Pollutants such as sediment, nutrients, pesticides and litter were found in many of our waterways and near shore marine areas. The Plan proposes practical and achievable actions but as ever the challenge for all levels of government will be to appropriately resource these actions.

Council will continue to implement its core business programs within its financial constraints in support of this Plan. We will continue to integrate programs across internal departments and responsibilities, while continuing to focus on our partnerships with Queensland and Australian Governments, industry, community groups and residents.

Preserving and managing our natural resources must be one of Townsville's highest priorities. We will follow Creek to Coral's implementation of the Black Ross (Townsville) Water Quality Improvement Plan and we challenge other levels of government and residents to become involved in helping to manage our waterways and the reef. Only through such partnerships will their long-term future be assured.

Cr Les Tyrell, OAM

Mayor
Townsville City Council

Ray Burton

CEO
Townsville City Council

ACKNOWLEDGMENTS

The Black Ross (Townsville) Water Quality Improvement Plan (WQIP) was developed by the Townsville City Council, through its Creek to Coral initiative, which is a partnership between Council, government and the community. The WQIP was developed with funding assistance from the Australian Government's Coastal Catchments Initiative (CCI), through the Department of Environment, Water, Heritage and the Arts.

Development of the WQIP was guided by a steering committee of key stakeholders from government, industry, non-government organisations and the scientific community. Members contributed their time and expertise and provided valuable information and feedback throughout the development process. Members of the steering committee were Jon Brodie (ACTFR), Niall Connolly (DERM/EPA), Melinda Louden and Anna Skillington (TPA), Peter Verwey and Ian Sinclair (DERM/NRW), Jane Waterhouse (CSIRO), Alan Walker and Clint Burgess (TCC), Jos Hill and Marie-Lise Schlappy (Reef Check Australia), Allan McManus (Defence), Adam Sadler and Ben Daniel (TCC), Margaret Gooch (JCU), Evan Kruckow and Greg Willcox (CVA), Scott Crawford, Ian Dight and Sarah Connor (NQDT) and Iony Woolaghan (DEEDI/DPI&F).

Significant in-kind support from the Queensland Government was gratefully received throughout the WQIP development process with particular thanks to Niall Connolly, John Bennett, Dane Moulton, Fiona Watson, Mark Kelton and Peter Curley from the Department of Environment and Resource Management (formerly the Environmental Protection Agency).

Zoe Bainbridge and Steve Lewis from the Australian Centre for Tropical Freshwater Research (ACTFR) deserve special mention for their commitment to our event water quality monitoring program, often in trying conditions. Theirs and Jon Brodie's advice, expertise and support during the WQIP development process was greatly appreciated.

Townsville City Council also provided significant in-kind assistance to this project through the valuable assistance and expertise of many staff members, including Alastair McHarg, Brian Bailey, Leif Hickey, Julie Cardiff, Karen Bird, Sonia Muller, Edgar Salvador, Anna Whelan, Daryl Antat, Rob Hunt, Renee Zielke, Neil Davies, Alan Walker and Denise Hinneberg. Thanks also to Greg Bruce and the team in Integrated Sustainability Services for their continued support, expertise and patience throughout this project, particularly through the challenging times of local government amalgamations. Former Creek to Coral coordinator D.J. Mackenzie is also acknowledged for his early work in securing funding for and initiating the Coastal Catchments Initiative project.

Finally special mention and acknowledgment is reserved for John Gunn for his commitment and professionalism throughout, and in particular for his contribution to the writing of the WQIP and many of its supporting documents.

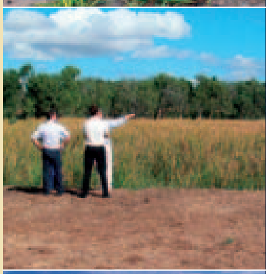
OTHER ACKNOWLEDGEMENTS:

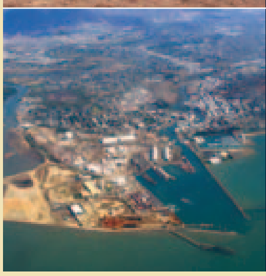
GIS layers were provided by Townsville City Council, the Great Barrier Reef Marine Park Authority, NQ Dry Tropics, CSIRO and Department of Environment and Resource Management.

Water quality data and other information was provided by Townsville City Council, Department of Environment and Resource Management, Townsville Port Authority, Great Barrier Reef Marine Park Authority, Australian Institute of Marine Science, Department of Defence, BHP Billiton (Queensland Nickel) and Conservation Volunteers Australia. Special mention to Mick Brady (CVA) and the members of our Creekwatch groups who volunteered their valuable time to collect some of the water quality data used in background reports and the WQIP.

Photos are provided by Townsville City Council and John Gunn unless otherwise acknowledged.

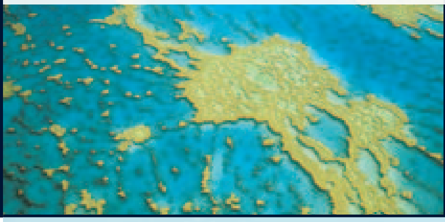
CONTENTS



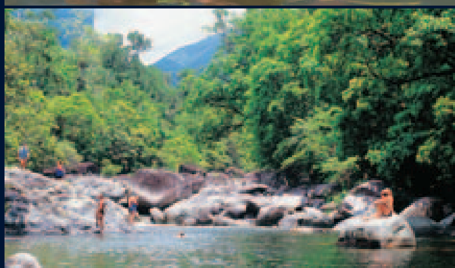


TABLES

FIGURES



Water quality improvement starts at the freshwater source and continues all the way to the Great Barrier Reef. Creek to Coral encompasses a catchment management philosophy to protect Townsville's waters for both human use and ecosystem health.



INTRODUCTION

1

1. INTRODUCTION

1.1 WHY WE NEED TO IMPROVE WATER QUALITY

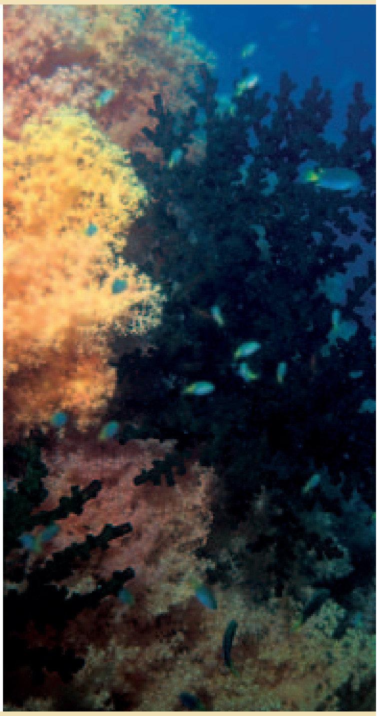
There are many pressures impacting water quality across Australia with some of the more intense pressures arising from population growth and the associated expansion of infrastructure, industry and urban areas. This urban expansion is often concentrated along the coastal strip including in regional centres such as Townsville. The rainwater that leaves the backyards and streets of Townsville, along with any pollutants it carries, flows on to meet the waters of the Great Barrier Reef.

THE GREAT BARRIER REEF – WORTH PROTECTING

The Great Barrier Reef Marine Park is almost 350,000 square kilometres in area and is located along 2,100 kilometres of the Queensland coastline, spanning 14 degrees of latitude. The Great Barrier Reef (GBR) is a complex system encompassing about 2,900 separate coral reefs, which account for around six percent of the area of the Great Barrier Reef Marine Park (GBRMP).

"The Great Barrier Reef is renowned internationally for its ecological importance and the beauty of its seascapes and landscapes. These natural values also provide important ecosystem services, which underpin $6.9 billion worth of economic activity and incalculable social values. In combination, the social-ecological system centred on the reef is extraordinary in its importance, and in its complexity."

Within the Great Barrier Reef (GBR) there *"are many different types of habitat and biological communities. The best known of these are the coral reefs, but there are also seagrass beds, algal meadows, sponge and soft coral gardens, sandy and muddy areas, mangrove forests and islands. This array of habitats supports an amazing biodiversity"* (Johnson and Marshall (eds) 2007, pp.2-3)



The quality of water in the GBR lagoon is important to the maintenance of the habitats and amazing biodiversity of the Marine Park, and especially of the near shore areas. The water quality of the GBR is impacted by the quality of water entering the Marine Park from the adjacent catchments, stretching from Cape York to the Burnett-Mary catchment (Bundaberg). Collectively known as the GBR catchments, the activities that take place on this land ultimately have significant impacts on the quality of the water of the GBR. The Black River and Ross River Basins are part of the GBR catchment and Townsville is home to the largest urban population adjacent to the GBR.

A report released by the Great Barrier Reef Marine Park Authority (GBRMPA) in 2001 raised the profile of water quality issues associated with the GBR. The report, *Great Barrier Reef catchment water quality action plan: A report to Ministerial Council on targets for pollutant loads* (Brodie et al 2001), generated a great deal of debate opening with the statement *"Decades of scientific research and evaluation has now clearly and unequivocally established that land use activities in the catchments adjacent to the Great Barrier Reef are directly contributing to a decline in water quality"* (Brodie et al 2001, p.i). In one way or another we are all involved in some form of land use activity.

The need for water quality improvement in the Marine Park was reiterated in the updated document titled *Synthesis of evidence to support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef* (Brodie et al 2008). The report found that *"Water discharged from rivers to the GBR continues to be of poor water quality in many locations"* (Brodie et al 2008, p.7) and *"Land derived contaminants, including suspended sediments, nutrients and pesticides are present in the GBR at concentrations likely to cause environmental harm"* (Brodie et al 2008, p.14). Along with sediment, nutrient and pesticide discharged from agricultural lands *"urban development sites can be local high impact sources of suspended sediment"* (Brodie et al 2008, p.8).

1.2 GBR WATER QUALITY PROTECTION INITIATIVES

To manage water quality in our populated coastal regions requires a joint effort at all levels of government, in partnership with industry and the community. A variety of water quality improvement initiatives are being implemented throughout Queensland and Australia at different scales and with a range of objectives. The health of the GBR has been the focus of water quality improvement for the GBR catchments in recent times with support from the Australian Government, state agencies and an array of land managers and community members within the catchments of the GBR.

1.2.1 REEF PLAN – IT'S ABOUT THE REEF AND THE LAND

The Reef Water Quality Protection Plan (Reef Plan) is an initiative of the Australian and Queensland Governments, in partnership with industry and the community. The Reef Plan was released in 2003 in response to concerns over the declining water quality of the GBR resulting from land based activities in the reef catchment. The Reef Plan was revised and updated in 2009.

The Reef Plan (2009, p.5) has an immediate goal *"to halt and reverse the decline in water quality entering the Reef by 2013"*. The longer-term goal is *"to ensure that by 2020 the quality of water quality entering the Reef from adjacent catchments has no detrimental impact on the health and resilience of the Great Barrier Reef"*.

The objectives of the Reef Plan (2009) to achieve the goals are:

- *"Reduce the pollutant load from non-point sources in the water entering the Reef; and*
- *Rehabilitate and conserve areas of the Reef catchment that have a role in removing water borne pollutants."*

Reef Plan is an umbrella plan designed to integrate and coordinate action on GBR water quality by government agencies and a wide range of industry and community groups; however it does not address urban diffuse water quality issues.

The Reef Plan now consists of three priority work areas and 11 supporting actions *"to minimise non-point source pollution from broad-scale land use. It specifically targets nutrients, pesticides and sediment which wash into waterways, leach into groundwater or flow overland across floodplains and ultimately enter the Reef lagoon as a result of agricultural activities in Reef catchments."* (2009, p.8)

1.2.2 COASTAL CATCHMENTS INITIATIVE AND WATER QUALITY IMPROVEMENT PLANS

The Coastal Catchments Initiative (CCI) was an Australian Government funded program aimed at achieving targeted reductions in pollution discharges to coastal water quality 'hot spots'. Hot spots, in this context are coastal waters with high conservation value and are threatened by pollution from various sources. The receiving waters of the GBR lagoon are considered to be one such hot spot.

The CCI supports the development and implementation of Water Quality Improvement Plans (WQIPs) in accordance with the Australian Government's Framework for Marine and Estuarine Water Quality Protection. The Framework is based on the *National Water Quality Management Strategy* and the *National Principles for the Provision of Water for Ecosystems*.

WQIPs identify the most cost effective and timely projects for investment by all parties, including the Australian, State and Local Governments, industry and the community. The development of WQIPs in the GBR catchment helps local governments and regional natural resource management (NRM) bodies to determine environmental values and water quality objectives for waterways in their local catchments. Once developed, WQIPs will be integrated with regional NRM plans and other relevant planning processes to ensure ongoing implementation and achievement of objectives, including water quality objectives for the GBR lagoon.

1.2.3 WQIPS IN THE GREAT BARRIER REEF CATCHMENT

WQIPs have been developed for the (former) Douglas Shire, the Mackay Whitsunday NRM region, the Tully and Murray River Basins, the Burdekin and Haughton Basins (Burdekin WQIP), the Burnett and Baffle Basins and the Barron River Basin (Cairns). A water quality improvement report has also been prepared for the Fitzroy NRM region to support the Central Queensland Strategy for Sustainability (CQSS).

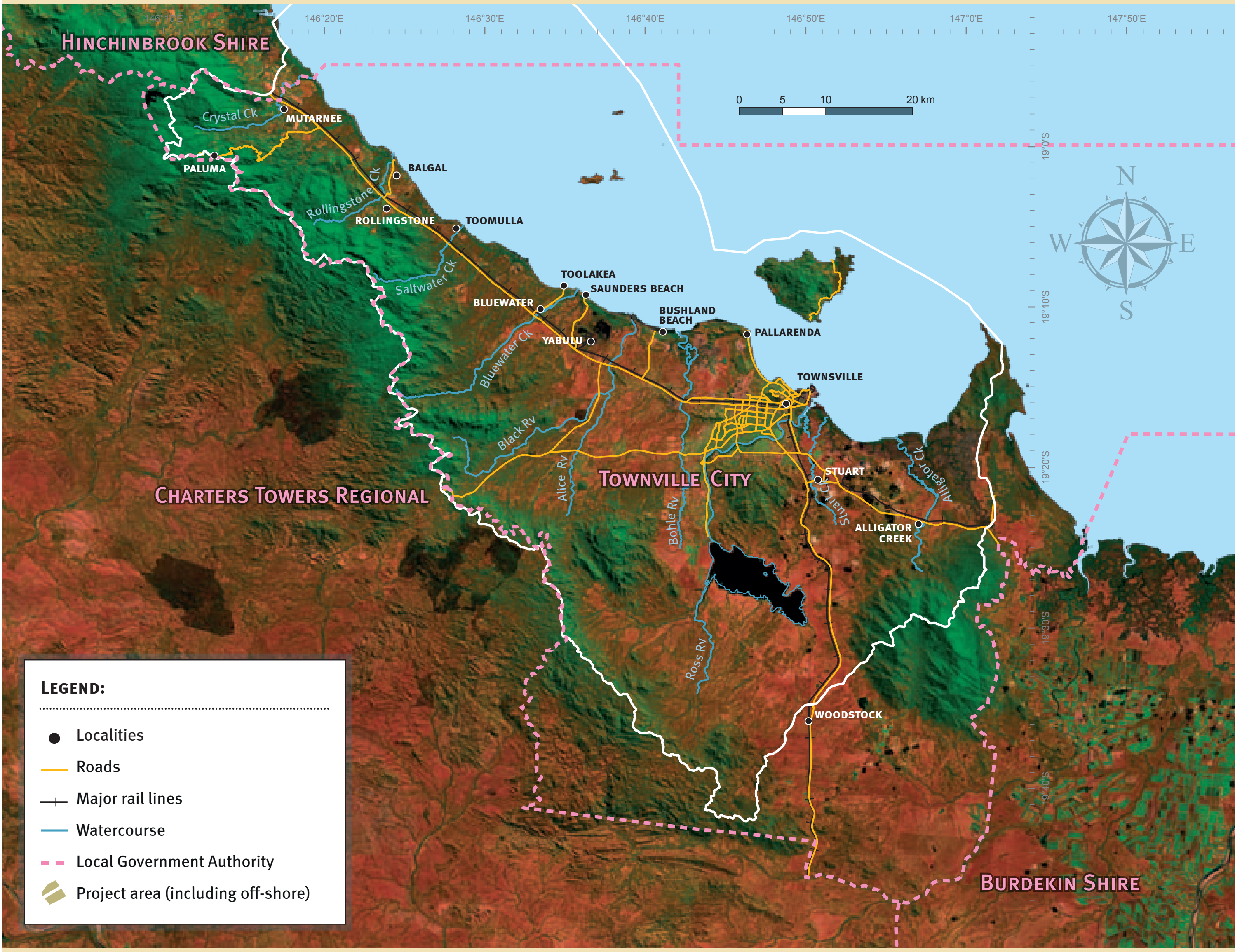
1.2.4 BLACK AND ROSS BASINS WQIP AREA

The Black Ross (Townsville) WQIP area (see Figure 1.1) covers most waterways within the Townsville City Local Government Area (LGA) with the exception of the Reid River and Major Creek catchments, which are part of the Haughton River Basin and are included in the Burdekin WQIP.

Top: A pelican glides above the waters of Ross Dam. An artificial wetland and Townsville's water supply.

Bottom: The Bruce Highway crosses Stuart Creek south of Townsville.

Figure 1.1 Black Ross WQIP Area



It should be noted that the Black Ross (Townsville) WQIP has adopted the Australian Water Resource Council (AWR) basins as its primary catchment units. The Black Ross (Townsville) WQIP area includes the Black River (No. 17) and Ross River (No. 18) AWR Basins and a small part of the Haughton River Basin (No. 19) where the waterways flow to Cleveland Bay. It also includes Magnetic Island, as well as the coastal and marine waters of Cleveland Bay and Halifax Bay (see Figure 1.1).

Drainage basins as defined by the predecessors of the Queensland Department of Environment and Natural Resources (DERM) differ from the AWR basins as the DERM Ross Basin is approximately 386 km² larger and includes part of the AWR Haughton Basin.

1.2.5 CREEK TO CORAL

Townsville City Council's (TCC) Creek to Coral initiative managed the Townsville CCI project for the Black and Ross River Basins and, with the assistance of its many partners, was responsible for the preparation of this WQIP.

Townsville and Thuringowa City Councils established the Creek to Coral initiative in 2003, in partnership with the Queensland Environmental Protection Agency (EPA) and supported by the Great Barrier Reef Marine Park Authority (GBRMPA). The Creek to Coral initiative is a locally adapted version of the South East Queensland (SEQ) Healthy Waterways Program and emphasises local concerns and issues in an environmental context that is relevant to the Townsville dry tropics, adjacent to the GBR.

The Creek to Coral concept is simple and all encompassing whereby 'creek' applies to the freshwater parts of the catchment, all the way through to estuarine waters which ultimately lead to the GBR, hence the choice of the word 'coral' (further information is available at www.creektocoral.org).

1.3 WATER QUALITY IMPROVEMENT PLAN DEVELOPMENT

The development of the Black Ross (Townsville) WQIP by Creek to Coral was guided by a steering group comprising representatives from the main stakeholder groups in the Townsville region (see Acknowledgements page). Consultation for the WQIP involved the steering group, technical panels and working groups, and community involvement (see Figure 4.2). The key components of the WQIP, involving the preparation of background reports and consultation (see Figure 1.2), included:

- Gathering background information, including identifying issues and threats;
- Defining draft environmental values and water quality guidelines;
- Setting water quality objectives (targets) for protecting environmental values;
- Identifying management options to achieve targets and determining the most cost effective actions; and
- Preparing an implementation plan incorporating adaptive management strategies and a WQIP evaluation framework.

Top: A workshop to investigate water sensitive urban design for the Townsville dry tropics.

Bottom: Out in the field looking at potential constructed wetland extensions (Lakes II)

1.3.1 COMPLEMENTARY COMPONENTS OF THE BLACK ROSS WQIP

The development of the Black Ross (Townsville) WQIP was underpinned by a number of complementary components of the Creek to Coral initiative. The two main components are briefly described below.

Water quality monitoring

Creek to Coral's limited water quality monitoring program was enhanced by CCI funds to develop an integrated water quality monitoring and modelling strategy for the WQIP. Components of the expanded water quality monitoring and modelling strategy were used as input to inform the WQIP. These include:

- An integrated water quality monitoring program including event monitoring in 2006/2007 and 2007/2008 'wet seasons';
- Sediment monitoring post 2007/2008 wet season;
- Modelling to establish pollutant loading;

- Identification of complementary elements between the WQIP, the *Stormwater Management Framework for Townsville* (Gunn 2006) and water sensitive urban design (WSUD); and
- Establishment of a report card format outlining catchment condition.

Support for the Strategic Partnership Approach and the Community Based Education and Involvement (CBEI) Network

The main elements of this task included:

- Establishment of a web based portal for information dissemination and exchange;
- Support for the Creek to Coral Community Based Education and Involvement (CBEI) program and network including CitiSchools, Creekwatch, Reefcheck, Seagrass Watch, and Reef Guardian Schools through the Sustainable Education Network (SEN). Community involvement opportunities (e.g. catchment tours), community events and school curriculum input;
- Development of a stakeholder consultation strategy; and
- Behaviour change investigations and training.

Top: Litter in waterways is a major community education and behaviour change topic.

Bottom: Constructed wetlands can assist with water quality improvement (Lakes II).

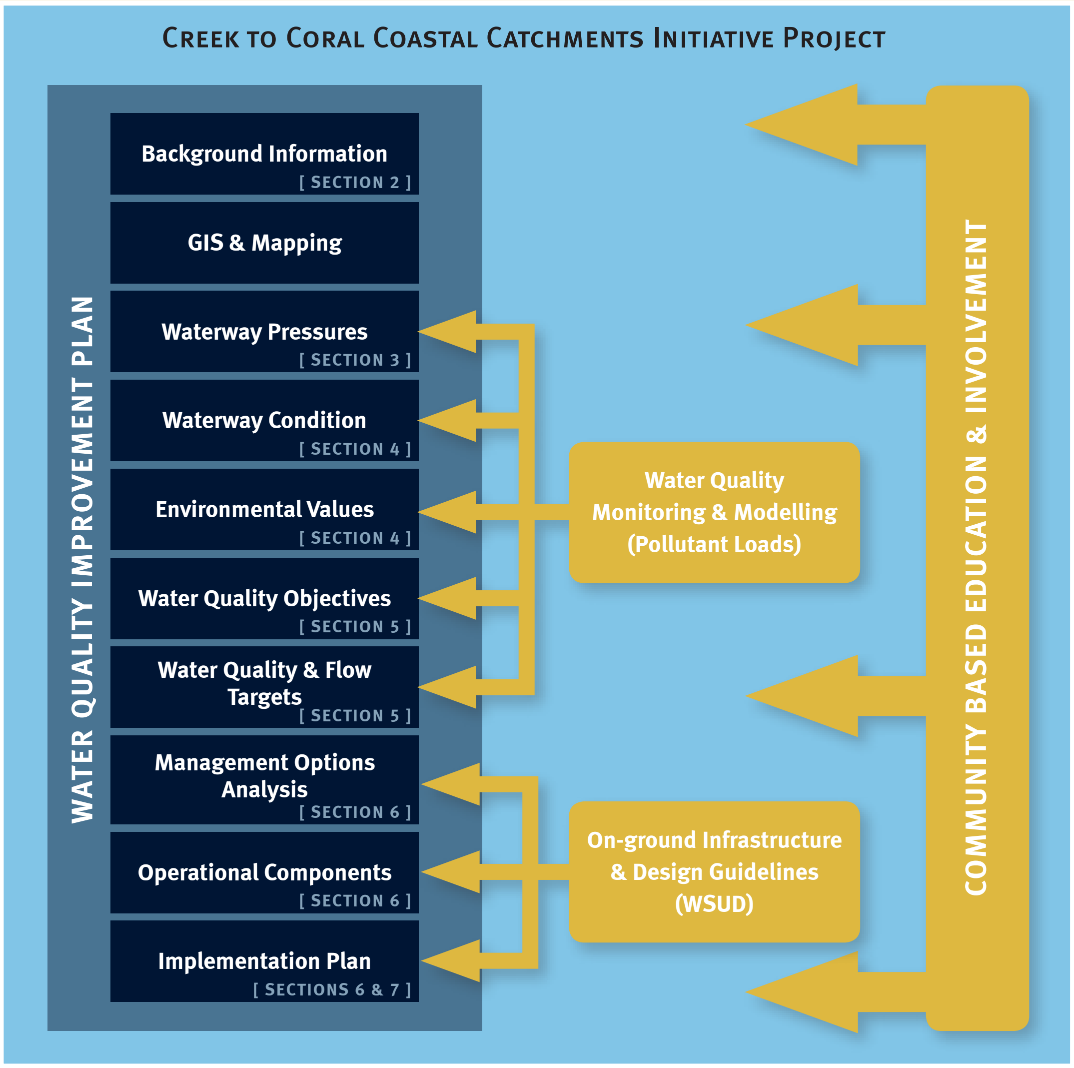
Another key initiative that emerged during the development of the Black Ross (Townsville) WQIP was the desire by Council departments and partner organisations to develop Water Sensitive Urban Design (WSUD) guidelines for the Townsville region. A set of draft WSUD technical design guidelines for Townsville were developed and the testing, refinement, adoption and delivery of the WSUD concept has been incorporated into the Black Ross (Townsville) WQIP as an integral management action for long-term diffuse source water quality improvement across the urban environment.

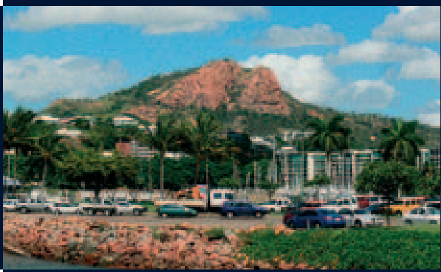
A list of the main supporting documents prepared to inform the Black Ross (Townsville) WQIP is provided below. These documents are available at www.creektocoral.org.

- *Event-based water quality monitoring of the Ross and Black River Basins during the 2006/07 wet season* ACTFR Report No. 07/09 (Liessmann et al 2007)
- *Assessment of Selected Riparian Systems of the Ross and Black River Basins and Selected Other Drainage Within the Townsville / Thuringowa Region* (C and R Consulting 2008)
- *Water Quality Condition of the Black and Ross River Basins* (Connell Wagner 2008)
- *Water Quality Monitoring of the Black Ross Basins: 2007/08 Wet Season* Report No. 08/04 (Lewis et al 2008)
- *Climate change in Townsville and potential impacts on water quality* (SEAO2 2008)
- *Integrated Monitoring and Modelling Strategy for the Black Ross Water Quality Improvement Plan*, ACTFR Report No. 08/17 (Bainbridge et al 2008)
- *Metal Concentrations in the Benthic Sediments of Ross River: Post Wet Season 2008*, ACTFR Report 08/20 (Butler 2008)
- *Development of a Report Card Format for the Waterways of the Black/Ross Basins* (Connell Wagner 2009)

- *Legislation, Institutional Arrangements and Planning Instruments Review for Water Quality Improvement* (Aurecon 2009)
- *Black Ross Water Quality Improvement Plan – Socio-Demographic Profile* (Cardiff 2009)
- *Storm Water Quality Improvement Devices in Townsville* (Scaf, Corbett, and Grier 2009)
- *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009)
- *Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area* (Gunn and Manning 2009)
- *Environmental Values, Water Quality Objectives and Targets for the Black Ross Water Quality Improvement Plan* (Gunn, Manning and McHarg 2009)
- *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2010)
- (Draft) *Social Approaches to Water Quality Improvement in the Black Ross WQIP Area* (Gunn 2010)

Figure 1.2 Creek to Coral CCI Components





Prominent features of Townsville include the Ross River Dam, Castle Hill, Mt Stuart and the Townsville Port. Recreational and commercial activities are often centred around the waters and waterways of the Townsville region.

CHARACTERISTICS OF THE BLACK ROSS WQIP AREA

2

SECTION 2

2. CHARACTERISTICS OF THE BLACK ROSS WQIP AREA

2.1 BACKGROUND

This section provides a brief summary of the main characteristics of the Black Ross (Townsville) WQIP area. For more detailed information refer to the report titled *Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area* (Gunn and Manning 2009).

The coastline of the Black Ross (Townsville) WQIP area (including Magnetic Island) is approximately 130 kilometres, which is equivalent to approximately six percent of the total GBR catchment coastline.

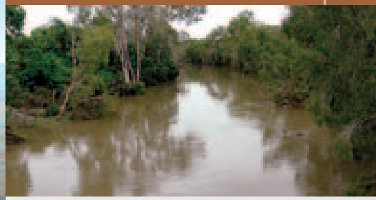
The total land area of the catchments in the Black and Ross Basins that flow to Cleveland Bay and Halifax Bay is approximately 268,400 hectares (approximately 2,700 square kilometres). This represents approximately 0.6 per cent of the total area of the GBR catchments.

The Black Ross (Townsville) WQIP area (see section 1.2.4) has been divided into 10 sub basins (see Table 2.1 and Figure 2.1) and 45 catchments and sub-catchments to assist with condition assessment, monitoring, modelling and reporting.

Figure 2.1 WQIP Area Sub Basins

creektocoral

BOHLE RIVER SUB BASIN 5



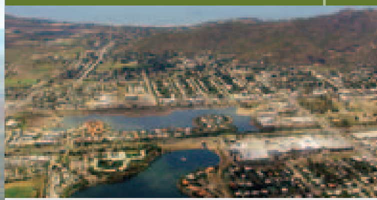
Three main catchments: Upper Bohle River, Lower Bohle River and Shelly Beach. The Lower Bohle catchment includes Louisa Creek and Saunders Creek.

Main waterways length: 296km
Land area: 322km²
Riparian vegetation intact: ..596 ha (80%)

Main land uses:
Grazing: 190km² (59%)
Urban: 58km² (18%)
Nature conservation: 32km² (10%)
Other minimal use: 21km² (6%)
Rural residential: 12km² (4%)

Population (2006): 62,026
Median age: .... 31 years
Average people per household: 3.1

LOWER ROSS RIVER SUB BASIN 6



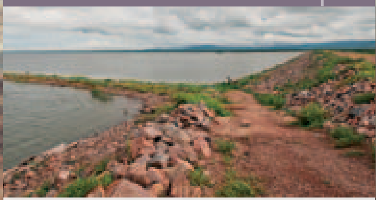
Five main catchments: Pallarenda, Mundy Creek, Esplanade, Ross Creek and Ross River (below the dam).

Main waterways length: 121km
Land area: 135km²
Riparian vegetation intact: ... 172 ha (57%)

Main land uses:
Urban: 68km² (51%)
Other minimal use: 46km² (34%)
Nature conservation: 9km² (7%)
Water/wetland: 8km² (6%)

Population (2006): 76,541
Median age: .... 34 years
Average people per household: 2.6

UPPER ROSS RIVER SUB BASIN 7



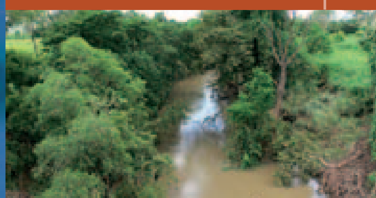
Six main catchments: Ross River (above the dam), Six Mile Creek, Toonpan Lagoon, Antill Plains, Sachs Creek and Mt Stuart.

Main waterways length: 670km
Land area: 755km²
Riparian vegetation intact: 1,404 ha (87%)

Main land uses:
Grazing: 541km² (72%)
Nature conservation: 82km² (11%)
Other minimal use: 75km² (10%)
Reservoir/dam: 43km² (6%)

Population (2006): 1,357
Median age: .... 38 years
Average people per household: 3.0

STUART CREEK SUB BASIN 8



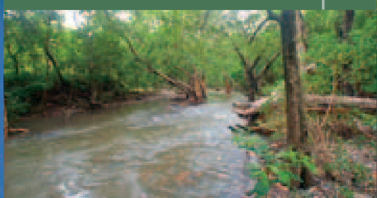
Two main catchments: Stuart Creek and Sandfly Creek.

Main waterways length: 91km
Land area: 104km²
Riparian vegetation intact: .. 196 ha (80%)

Main land uses:
Grazing: 51km² (49%)
Other minimal use: 17km² (16%)
Nature conservation: 14km² (13%)
Water/wetlands: 10km² (10%)
Urban/industrial: 7km² (7%)

Population (2006): 1,230
Median age: .... 34 years
Average people per household: 2.7

ALLIGATOR CREEK SUB BASIN 9



Four main catchments: Alligator Creek, Crocodile Creek, Cocoa Creek and Cape Cleveland.

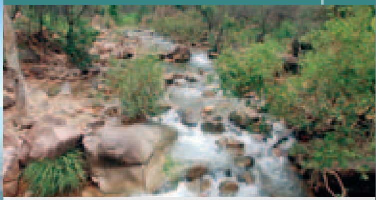
Main waterways length: 271km
Land area: 265km²
Riparian vegetation intact: ..580 ha (89%)

Main land uses:
Nature conservation: 142km² (54%)
Grazing: 41km² (16%)
Other minimal use: 37km² (14%)
Rural residential: 24km² (9%)

Population (2006): 2,100
Median age: .... 41 years
Average people per household: 2.8

THE WQIP REGION

BLUEWATER CREEK SUB BASIN 3



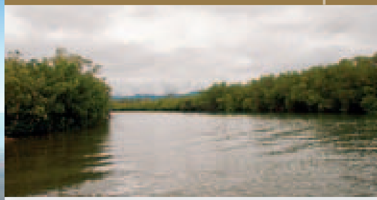
Four main catchments: Sleeper Log Creek, Two Mile Creek, Bluewater Creek and Deep Creek.

Main waterways length: 259km
Land area: .... 290km^2
Riparian vegetation intact: ..609 ha (92%)

Main land uses:
Grazing: .... 219km^2 (75%)
Other minimal use: .... 31km^2 (11%)
Nature conservation: .... 16km^2 (6%)
Rural residential: .... 13km^2 (5%)

Population (2006): 2,876
Median age: .... 38 years
Average people per household: 2.8

ROLLINGSTONE CREEK SUB BASIN 2



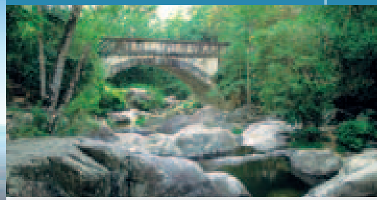
Eight main catchments: Rollingstone Creek, unnamed, Surveyors Creek, Wild Boar Creek, Station Creek, Saltwater Creek, Cassowary Creek and Leichhardt Creek.

Main waterways length: 230km
Land area: .... 220km^2
Riparian vegetation intact: .. 532 ha (92%)

Main land uses:
Nature conservation: .... 159km^2 (72%)
Other minimal use: .... 29km^2 (13%)
Grazing: .... 24km^2 (11%)
Intense agriculture: .... 4km^2 (2%)

Population (2006): 863
Median age: .... 53 years
Average people per household: 2.4

CRYSTAL CREEK SUB BASIN 1



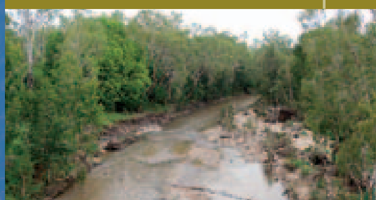
Five main catchments: Crystal Creek, Lorna Creek, Ollera Creek, Scrubby Creek and Hencamp Creek.

Main waterways length: 229km
Land area: .... 240km^2
Riparian vegetation intact: .. 525 ha (89%)

Main land uses:
Nature conservation: .... 118km^2 (49%)
Other minimal use: .... 74km^2 (31%)
Grazing: .... 23km^2 (10%)
Irrigated cropping (sugar): ..... 7km^2 (7%)

Population (2006): 190
Median age: .... 47 years
Average people per household: 2.5

BLACK RIVER SUB BASIN 4



Two main catchments: Black River and Alice River. Alice River is a tributary of Black River.

Main waterways length: 272km
Land area: .... 304km^2
Riparian vegetation intact: .. 647 ha (89%)

Main land uses:
Grazing: .... 231km^2 (76%)
Rural residential: .... 21km^2 (7%)
Other minimal use: .... 20km^2 (7%)
Nature conservation: .... 20km^2 (7%)

Population (2006): 4,917
Median age: .... 36 years
Average people per household: 3.2

BLACK ROSS (TOWNSVILLE) WQIP

The Black Ross (Townsville) WQIP area consists of the Black River Basin, Ross River Basin and Magnetic Island. The Townsville WQIP area has been further divided into ten sub basins (numbered and shown here) and 45 catchments.

Main waterways length:....... 2,466km
Land area:.......................... 2,684km^2
Riparian vegetation intact..... 5,321 ha (86%)

Main land uses:
Grazing...................... 1,335km^2 (50%)
Nature conservation......618km^2 (23%)
Other minimal use......... 355km^2 (13%)
Urban/Residential.......... 238km^2 (9%)

Population (2006):................165,000
Median age:......................... 33 years
Average people per household:..... 2.8

MAGNETIC ISLAND SUB BASIN 10

Eight main catchments: West Coast, Picnic Bay, Nelly Bay, Arcadia, Radical Bay, Horseshoe Bay, Five Beach Bay and Rollingstone Bay.

Main waterways length: 27km
Land area: .... 51km^2
Riparian vegetation intact: ....59 ha (88%)

Main land uses:
Nature conservation: .... 26km^2 (53%)
Other minimal use: .... 19km^2 (39%)
Urban: .... 3km^2 (6%)
Rural residential: .... 1km^2 (2%)

Population (2006): 2,111
Median age: .... 45 years
Average people per household: 2.5

Profiles of the Black River and Ross River Basins, sub basins, catchments and associated waterways and wetlands are provided in the *Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area* background report (Gunn and Manning 2009).

Table 2 1 Sub Basins of the Black/Ross WQIP Area

No.	Sub basin	Main waterways/catchments	Area (Ha)
1	**Crystal Creek**	Crystal Creek, Lorna Creek, Ollera Creek, Scrubby Creek, Hencamp Creek	23,969
2	**Rollingstone Creek**	Rollingstone Creek, Surveyors Creek, Saltwater Creek, Leichhardt Creek	22,003
3	**Bluewater Creek**	Bluewater Creek, Sleeperlog Creek, Althaus/Deep Creek, Healy Creek	29,037
4	**Black River**	Black River, Alice River, Alick Creek, Log Creek, Scrubby Creek, Canal Creek	30,377
5	**Bohle River**	Bohle River, Saunders Creek, Stony Creek, Louisa Creek, Town Common	32,229
6	**Lower Ross River**	Ross River, Ross Creek, Pallarenda, Mundy Creek, Esplanade	13,475
7	**Upper Ross River**	Ross River, Six Mile Creek, Sachs Creek, Antill Plains Creek, Toonpan Lagoon, Mt Stuart	75,460
8	**Stuart Creek**	Stuart Creek, Sandfly Creek	10,371
9	**Alligator Creek**	Alligator Creek, Crocodile Creek, Cocoa Creek, Cape Cleveland	26,489
10	**Magnetic Island**	Gustav Creek, Petersen Creek, Gorge Creek, Endeavour Creek, Retreat Creek, Butler Creek	4,990

The main elements for determining water quality issues and pressures in the Black Ross (Townsville) WQIP area are land use and associated management practices. Climatic and geographic factors also play a part in the overall impacts, however it is acknowledged that land use and management practices are the most influential factors on water quality. Land use is therefore the main focus of this section.

2.2 LAND USE

Land use mapping for the Townsville region, from the Queensland Land Use Mapping Program (QLUMP) (DNRM 1999), was updated by Creek to Coral as part of the CCI project (see Figure 2.2). This was necessary to better reflect the present land use situation, particularly in the expanding urban area and the surrounding peri-urban zone. The purpose was to enable more accurate assessment of land use based water quality impacts and potential outcomes of water quality improvement interventions, especially through the use of catchment modelling tools. The main land use groupings adopted for the purposes of the Black Ross (Townsville) WQIP, along with the constituent land uses, are shown in Table 2.2.

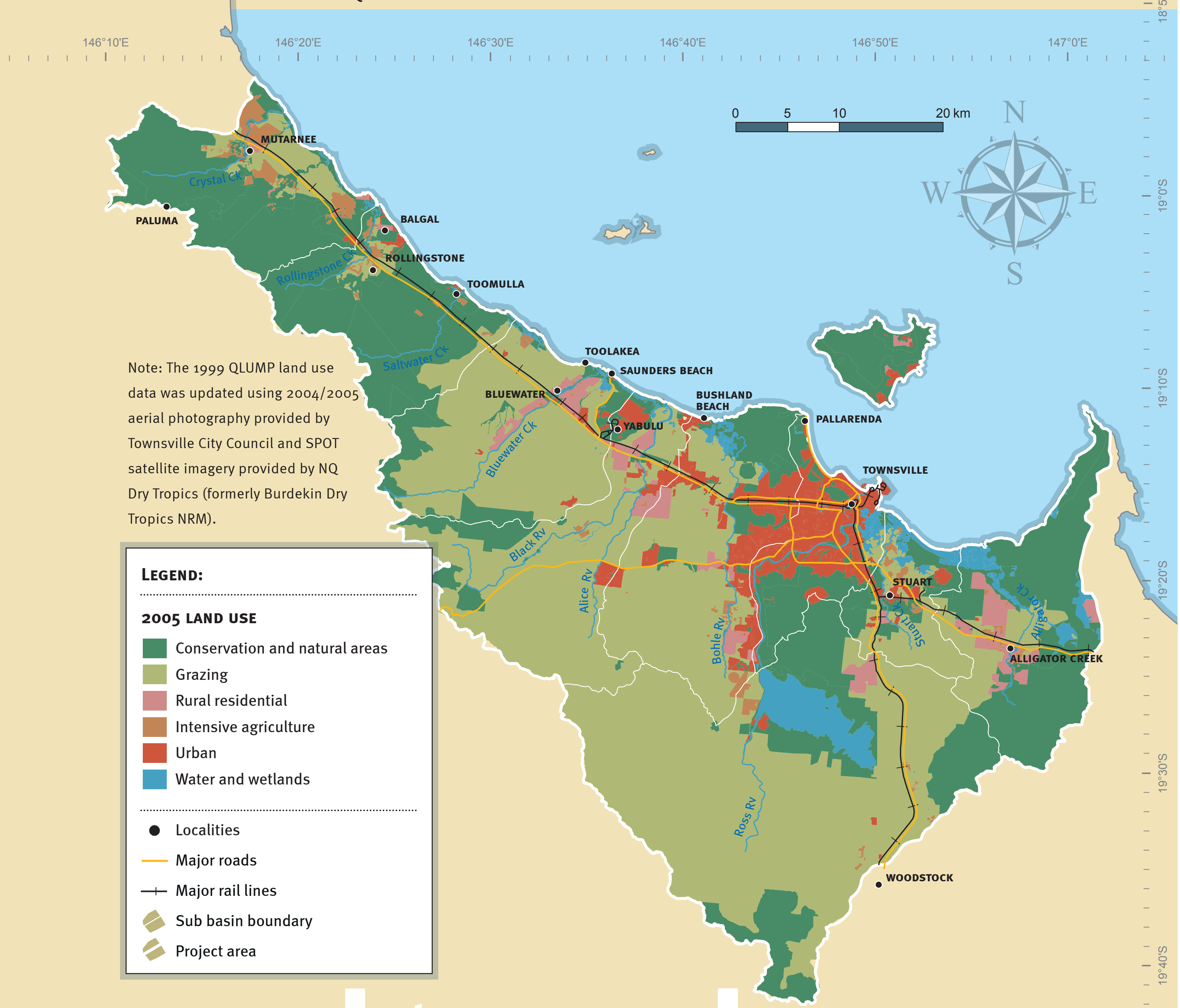
The dominant land use is grazing, occupying approximately half of the WQIP area, with a further 37 per cent of the WQIP area consisting of minimal use and conservation areas. The urban land use extent, at 5.8 per cent, is well above the average of the neighbouring rural based WQIPs i.e. Burdekin at 0.09 per cent and Mackay Whitsunday at one per cent.

The peri-urban zone 'surrounds' the urban areas and is comprised of rural residential and 'small' block rural land uses. The peri-urban zone has been loosely defined through the cadastral database as blocks between one hectare and 300 hectares in size. On this basis, the peri-urban zone covers approximately 30 per cent of the total Black Ross (Townsville) WQIP area. A more detailed summary of land use by sub basins in the Black Ross (Townsville) WQIP area is provided in Table 2.3.

Table 2.2 Principal Land Use Categories

Underlying land use	Adopted land use groups	Hectares	%
Nature conservation, other minimal use	Conservation and natural areas	98,527	36.7
Grazing natural areas, production forestry	Grazing	132,209	49.3
Residential	Rural residential	8,173	3.0
Cropping, perennial horticulture, plantation forestry, irrigated cropping, irrigated horticulture (perennial and seasonal), intensive animal production.	Intensive agriculture	4,108	1.5
Residential, manufacturing and industrial, services, utilities, transport and communication, waste treatment and disposal, mining.	Urban	15,565	5.8
Channel/aqueduct, marsh/wetland, reservoir/dam, river.	Water and wetlands	9,819	3.7
	Black Ross WQIP area total	268,400	

Figure 2.2 Black Ross WQIP Area Land Use Map



Note: The 1999 QLUMP land use data was updated using 2004/2005 aerial photography provided by Townsville City Council and SPOT satellite imagery provided by NQ Dry Tropics (formerly Burdekin Dry Tropics NRM).

Table 2.3 Land Use Summary by Sub Basin

	Crystal Creek		Rollingstone Creek		Bluewater Creek		Black River		Bohle River		Lower Ross River		Upper Ross River		Stuart Creek		Alligator Creek		Magnetic Island	
Land use	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Nature conservation	11,786	49.2	15,865	72.1	1,645	5.7	1,962	6.5	3,197	9.9	944	7.0	8,218	10.9	1,366	13.2	14,194	53.6	2,639	52.9
Other minimal use	7,365	30.7	2,863	13.0	3,133	10.8	1,962	6.5	2,053	6.4	4,584	34.0	7,461	9.9	1,704	16.4	3,663	13.8	1,924	38.6
Grazing natural vegetation	2,287	9.5	2,382	10.8	21,893	75.4	23,063	75.9	19,018	59.0	316	2.3	54,082	71.7	5,054	48.7	4,111	15.5		
Production forestry	1	0.0	2	0.0																
Plantation forestry			70	0.3																
Cropping	10	0.0	28	0.1			103	0.3	4	0.0							43	0.2		
Irrigated cropping	1,697	7.1	52	0.2			7	0.0	88	0.3			63	0.1	299	2.9	26	0.1		
Irrigated perennial horticulture	88	0.4	70	0.3	77	0.3	58	0.2	299	0.9			323	0.4	56	0.5	185	0.7		
Irrigated seasonal horticulture	178	0.7	215	1.0									35	0.0			15	0.1		
Perennial horticulture	4	0.0							10	0.0							3	0.0		
Intensive animal production			40	0.2	117	0.4			101	0.3					23	0.2				
Residential	171	0.7	253	1.1	1,473	5.1	2,081	6.9	4,755	14.8	4,046	30.0	647	0.9	191	1.8	2,439	9.2	383	7.7
Manufacturing and industrial					48	0.2	564	1.9	1007	3.1	381	2.8	11	0.0	353	3.4			5	0.1
Services	25	0.1	34	0.2	45	0.2	58	0.2	532	1.7	2,004	14.9	75	0.1	32	0.3			27	0.5
Transport and communication	85	0.4	15	0.1			7	0.0	485	1.5	416	3.1			68	0.7				
Utilities									21	0.1	9	0.1			2	0.0				
Waste treatment and disposal			5	0.0	4	0.0			17	0.1					62	0.6			13	0.3
Mining	4	0.0			177	0.6			110	0.3	21	0.2	173	0.2	116	1.1	11	0.0		
Channel/aqueduct					7	0.0														
Reservoir/dam	2	0.0	5	0.0	20	0.1	5	0.0	3	0.0	149	1.1	4,332	5.7	14	0.1				
River	61	0.3	10	0.0	58	0.2	343	1.1	16	0.0	91	0.7	27	0.0			43	0.2		
Marsh/wetland	205	0.9	96	0.4	341	1.2	165	0.5	514	1.6	515	3.8	12	0.0	1,033	10.0	1,755	6.6		
Total (hectares)	**23,969**		**22,003**		**29,037**		**30,377**		**32,229**		**13,475**		**75,460**		**10,371**		**26,489**		**4,990**	

Note: The dominant land use is shaded as:
- Most
- Second
- Third
- Fourth

SECTION 2

2.3 RECENT POPULATION GROWTH

More detail on the socio-economic characteristics of the Black Ross (Townsville) WQIP area is provided in the *Black Ross Water Quality Improvement Plan – Socio-Demographic Profile* (Cardiff 2009) and *Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area* report (Gunn and Manning 2009) A summary of recent population trends is provided below, with longer-term population projections provided in section 3.3.

The amalgamated City of Townsville covers an area of 3,736 km², encompassing the Black Ross (Townsville) WQIP area (approximately 2,700 km²). In 2005 (the base year for the WQIP using the updated land use mapping) the Estimated Resident Population (ERP) for Townsville stood at 160,220 people, representing an annual increase of 3.1 per cent from 2004. The average annual population increase over the five years to 2008 was 3 per cent. Recent estimated resident population (ERP) trends are listed in Table 2.4 and shown graphically in Figure 2.3.

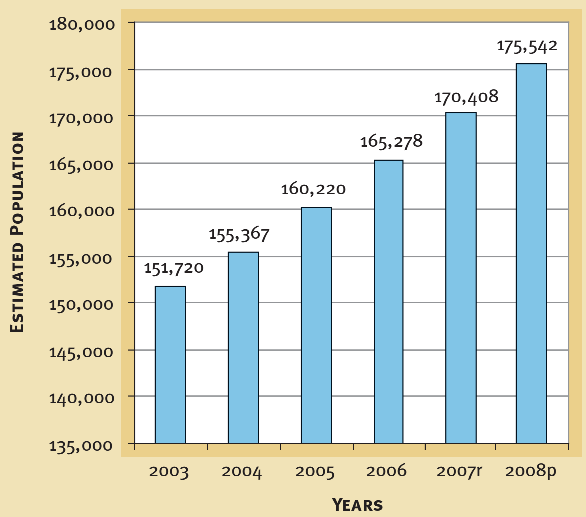
Table 2.4 Estimated Resident Population Growth Trends

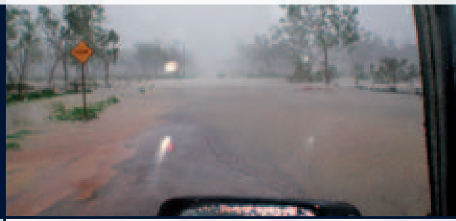
Year	Estimated population	Year to 30 June	Population growth		New dwellings	
			Number	Percentage	Number	Area (Ha)
2003	151,720					
2004	155,367	2004	3,647	2.40%	1,303	130
2005	160,220	2005	4,853	3.10%	1,733	173
2006	165,278	2006	5,058	3.20%	1,806	180
2007r	170,408	2007r	5,130	3.10%	1,832	183
2008p	175,542	2008p	5,134	3.00%	1,834	183
2003-2008p		**(Total)**	**23,822**	**3.00%***	**8,507**	**850**

Source: Australian Bureau of Statistics (ABS) Catalogue Number: 3218.0 - Regional Population Growth, Australia, 2007-08; released 23 April 2009.

Note: Population estimates are final for 2003 to 2006 and revised for 2007 (2007r) to align with new June 2007 state totals released in September 2008. Estimates for 2008 are preliminary (denoted 2008p).
* Annual average increase. New dwellings data is based on an average occupancy rate of 2.8 people and an average area per dwelling of 1,000 m², including roads and parks (does not include other urban expansion e.g. commercial and industrial).

Figure 2.3 Townsville Recent Population Growth Trend





SECTION 3

Townsville, like many other coastal regions, has a range of pressures associated with population growth and development. Add climatic extremes and the dry tropics becomes a natural resource management challenge.

Know the Issues, Pressures and Threats

3

3. KNOW THE ISSUES, PRESSURES AND THREATS

3.1 SOME BACKGROUND AND ASSUMPTIONS

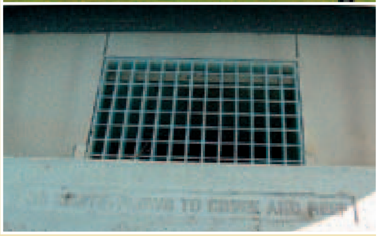
Pressures and threats to water quality are assumed to be those things resulting from human actions (past, current and future), which have potential to impact water quality, along with natural phenomena and environmental factors. 'Issues' includes the whole range of pressures and threats, which may be natural phenomena, natural phenomena exacerbated by human interaction, inappropriate land management practices, and misdirected policy settings and incentives. It is assumed that the majority of water quality issues are associated with land based human activities. These can generally be defined in terms of pollutant type and source associated with land use and management practices.

It is recognised that not all pressures are threats, and that pressures and threats may not be translated to actual impacts on water quality. Determining the level of impact is a function of observation over time, often through water quality monitoring and analysis of the collected data in relation to the upstream catchment. In the absence of adequate resources to collect water quality data, catchment modelling is used to predict the theoretical impact of pressures. This is an iterative learning process of monitoring and modeling in order to better understand the correlation between pressures and actual water quality impacts.

Where information is available to observe or predict a correlation between pressures and impacts it should then be possible to develop appropriate management measures with reasonable assurance that the cause of the water quality issue will be addressed. Where the link between a pressure and a water quality impact is still uncertain, additional investigations may be required to ensure adequate understanding of the situation to enable meaningful planning and design for effective interventions.

In most situations, it is acknowledged that we are not directly managing the environment; rather we are assisting people to manage their behaviour to avoid adverse impacts on their life support system i.e. the environment and associated ecosystem services.

Within the Black Ross (Townsville) WQIP area the principal pressure impacting water quality, and other environmental parameters, is land use intensification resulting from population growth. Threats to water quality from land use intensification are generally due to inappropriate planning, design and/or management. It follows that improvements in planning, design and management practices can have a positive impact on water quality compared to the 'business as usual' scenario.



Top: Urban expansion continues apace across the Townsville coastal plains.

Bottom: Stormwater flows to creeks and then the reef.

3.1.1 ISSUES BY LOCATION

Land use type is the primary geographic division used when; identifying and locating pressures and threats, determining natural asset condition and subsequently for implementing management actions. Along with the general land use divisions (e.g. residential and commercial), the urban and peri-urban environment can be classified as being either developed (brownfield) or developing (greenfield). As with different types of

SECTION 3

rural land use, this is a significant distinction in terms of the pressures and threats, and the type and amount of pollutants generated. While land use type and development stage are the two main points of reference at the 'local' level one or more of the following geographic divisions may also be appropriate for condition assessment, monitoring, modelling and reporting purposes:

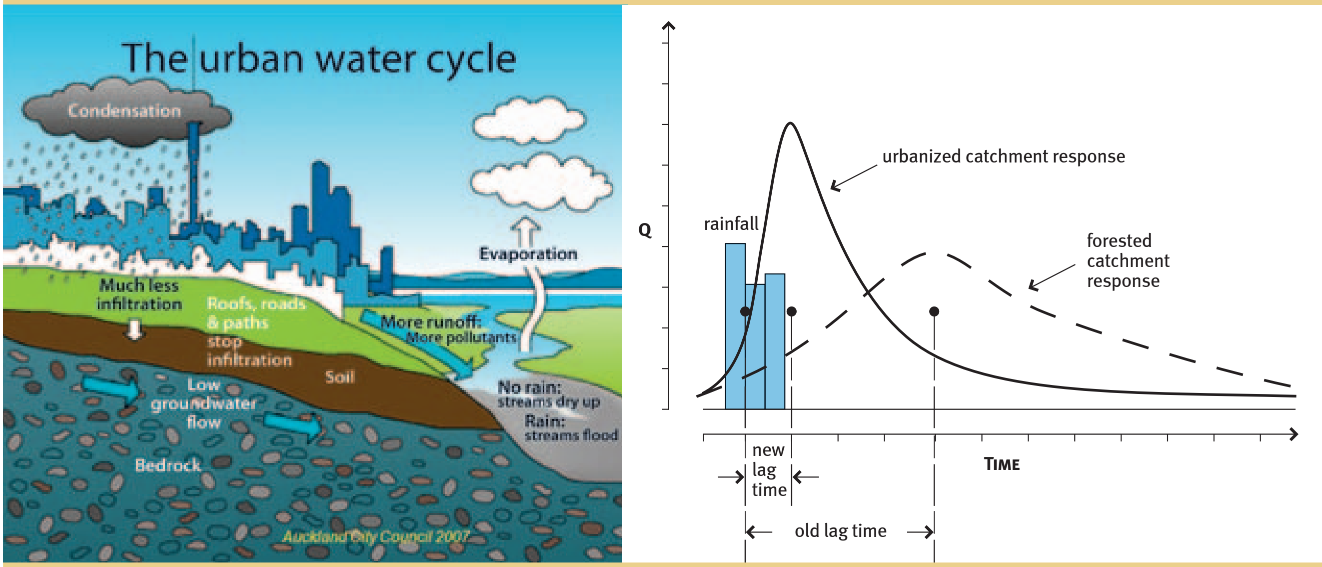
- The whole WQIP study area;
- Terrestrial areas;
- Waterway types (freshwater, estuarine or marine);
- Basin, sub basin, catchment and sub catchment units; and
- Specific physical features e.g. floodplains.

3.2 ISSUES AND DEVELOPMENT STAGE

Water quality issues vary across catchments as a function of land use, management regime and the level or stage of development. Issues associated with developed urban areas are significantly different from those of developing areas and relatively undeveloped and rural areas.

In addition to an increase in pollutants in runoff, the conversion of natural areas to urban land use changes the hydrology of sub catchments due to physical alterations, including through an increase in impervious surfaces and the installation of stormwater systems i.e. less infiltration leading to an increase of stormwater run off. This increase in runoff and flow has implications for instream health as an increase in bank and bed erosion may result (see Figure 3.1).

FIGURE 3.1 HYDROLOGY CHANGE THROUGH URBANISATION



Source: Auckland City Council 2007 Source: Marina Alberti 2008

Notes: As illustrated in the urban water cycle diagram there is more runoff and much less infiltration to groundwater. This is represented graphically in the diagram on the right where the peak flow from urban catchments happens sooner and is more intense in comparison to a forested (natural) catchment.

The variability of water quality issues also applies to rural areas where development is often associated with land use transitions from a relatively natural state to more intensive production systems. This change can be gradual with relatively low potential water quality impacts e.g. bush land to grazing, or more sudden with potential for greater impacts as with conversion from bush land to intensive agriculture. Management practices associated with each land use type and development activity also have a critical role in the magnitude of water quality impacts.

The different pressures and threats in both urban and rural areas require appropriate management measures to address any associated water quality impacts.

It is recognised there will be areas that fall somewhere between urban and rural land uses, namely peri-urban. To assist with the definition of relevant water quality issues and impacts, and the subsequent development of appropriate management measures, land use has been aggregated into urban, peri-urban and rural groupings.

It is generally the peri-urban areas that are under the most pressure from the intensification of land use due to urban expansion and development. This has been identified in the functional state column in Table 3.1, where peri-urban constitutes the main proportion of the 'Developing' functional state.

Table 3.1 Land Use Divisions for Urban WQIP Purposes

<table>
<tr><th>Broad land use</th><th>Principal land uses</th><th>Functional state</th><th>New land use distribution</th></tr>
<tr><td rowspan="8">Urban</td><td>Residential - traditional housing</td><td rowspan="5">Operational (Developed)</td><td rowspan="9">Urban</td></tr>
<tr><td>Residential - high density</td></tr>
<tr><td>Commercial</td></tr>
<tr><td>Light industrial</td></tr>
<tr><td>Heavy industrial</td></tr>
<tr><td>Formal parks</td><td rowspan="12">Developing</td></tr>
<tr><td>Minimal use</td></tr>
<tr><td>Natural areas</td></tr>
<tr><td rowspan="7">Peri-urban</td><td>Natural areas</td></tr>
<tr><td>Minimal use</td><td rowspan="9">Peri-urban</td></tr>
<tr><td>Forestry</td></tr>
<tr><td>Rural residential</td></tr>
<tr><td>Grazing</td></tr>
<tr><td>Intensive agriculture</td></tr>
<tr><td>Mining / quarrying</td></tr>
<tr><td rowspan="6">Rural</td><td>Grazing</td></tr>
<tr><td>Natural areas / Minimal use</td></tr>
<tr><td>Forestry</td><td rowspan="4">Operational (Developed)</td></tr>
<tr><td>Intensive agriculture</td><td rowspan="3">Rural</td></tr>
<tr><td>Mining / quarrying</td></tr>
<tr><td>Dam catchment</td></tr>
</table>

Note: Developing includes change to a more intensive land use e.g. grazing to horticulture. The catchment area of Lake Ross is classed as a separate land use as it requires special management attention to ensure that existing land uses within the catchment do not compromise water quality of the urban water supply storage.

Appropriate management actions for water quality improvement will be based on the identified threats to water quality (current and potential future) associated with the general land use divisions described above and the associated water quality pollutants identified from existing literature as well as the experience of stakeholders involved in the development of the Black Ross (Townsville) WQIP. Additional investigations are required to gain a better understanding of peri-urban areas and their impact on water quality.

3.3 POPULATION GROWTH

Population growth is the primary driver of development activity and the associated demand for infrastructure and services in the region. This results in pressures associated with land use change and intensification. Projections published by the Department of Local Government and Planning in 2006 (see Table 3.2) indicate that the population of the new Townsville City LGA will increase from 144,789 in 2001 to 255,986 (medium rate) by 2026. The annual average growth rate between 2001 and 2026 in the new Townsville City is projected to be 1.7 per cent. This is consistent with an annual average growth rate of 1.7 per cent for Queensland as a whole.

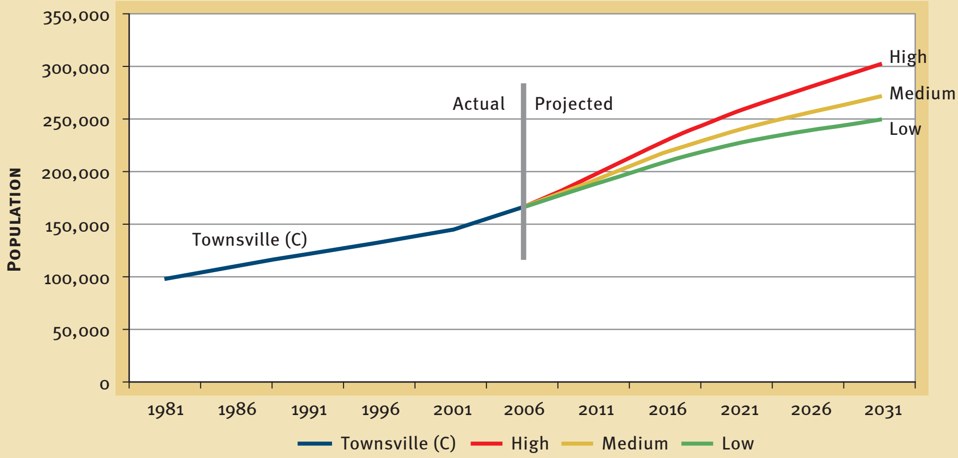
Table 3.2 Population Growth Projections for Townsville

Year	Projections			Population change	
	Low	Medium	High	Five years to 30 June	Annual average change
2011	187,441	191,329	196,145	2011	3.0%
2016	210,078	218,660	229,941	2016	2.7%
2021	226,401	239,619	257,722	2021	1.8%
2026	238,451	255,986	280,736	2026	1.3%
2031	248,287	270,500	302,044	2031	1.1%

Note: Future Trends data is not comparable to Estimated Resident Population (ERP) due to ERP using more up to date/revised data. For regions within the Fitzroy and Mackay statistical divisions, the Department of Local Government and Planning have recommended the use of the High series.

Townsville's share of Queensland's population is projected to be 3.9 per cent in 2026 compared with 4.0 per cent in 2001. The graph in Figure 3.2 illustrates past and projected future growth for Townsville.

Figure 3.2 Longer Term Population Projection



Note: A 1.1 per cent growth rate for the medium forecast was used to project the growth beyond the life of the current Planning Scheme(s) i.e. beyond Population Information and Forecasting Unit (PIFU) 2031 projections in Table 3.2. The current planning scheme(s) population of 361,338 is achieved in 2057.

Source: Department of Infrastructure and Planning population projections, 2008 ed.

Population growth estimates used in the Black Ross (Townsville) WQIP have been generated using a population growth model developed by TCC for the Townsville strategic road network planning process to guide a 20 year capital works program (Bailey 2009, Unpublished internal report). The model uses population growth projection figures from the Population Information and Forecasting Unit (PIFU) to generate population increase estimates across the various planning scheme zones. These estimates were then used to generate predicted land use extent in the modelling sub catchments used by Creek to Coral to determine pollutant loads across a range of scenarios.

Predicted population growth was coupled with known dwelling occupancy rates, known and anticipated urban expansion areas, planning scheme zonings, the Townsville-Thuringowa Strategy Plan and land use mapping to produce population and development growth maps across the following scenario horizons for the Black Ross (Townsville) WQIP: 2005 (base case), 2012 (Wastewater upgrades), 2021 (achievable management practice adoption timeframe) and 2045 (measurable ecosystem health improvement timeframe).

Following the collation of this information scenarios were examined using the Water and Contaminant Analysis and Simulation Tool (WaterCAST) catchment model, for both rural and urban land uses in the Black Ross (Townsville) WQIP area. The urban scenarios were designed primarily to predict the likely water quality outcomes, with and without the proposed urban water quality improvement measures, and to help verify the need to implement these actions to alleviate the impact of the anticipated population growth in the region. The rural scenario was based on potential improvements in water quality associated with the uptake of improved horticultural and pasture management practices.

Predicted changes to pollutant loads (sediment and nutrients) resulting from population growth in Townsville are explored in more detail in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2010).

3.4 WATER QUALITY POLLUTANTS AND SOURCES

This section, amongst other things, summarises the key findings of the *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009), prepared for the Creek to Coral CCI project. More detail on urban and rural water quality pollutants can be found in that report (see www.creektocoral.org).

Determining pollutant types and their source within the Black Ross (Townsville) WQIP area was essential particularly as many of the pollutants emanating from urban and peri-urban areas are not the same as the pollutants from rural and agricultural dominated GBR catchments, which are dealt with in other WQIP regions.

The key pollutants generated from the GBR catchments leading to water quality decline are sediment i.e. total suspended solids (TSS), and nitrogen and phosphorus (also collectively referred to as nutrients). Pesticides (herbicides in particular) are recognised as another pollutant of concern in agricultural areas, however water quality monitoring to date has not indicated pesticides are a significant issue in the Black Ross (Townsville) WQIP area. Sediment and nutrients are the focus of the Black Ross (Townsville) WQIP due to their impact on the water quality of local waterways and subsequently on ecosystem health of the GBR. Pollutants associated with the main land use categories and their impact on receiving waters are discussed in the following sections.

Top: Erosion and sediment control is necessary for all development and construction works.

Bottom: Industrial areas have their own water quality issues.

3.5 LAND USE AND POLLUTANT CONTRIBUTIONS

The water quality pollutant and sources information, combined with land use information, and event water quality monitoring data from the 2006/07 and 2007/08 wet seasons (*Water Quality Monitoring of the Black Ross Basins: 2007/08 Wet Season, Report No. 08/04* (Lewis et al 2008)), was used to estimate the contribution of sediment and nutrients from various land uses in the Black Ross (Townsville) WQIP area. This information was then used to inform catchment models to identify and quantify the level of pollutants discharged annually from the catchments of the Black Ross (Townsville) WQIP area, and changes in pollutant discharges based on the land use change over time in each catchment.

For detailed information on modelled end of catchment pollutant loads see *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009), *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2010) and *Black and Ross River Water Quality Improvement Plan Catchment and Water Quality Modelling* (BMT WBM Pty Ltd 2010).

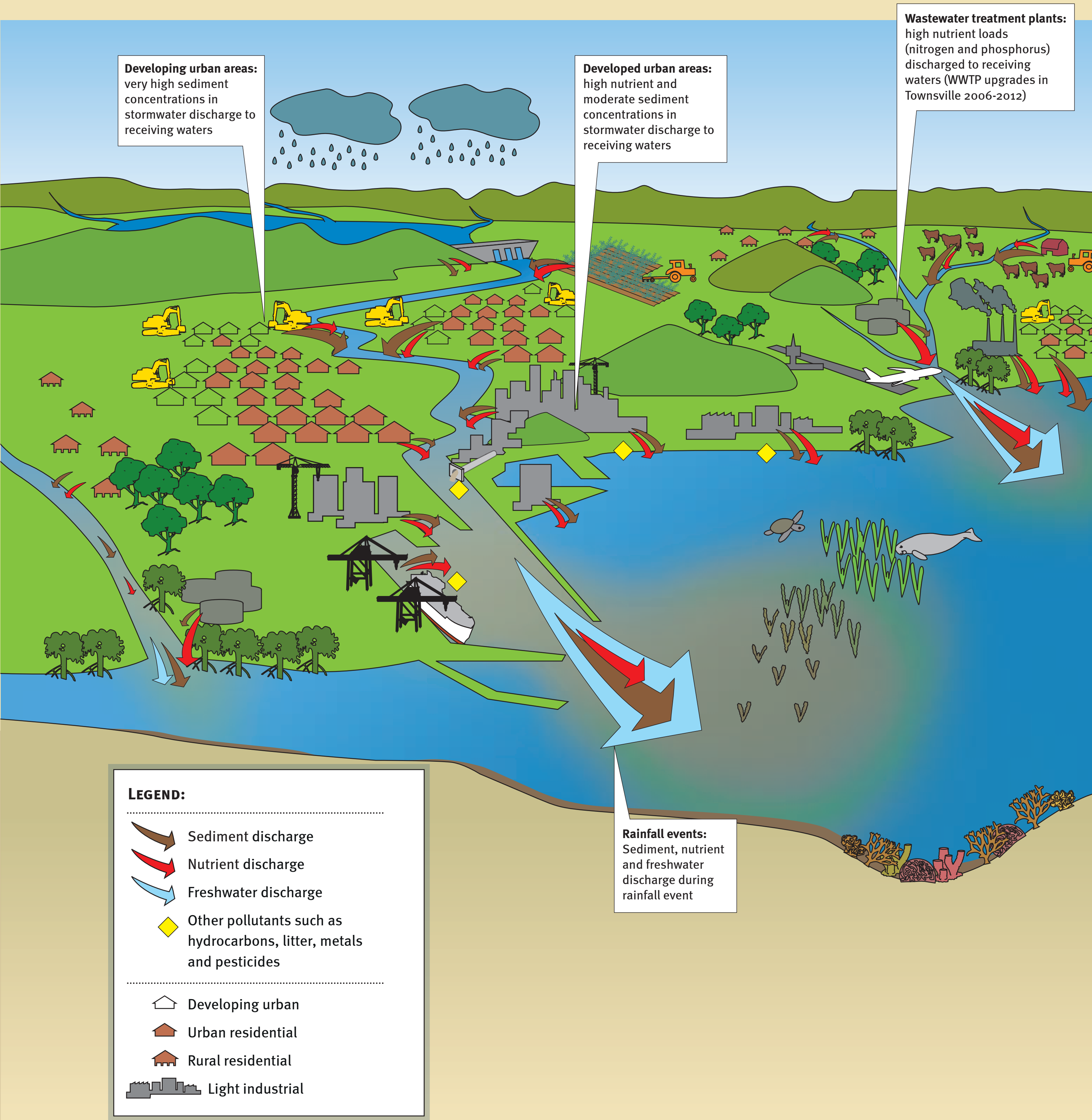
Pollutant runoff coefficients for various land uses used in the catchment models and a summary of the modelled end of catchment loads can be found in sections 5.5.1 and 5.7 respectively.

3.6 URBAN SPECIFIC AND POINT SOURCE POLLUTANTS

The urban environment is generally dominated by small 'paddock' residential allotments, transport and infrastructure corridors and commercial and industrial centres. The urban environment also has a high proportion of impervious surfaces, a greater number of 'land managers', larger waste management issues, concentrated industrial areas and constructed stormwater systems. Urban areas are often associated with point source pollutants, and rightly so, as it is the concentration of people and industry that results in the waste management water quality issues associated with large population centres.

However, with a few exceptions, urban diffuse pollutant sources are the greatest overall contributors to water quality issues. A conceptual diagram of urban and peri-urban pollutant sources and destinations, loosely based on the Townsville region, is shown in Figure 3.3.

Figure 3.3 Black Ross WQIP Urban/Peri-urban Water Quality Pollutants Concept Model



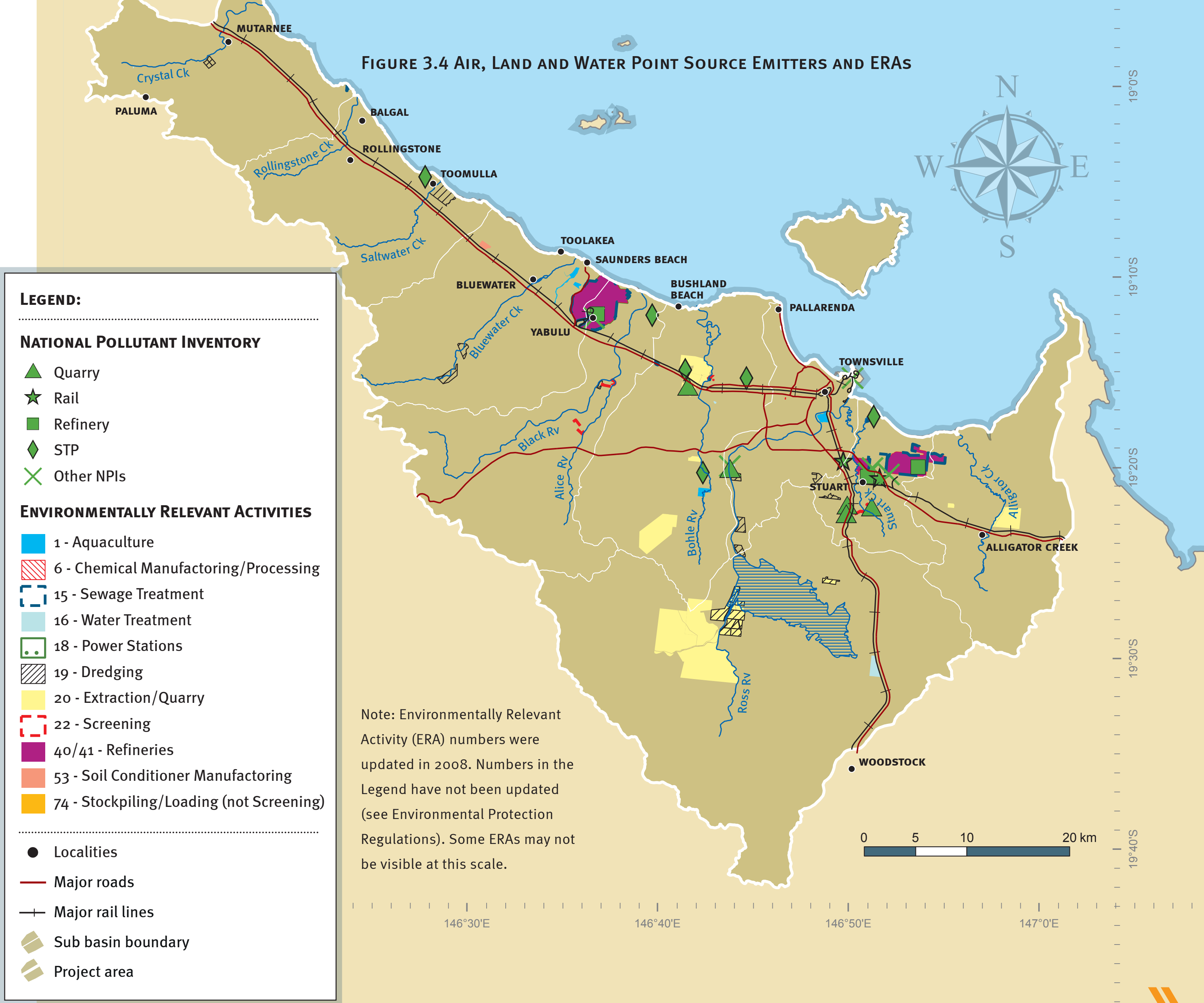
3.6.1 POINT SOURCES AND INDUSTRY

Point source pollution is easily identified as it involves intensive land use in a relatively small area, usually involving an industrial activity. The pollutants, generally waste products, are discharged from the facility at a specific point or points e.g. pipe or chimney, hence the term point source discharge.

The main point source pollutant emitters in Townsville have been identified and described in detail in the *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009). The locations of the main point source pollutant emitters in the Black Ross (Townsville) WQIP area are illustrated in Figure 3.4.

The only significant point source pollutant emitters identified in terms of water quality impacts in the Townsville region were the wastewater treatment plants, as most plants discharge direct to receiving waters. Other industrial activities generally emitted pollutants to air or land and as such did not have a direct and measurable impact on water quality.

FIGURE 3.4 AIR, LAND AND WATER POINT SOURCE EMITTERS AND ERAs



Note: Environmentally Relevant Activity (ERA) numbers were updated in 2008. Numbers in the Legend have not been updated (see Environmental Protection Regulations). Some ERAs may not be visible at this scale.

The emissions to air were taken into account as diffuse sources of pollution and are considered in the section on atmospheric deposition (see section 3.10). Emissions to land are regulated under the *Environmental Protection Act 1994* (EP Act) and licence conditions require that they be contained and not discharged directly to waters.

Current average annual point source pollutant contributions from wastewater treatment plants (WWTPs) have been estimated and are shown in Table 3.3.

The percentage contribution from point sources will vary from year to year depending on rainfall, runoff and subsequent river flow, while actual discharge volumes from WWTPs remain relatively constant albeit with predictable incremental increases. Percentage contributions from WWTPs vary throughout the year also with proportional increases as the natural flow decreases during the drier months. Annual increases in discharge volumes associated with WWTPs can be easily related to population growth and can be readily predicted based on the 'business as usual' scenario.

Table 3.3 Point Source Pollutant Load Contributions (WWTPs)

Receiving waters	Facilities	Total N (t/yr)	%	Total P (t/yr)	%
Bohle River	Condon, Deeragun, Mount St John	131	~60%	21	~50%
Black River	Mount Low	1.9	~3%	1.3	~8%
Cleveland Bay[1]	Cleveland Bay (pre 2006)	126	[1]~40%	40	[1]~63%
Sandfly Creek[2]	Cleveland Bay (post 2006)	42	[2]~69%	17	[2]~85%

Source: Townsville City Council provided discharge figures for WWTPs with additional data from Lewis et al (2008) and BMT WBM (2009).

Note: Percentage is the proportional average annual contribution to the end of catchment load from point sources.

[1] Cleveland Bay was initially calculated by adding the discharge loads for the Ross River, Stuart and Sandfly Creeks (estimate) and Alligator Creek and expressing the point source input as a proportion of the aggregated loads i.e. point source load divided by the combined waterway loads plus the point source load, to give a Cleveland Bay receiving waters load contribution rather than an end of catchment load. Cleveland Bay load contribution was based on average 2004 to 2006 discharge figures and nutrient concentrations i.e. prior to the upgrade.

[2] Cleveland Bay discharge was recalculated as an end of catchment load for Sandfly Creek (in the Stuart Creek sub basin) using the Stuart Creek sub basin discharge figures provided from catchment modelling results (BMT WBM 2009) (see Table 5.10 and Table 5.11 also). These are post-upgrade figures.

The wastewater treatment plants servicing Townsville are being progressively upgraded to provide capacity for the expected population growth up to 2025 (Maunsell Australia 2008). These upgrades will result in significant reductions in the nutrient concentration and loads (at current population levels) being discharged to receiving waters. Upgrade of the Cleveland Bay plant has been completed and this is reflected in the nutrient load reduction (t/yr) pre and post upgrade, as illustrated in Table 3.3 for total nitrogen (TN) and total phosphorus (TP).

However, with the expected population increases the amount of wastewater requiring treatment also increases. Regardless of the improved efficiency of treatment plants and nutrient concentration reductions population increase will inevitably result in increased nutrient loads as additional volumes of wastewater are treated and subsequently released from the WWTPs. Alternative measures to the release of treated wastewater to receiving waters need to be put in place if this significant source of increasing nutrient load is to be adequately addressed in the longer term. The obvious solution is the reuse of treated wastewater for industrial purposes or some form of land based distribution e.g. irrigation.

There are no other significant industrial (point source) activities that have been identified as adversely impacting water quality in the Black Ross (Townsville) WQIP area (see Gunn and Barker 2009).

3.7 URBAN DIFFUSE

Diffuse source pollutants are those that cannot be identified as discharge from a particular point e.g. pipe or chimneystack. In terms of water quality, air quality pollutants emanating from a chimneystack, or similar, are considered to be diffuse source pollutants as they are dispersed through the atmosphere and may eventually settle on land and water surfaces.

Principal pollutants of urban areas are; sediments, nutrients (principally nitrogen and phosphorus), oxygen demanding materials (biodegradable organic material), metals, toxic organic wastes (garden and household chemicals), pathogenic micro-organisms (bacteria, viruses etc), hydrocarbons and litter.

Some pollutants can be carried relatively long distances by wind and rain before being deposited (distributed sources) while others have local origins. Some of the more significant local sources of pollutants in developed areas are associated with motor vehicles and roadways. The main urban diffuse pollutants are listed in Table 3.4.

Table 3.4 Urban Diffuse Water Quality Pollutants

Local sources	Water quality issue
Leaf litter, grass clippings and other vegetation	BOD, N, P
Dog and other domesticated animal faeces	P, N, BOD, biological pathogens
Pesticides, herbicides and fertilisers	Pesticide, N, P
Sewer overflows	N, P, biological pathogens
Sewer outlets illegally connected to stormwater systems	N, P, biological pathogens
Septic tank leakage	N, P, biological pathogens
Leakage and spillage of materials from vehicles, storage tanks and bins	Hydrocarbons, chemicals, litter
Seepage from land fill waste disposal sites	Metals, biological pathogens
Waste water from cleaning operations	Hydrocarbons, chemicals, P
Corrosion of roofing and other metallic materials	Metals
Industrial emissions	PM, NO_2, SO_2, NH_4
Vehicle emissions	PM, NO_2,
Vehicle component wear including tyres and brakes	PM, metals
Wear of road surfaces	PM, metals, hydrocarbons
Erosion from construction activity and vegetation removal	SS, P, N
Litter – plastic, glass and metal containers, plastic, foam etc	Gross pollutants
Ash and smoke from fires	PM, nutrients, VOC, metals
Windblown pollen, insects and micro-organisms	PM, N, P, VOC

Notes: BOD is biochemical oxygen demand, N is nitrogen, P is phosphorus, PM is particulate matter, SS is suspended solids, NO2 is nitrogen dioxide, VOC is volatile organic compounds, SO2 is sulphur dioxide, NH4 is ammonia.

It should be noted that the majority of the pollutants listed are associated with developed urban areas. The main local source of pollutants from developing areas is listed as "Erosion from construction activity and vegetation removal". Additional information on the main groupings of urban pollutants is provided in the sections below.

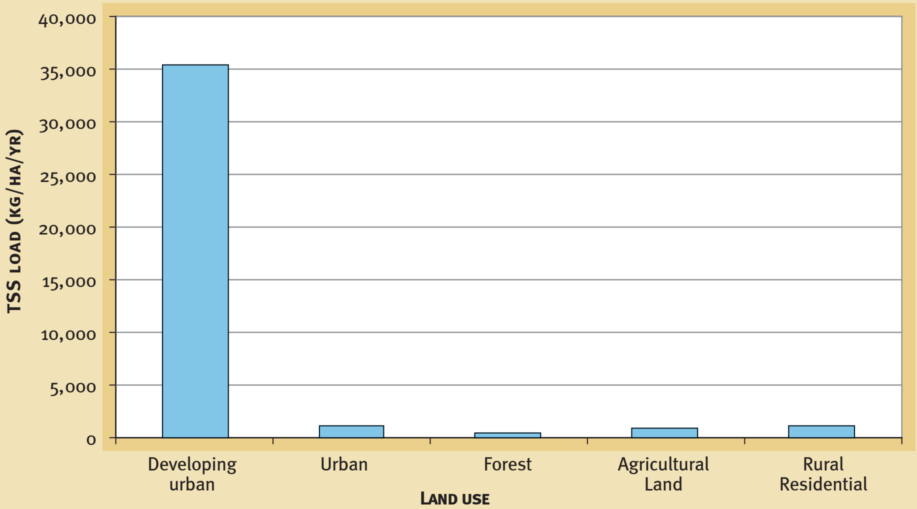
3.7.1 SEDIMENT

The amount of sediment (total suspended solids) generated annually from developed urban areas is higher than for natural areas, on an areal basis (i.e. kilograms per hectare), and similar to agricultural land use sediment generation rates, according to modelled results.

Sediment generation from developing areas however, is at the high end of the spectrum. This is graphically illustrated in modelled results, showing that the sediment generation rate from developing areas as a result of soil erosion is significantly higher per hectare than for any other land use. If we assume that a soil erosion rate of 1mm per hectare is roughly equivalent to 10 tonnes of sediment generation per hectare then this equates to an erosion rate of 3.5mm per hectare per year for developing areas compared to less than 0.1mm per hectare per year for 'mature' land uses.

Sediment concentrations measured in waterways of catchments associated with particular land uses are shown in Figure 3.6. These results confirm the observed high erosion rates and sediment movement associated with developing areas and, to a lesser degree, grazing lands.

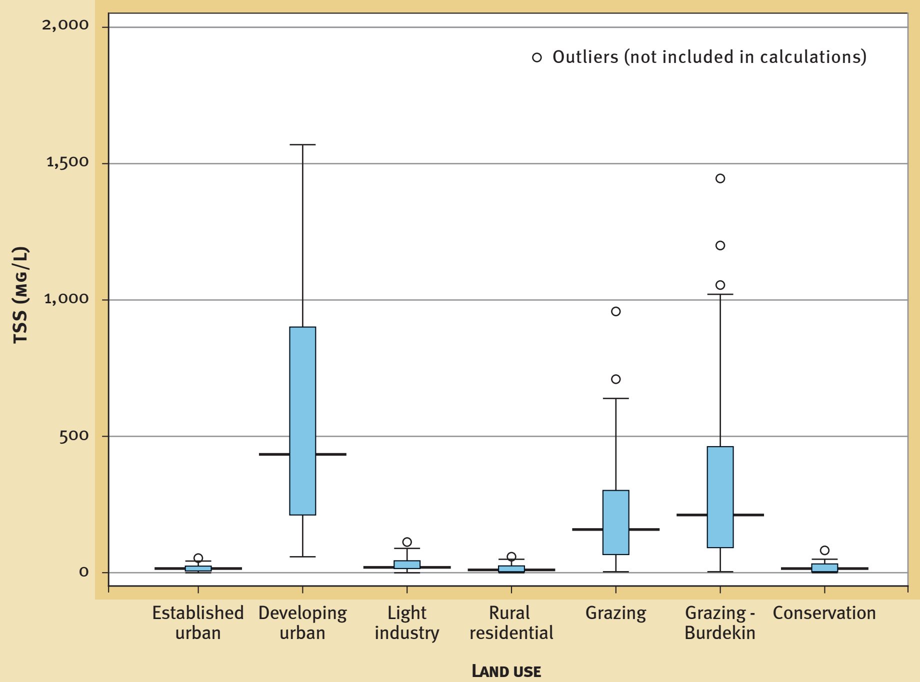
Figure 3.5 Relative Annual Areal Sediment Generation Rate by Land Use



Source: BMT WBM erosion and sediment control scenarios calculations (2009)

SECTION 3

FIGURE 3.6 SEDIMENT CONCENTRATIONS ASSOCIATED WITH LAND USE

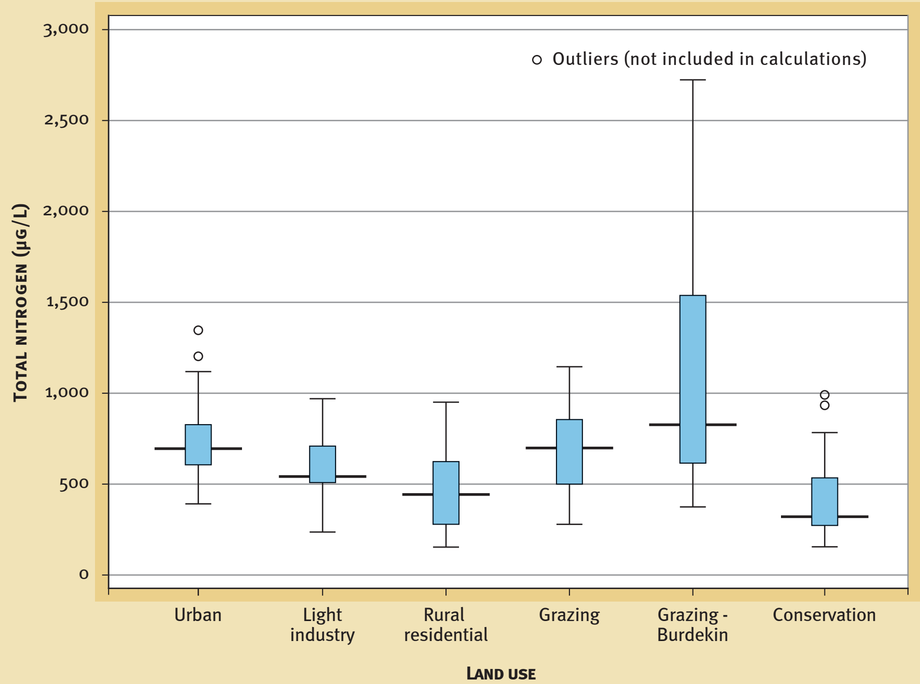


Source: ACTFR event water quality monitoring Black Ross WQIP area and Burdekin region (Grazing-Burdekin).

3.7.2 NUTRIENTS

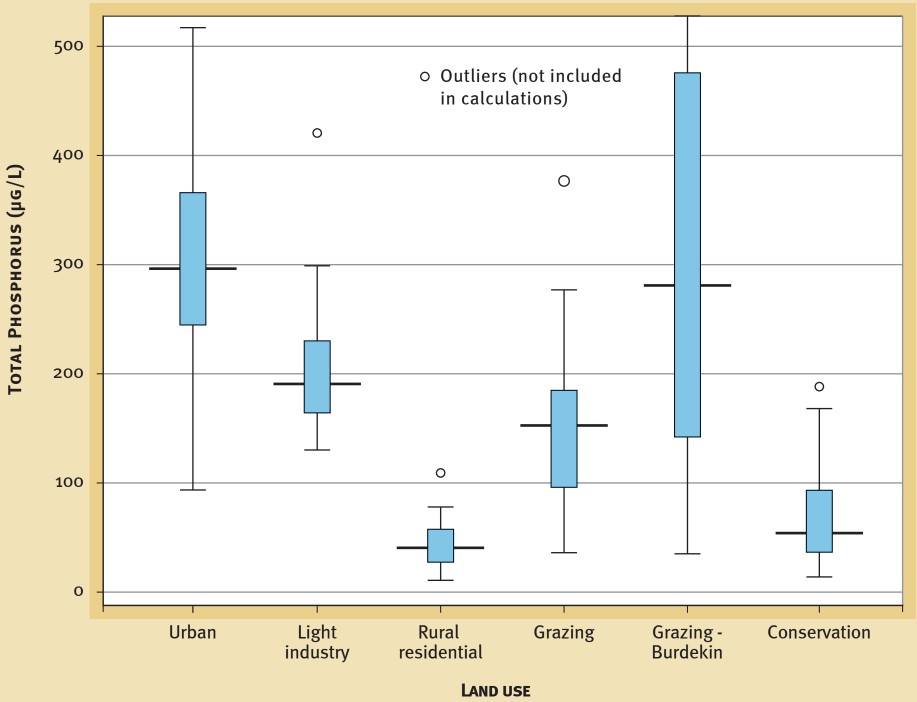
Measured nutrient concentrations in receiving waters with stormwater runoff from developed urban areas are generally less than concentrations in receiving waters with runoff from areas of intensive agriculture, and are significantly greater than from forested catchments (phosphorus is two to ten times greater) and undeveloped catchments (nitrogen is two to five times greater). Nutrient concentrations measured in waterways of catchments with particular land uses are shown in Figure 3.7 for nitrogen and Figure 3.8 for phosphorus.

FIGURE 3.7 RELATIVE NITROGEN CONCENTRATION BY LAND USE (μG/L)



Source: ACTFR event water quality monitoring Black Ross WQIP area and Burdekin region (Grazing-Burdekin).

Figure 3.8 Relative Phosphorus Concentration by Land Use (μg/L)



Source: ACTFR event water quality monitoring Black Ross WQIP area and Burdekin region (Grazing-Burdekin).

Nutrient concentrations generated from developing areas can be as high as those from intensive agriculture and grazing, due in part to activities associated with development such as vegetation removal and soil disturbance. This disturbance can lead to higher erosion rates and the mobilisation of near-surface nutrient stores in the soil, with potential for transport of the nutrients to waterways in both particulate and soluble forms.

3.7.3 METALS

Heavy metals are often found to be more prevalent in runoff from urban areas than in rural streams, as a result of higher densities of source emissions such as motor vehicle wear of tyres and brakes, vehicle emissions, road and pavement degradation, water pipes, roof corrosion and industrial activity e.g. spillages and dust from material handling of metal ores. Metals (cadmium, chromium, copper, nickel, lead, zinc) and their compounds are therefore a potential pollutant issue in the Black Ross (Townsville) WQIP area. Excessive levels of metals can be toxic to aquatic organisms and can bioaccumulate and be passed along the food chain. Metals are known to accumulate in sediments and can be remobilised and return to the water column under certain conditions.

A limited study of the Lower Ross River Sub Basin (see Butler 2008) investigated metal concentrations in benthic sediments and found that metal concentrations are not an issue in the Ross River and Stuart Creek catchments. The report recommended that a similar study is undertaken for the Bohle River catchment and it was noted that there is pre-existing evidence showing metal contamination issues associated with Ross Creek and the Townsville Harbour area.

3.7.4 HYDROCARBONS (FOSSIL FUELS, OIL AND GREASE)

Hydrocarbons are generally liquid fuels and oils e.g. diesel and petroleum, however there is a wide range of hydrocarbons in everyday use e.g. cleaning fluids. Many are highly volatile and readily evaporate when exposed to air. Hydrocarbons with higher oil content are more likely to persist in the environment. Hydrocarbon derivatives stem from oil and grease used in lubricants, protective coatings, combustible fuels and detergents.

Spills of such oils can exceed recommended levels and result in short term toxicity. Further, surfactants found in detergents can impact on aquatic flora and fauna by damaging biological membranes. Excessive hydrocarbons can result in smothering of aquatic habitats. They can also increase morbidity and mortality in freshwater species, and have impacts upon reproductive cycles.

3.7.5 OTHER CHEMICALS

Detergents, acids and other chemicals used in the urban environment can contribute to water quality issues especially when they are used on impervious surfaces and are washed directly into urban stormwater systems. While most chemicals do not enter waterways in large enough quantities to have an impact, chemicals that add to the load of other pollutants are a water quality issue e.g. phosphates in detergents.

Top: The main types of gross pollutants often come from our gardens and lawns.

Bottom: Litter needs a home as well. Better home in the bin than in our waterways.

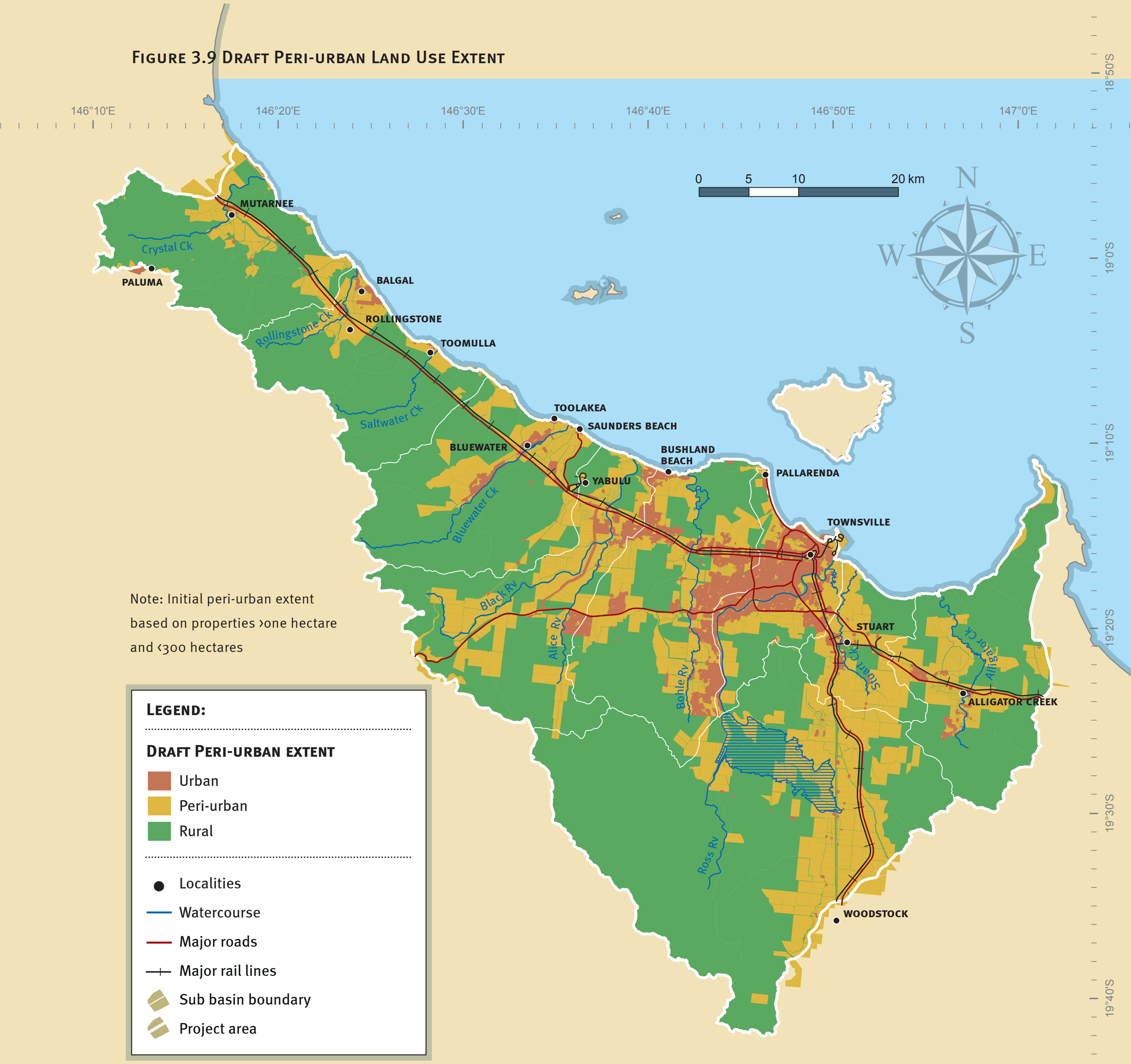
3.7.6 GROSS POLLUTANTS

Gross pollutants include plastics and other packaging, garden waste (lawn clippings, leaves and other plant material) and coarse sediment. While the litter component of gross pollutants is an aesthetic water quality detractor, there can also be deleterious impacts on aquatic animals from plastic litter in waterways through ingestion and entanglement. Organic material i.e. leaves, twigs and grass clippings, constitute the largest proportion of gross pollutant load (by mass) carried by urban stormwater. Organic gross pollutants can lead to oxygen depletion during decomposition as a result of biochemical oxygen demand (BOD), and also release nutrients, albeit relatively slowly. Oxygen depletion can result in fish kill events. If unmanaged gross pollutants also have the potential to obstruct stormwater systems and may contribute to localised flooding.

3.8 PERI-URBAN DIFFUSE

While the peri-urban land use area has not been extensively investigated, it is recognised as an important landscape component being the transition zone between rural and urban areas. Peri-urban areas are typified by ‘small’ rural blocks; industry located away from mainstream urban areas e.g. quarries, and outlier or ‘village’ communities. Peri-urban areas are generally not serviced with reticulated water and wastewater systems. The concentration of septic systems in peri-urban areas creates a potential water quality issue especially with regard to seepage to groundwater and possibly to the baseflow of waterways.

Figure 3.9 Draft Peri-urban Land Use Extent



Note: Initial peri-urban extent based on properties >one hectare and <300 hectares

The peri-urban land use area is where the majority of development takes place and as such is a principal source of 'intensive' short term diffuse pollutants, the range of rural pollutants and some specific peri-urban pollutant concentrations e.g. septic.

Given the larger number of properties and land managers per unit area compared to rural areas, it is likely that the pollutant output from peri-urban areas is greater than that for rural areas on a per unit area basis. Further work is required to determine the relationship between peri-urban areas and pollutant outputs. A preliminary map of peri-urban areas is provided in Figure 3.9.

3.9 RURAL DIFFUSE

Rural land uses are generally grouped into minimal use/conservation, grazing and intensive agriculture. Intensive agriculture is often subdivided by crop type and irrigated crops versus non-irrigated (dryland) crops. The different management activities associated with these different land uses result in different types and/or quantities of water quality pollutants.

Typical diffuse source pollutants in rural areas include sediment, nutrients (nitrogen and phosphorus) and pesticides, which are eroded and/or collected from land surfaces, typically in rainfall runoff, and carried to receiving waters e.g. streams, lakes, reservoirs and wetlands. This overland flow, also known as sheet or hillslope erosion, combines with gully erosion and streambank erosion to provide the majority of the total end of catchment pollutant loads. Atmospheric deposition and small quantities of wind-transported pollutants make up the remainder of diffuse source pollutants in rural areas.

Movement of sediment and nutrients in rainfall runoff is a normal component of natural weathering and erosion processes. Additional inputs of bioavailable/soluble nutrients combined with land disturbance and inappropriate management practices often results in accelerated run off and erosion rates and the subsequent transport of sediment and nutrients to receiving waters, well above normal background levels. It is the delivery of sediment and nutrients to receiving waters at elevated levels (and for nutrients in forms that are bioavailable) that create threats to aquatic habitats and biodiversity and, in some cases, human health.

Sediment and nutrient pollutants, their sources and environmental threat rating, as identified for the Burdekin WQIP, are listed in Table 3.5.

Table 3.5 Main Rural Pollutants

Pollutant	Source	Rating	Notes
Nutrients			
Nitrate (NO_3)	Fertiliser	5	Low natural levels
Ammonia (NH_4)	Fertiliser	2	Low natural levels
DON	Fertiliser	2	Moderate natural levels, slow turnover
PN	Fertiliser and erosion	4	Moderate natural levels, loss to sediments
Phosphate (PO_4)	Fertiliser, salt licks	2	Low natural levels
DOP	Fertiliser	1	Moderate natural levels, slow turnover
PP	Fertiliser and erosion	3	Moderate natural levels, loss to sediments
Silicate ($Si(OH)_4$)	Erosion	0	
Sewage	STP discharge, septics	5	Contains all N, P forms at high levels
Suspended sediment			
Coarse (>63 µm)	Erosion	0	No likely impact, forms delta fans
Medium (2-63 µm)	Erosion	2	Carried only short distance
Fine (< 2µm)	Erosion	4	Carried widely over shelf, especially after dry year

Source: Mitchell et al 2007 (p.7)

Note: Suspended sediment varies between sub-catchments and is greatly increased by grazing. Urban specific sources, other than STPs, have not been included as there are a variety of chemicals that may contribute to N and P levels but there is little water quality monitoring evidence available for Townsville to be specific.

Rating is potential threat posed by the pollutant where 5 is greatest threat and 0 is no threat.

Unlike sediment and nutrients, pesticides are a water quality pollutant not measured against natural background levels, as there are no 'natural' background levels. Inappropriate management practices, increased stormwater run off and accelerated erosion rates also affect the amount of pesticides reaching receiving waters. Pesticides that enter waterways become a water quality threat with a range of impacts depending on the pesticide type and concentration.

In addition to sediment and nutrients a range of pollutant groupings relevant to rural areas were identified by Mitchell et al (2007) and are listed in Table 3.6. The 'rural' pollutants are also applicable to the Black Ross (Townsville) WQIP given that rural land uses occupy the majority of the Black Ross (Townsville) WQIP area. Some of the pollutants are also generated from urban and peri-urban areas.

SECTION 3

Table 3.6 Other Rural Pollutants

Pollutant group	Specific pollutant and comments
Herbicides	Diuron, Atrazine, Ametryn, Hexazinone and 2,4-D are principally used in the sugar industry. Simazine used in forestry. Tebuthiuron used in grazing industry. Glyphosate and Paraquat used broadly in sugar cane and horticulture.
Insecticides	Organochlorines e.g. Endosulfan, and a variety of others are used principally in horticulture and, to a lesser extent, sugar cane. Chlorpyrifos used in sugar cane for cane grubs.
Non insecticide organochlorines	PCB's from industry (reduced use but residues may persist) and Dioxins from agriculture and industry. PAH's (polycyclic aromatic hydrocarbons) from cane firing, forest fires and oil spills.
DO reducing materials (organic material)	Manure principally from cattle grazing. Sewage from urban areas. Plant litter occurs naturally and is increased as by products of intensive agriculture.
Heavy metals	Cadmium and potassium from fertiliser and mercury from fungicide. Other trace elements.
Oil or hydrocarbons	Primarily from liquid fossil fuels and oil spills.
Salinity	Both dryland and irrigation salinity resulting from land clearing (dryland) and irrigation activities.
Antifoulants	Used primarily in the fishing industry at mooring sites (TBT is now banned).
Acid	Principally associated with disturbance of acid sulphate soils.

Source: Mitchell et al 2007, pp.7-8

3.10 ATMOSPHERIC DEPOSITION

The principal pollutants by volume associated with atmospheric deposition are particulate matter and oxides of nitrogen. Background deposition levels of both these pollutants are not known specifically for the Townsville area and current air quality monitoring is principally associated with airborne concentrations as a function of human health.

The total contribution of pollutants from atmospheric deposition is a combination of natural background levels and any additional contributions from human sources.

The main source of nitrogen dioxide (NO_2) is a by-product of the combustion of fossil fuels from industrial facilities and motor vehicles, adding to the natural background levels of atmospheric nitrogen. The elevated atmospheric deposition rates attributable to human sources have been applied to the Townsville urban footprint i.e. Lower Ross River, Bohle River and Stuart Creek sub basins (see Table 3.7 and Table 3.8).

There are two components to atmospheric deposition i.e. direct deposition to water and deposition to land. Atmospheric deposition to land becomes a potential component of runoff from land while atmospheric deposition to water is a direct pollutant contribution. Only deposition to water has been calculated, as deposition to land is confused by land based runoff signals and cannot be readily calculated.

Deposition to water has been calculated by determining the area of water in each catchment and multiplying this by the deposition rate to give a load that can be used to determine the overall contribution relative to the end of catchment loads.

Atmospheric deposition contributions for the main GBR water quality pollutants (particulate matter, nitrogen and phosphorus) were calculated using end of catchment (EOC) load estimates from WaterCAST modelling. The results by sub basin are displayed in Table 3.7 with the atmospheric deposition rates applied to the sub basins listed in Table 3.8. Noticeably elevated TN and TP contributions from atmospheric deposition in some sub basins is explained by the higher deposition rates adopted for the urban catchments and the ratio of water to land for the particular sub basin.

Table 3.7 Atmospheric Deposition Contributions Using Modelled EOC Loads

Sub basin	Area (ha)	Water (ha)	PM_{10} (kg)	%	TN (kg)	%	TP (kg)	%
Crystal Creek	22,629	268 [1]	2,144	0.04	536	0.59	54	0.58
Rollingstone Creek	21,822	110 [0.5]	880	0.05	220	0.54	22	0.55
Bluewater Creek	28,872	426 [1.5]	3,408	0.12	852	0.92	85	1.83
Black River	29,539	513 [1.7]	4,104	0.06	1,026	1.48	103	1.03
Bohle River	33,194	532 [1.7]	7,980	0.09	2,128	2.72	213	1.51
Lower Ross River	13,244	754 [5.6]	11,310	0.27	3,016	9.11	302	4.33
Upper Ross River	74,929	4,372 [5.8]	34,976	0.43	8,744	8.71	874	6.84
Stuart Creek	11,024	1,047 [10]	15,705	0.95	4,188	22.09	419	14.16
Alligator Creek	27,490	1,798 [6.8]	14,384	0.68	3,596	8.42	360	7.48
Totals	**267,558**	**9,820 [3.7]**	**94,891**	**0.22**	**24,306**	**4.25**	**2,432**	**3.44**

Notes: The Water primary land use category was used to determine the area for calculating atmospheric deposition contributions to water. The Water primary land use category includes the secondary land use categories; Marsh/wetland, River, Channel/aqueduct and Reservoir/dam.

PM_{10} refers to particulate matter that is ≤ 10 µm. TN is total nitrogen and TP is total phosphorus.

In the Water column the figures in square brackets indicate the percentage of the sub basin comprised of the Water land use category. % is percentage contribution of atmospheric deposition in terms of total end of catchment loads. End of river (catchment) load figures to calculate percentage contributions were sourced from the modelling prepared by BMT WBM.

Magnetic Island is not included due to the absence of "Water" area land use.

The urban footprint consists of Lower Ross River, Bohle River and Stuart Creek sub basins.

Table 3.8 Atmospheric Deposition Rates Applied

Area	PM_{10}	Nitrogen	Phosphorus
Urban footprint	15 kg/ha/year	4kg/ha/yr	0.4 kg/ha/year
All other WQIP areas	8 kg/ha/year	2kg/ha/yr	0.2 kg/ha/year

Note: The urban footprint consists of Lower Ross River, Bohle River and Stuart Creek sub basins.

From the information assessed in the report titled *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009), atmospheric deposition of sediment, phosphorus, heavy metals, pesticides and sulphur dioxide does not contribute measurably to water quality issues. An estimate of average atmospheric deposition of particulate matter (PM_{10}) from all sources for the Townsville urban footprint (250 square kilometres) is 15 kg/ha/year, which is equivalent to a depth of 0.0015 millimetres per year. The low contribution of sediment from atmospheric deposition is confirmed in Table 3.7.

3.11 CLIMATE CHANGE

Creek to Coral commissioned local sustainability consultant SEAO2 to compile a report on the potential impacts of climate change on water quality in Townsville (available at www.creektocoral.org). Townsville is part of the Dry Tropics Region and has a significantly different climatic regime from neighbouring regions i.e. Wet Tropics (north) and Central Queensland Coast (south), and other parts of Australia. In order to obtain locally relevant results Creek to Coral commissioned CSIRO to run a climate model specific to Townsville (*Climate Change Projections for the Townsville Region*) (available at www.creektocoral.org).

Top: Cyclones are a feature of the tropics.

Bottom: Flooded roads from rain and storm surges are not uncommon around Townsville during the wet season.

The CSIRO climate change projections are presented as 10^{th}, 50^{th} and 90^{th} percentile units, reflecting the uncertainty inherent in global climate modelling. While the 10^{th} and 90^{th} percentiles give an indication of the range of uncertainty contained in the projections, the 50^{th} percentile, or central estimate, can be taken as the most likely scenario based on current knowledge. The climate change projections for Townsville in the years 2030 and 2070 were developed by CSIRO for the following features:

- Mean temperature;
- Number of days over 35° C;
- Precipitation;
- Potential evapo-transpiration;
- Wind speed;
- Relative humidity;
- Fire risk;
- Solar radiation;
- Sea surface temperature and sea level rise.

The SEAO2 report considers how climate change scenarios are developed then reviews the results of the climate change model run by the CSIRO specifically for the Townsville region. Using these results, a qualitative assessment of the potential impacts on local water quality was made.

As with the overall impacts of global warming on climate change, the exact impacts of climate change on water quality are uncertain. It has been possible to identify a range of factors associated with climate change, which could impact water quality. Quantifying the water quality impacts with any level of certainty will, however, require further research and/or modelling.

Potential impacts on water quality as a result of climate change are primarily indirect and are associated with changes to the physical condition and structure of vegetation and vegetation communities, with potential corresponding changes in soil erosion rates.

The most significant potential direct impact on water quality associated with climate change may result from any increase in the severity and/or intensity of rainfall events. This change has the potential to:

- Increase sheet and gully erosion and subsequent pollutant loads entering receiving waters; and
- Increase instream bank and channel erosion and subsequent discharge loads to marine receiving water.

Beach access can be compromised by wild weather and coastal erosion.

An associated impact of an increase in intensity of rainfall events could be an increase in the quantity of freshwater discharge to marine waters leading to coral bleaching. If this is associated with an increase in sediment and nutrient loads entering the GBR lagoon then the ecological health impacts on marine waters and near shore reefs could be significant. A reduction in pollutant loads entering marine waters is required to ensure the resilience of the GBR is maintained.

Other direct impacts of climate change on waters could include an increase in the temperature of water bodies due to increases in average temperatures and extreme daily temperatures i.e. number of days with temperatures over 35 degrees Celsius, and sea level rise altering fresh water coastal wetlands to brackish or salt water. These impacts are not direct water quality impacts, at least in terms of our definition based on pollutant increases, however they will impact aquatic ecosystems due to the physical changes associated with temperature and salinity variations.

What we can conclude from the short-term projections about climate change in Townsville is that there is unlikely to be any significant direct or indirect impacts on water quality during the initial term of the Black Ross (Townsville) WQIP i.e. 2009-2014.

This conclusion is based on the fact that there will only be minor climatic variations, which will not have significant broadscale impacts on the distribution or structure of vegetation through direct association i.e. reduced rainfall and increased temperatures, or through indirect means e.g. increased fire weather. Therefore the main factor impacting water quality, erosion and sedimentation, is unlikely to be impacted in the short-term.

In the marine environment rising sea temperature has already highlighted climate change impacts.

In the longer term (2050-2100) the impacts of global warming and climate change on water quality are uncertain (especially for freshwater) and further investigation is required to provide a better understanding of the potential implications of climate change. Regardless of the lack of certainty with regard to future climate change impacts on water quality, local and regional planning should take a precautionary approach and allow for a worst case scenario. If this risk management approach is taken then the costs of adaptation should be minimal in comparison to the potential remediation costs.

3.12 IMPACTS ON RECEIVING WATERS' ECOSYSTEM HEALTH

While we generally measure the concentrations and loads of physico-chemical pollutants entering receiving waters it is the subsequent ecosystem health impacts of these pollutants that are the real concern. Both nitrogen and phosphorus are essential nutrients often found in limiting quantities in natural ecosystems. The introduction of additional nutrient loads can rapidly alter natural water bodies, influence primary production and biomass concentration and impact ecosystem health in fresh, estuarine and marine receiving waters. As mentioned above an increase in freshwater discharge can also impact the near shore marine environment and habitats.

The main ecosystem health impacts in freshwater include:

- Algal blooms from excessive nutrients;
- Alteration of habitat due to sedimentation;
- Eutrophication and reduced oxygen levels associated with excess nutrients and primary production and organic gross pollutants (may result in fish kills).

The aim of pollutant load reductions for estuarine and marine receiving waters is to reduce ecosystem health impacts and increase the resilience of the Great Barrier Reef to climate change impacts. Elevated sediment and nutrient concentrations have a range of impacts on marine ecosystems and most notably on coral communities and sea grass beds. In extreme situations elevated nutrient concentrations can result in the collapse of coral reef communities.

Research results have shown that coral reefs adjacent to heavily impacted catchments have lower coral biodiversity, lower rates of coral recruitment and different coral community structure compared with reefs in relatively pristine areas (GBRMPA 2006).

Some of the ways in which elevated nutrients affect corals are:

- Increased phytoplankton growth, which in turn supports increased numbers of filter feeding organisms such as tubeworms, sponges and bivalves, which compete with coral for space;
- Macro algae blooms that may overgrow coral structures, outcompeting the coral polyps for space and shading the coral polyps;
- Inhibition of fertilisation rates and embryo formation in some corals;
- Excessive phosphorus concentrations can also result in coral colonies with less dense, and hence weakened skeletons, which make colonies more susceptible to damage from storm action.

Prolonged exposure to levels of terrestrial sediment and organic matter in excess of normal conditions can kill affected coral reefs through:

- Smothering and burial when particles settle out (sedimentation);
- Reducing light availability (turbidity) and potentially reducing coral photosynthesis, growth and reproduction; and
- Altering the ecology and nutrient dynamics of a reef.

Elevated sediment and nutrient concentrations can also negatively affect seagrass beds by lowering ambient light levels and reducing the photosynthetic capability of affected seagrass. Three major factors cause a reduction in light availability:

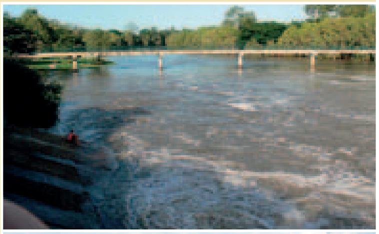
- A proliferation of light adsorbing algae from increases in dissolved nutrients;
- Increased water column turbidity from suspended sediments; and
- Pulsed increases in suspended sediments and/or phytoplankton blooms that cause a dramatic reduction of water column light penetration for a limited time.

Just as the flow on effects of sediment and nutrient discharge from terrestrial sources impacts marine water ecosystem health it is the products that impact ecosystem health that are monitored in the marine environment rather than the sediment and nutrient concentrations. The two main ecosystem health indicators for marine waters are chlorophyll a and turbidity. Monitoring of coral reefs and seagrass beds over time provides the direct data about ecosystem health. Monitoring chlorophyll a and turbidity provides an indication of when ecosystem health issues are likely to occur and is less time consuming and expensive than direct observation.

What we know about the receiving waters of the Black Ross (Townsville) WQIP area at present is:

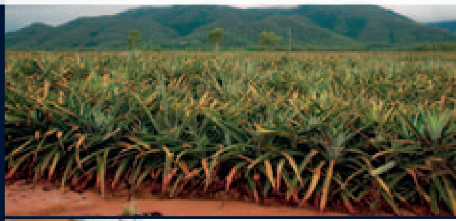
- Generally chlorophyll a, turbidity and secchi depth maximums exceed the guidelines during flood events;
- Generally mean chlorophyll a exceeds guideline values 46% of the time and phytoplankton biomass is a concern over the year;
- Geoffrey Bay reef had the highest mean turbidity in the Burdekin region of ~3 NTU (5 NTU is the suggested limit for coral stress);
- Middle Reef has experienced coral bleaching (thermal and freshwater) and coral disease in recent years 2008/2009 (Source: Schaffelke et al 2008).

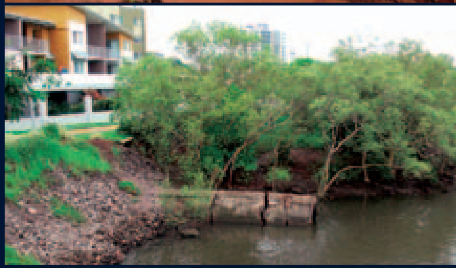
What needs to be determined is the amount of sediment and nutrient that can be discharged from the catchments of the Black Ross (Townsville) WQIP area to marine waters without adversely impacting the ecosystem health of the marine receiving waters. Further work is required to make the linkage between end of catchment loads and marine receiving waters ecosystem health.



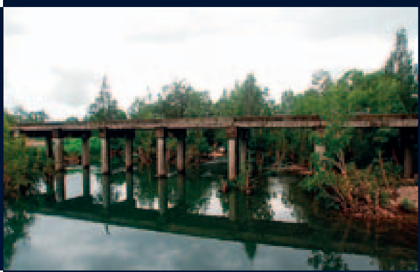
Top: Ross River in flow after summer rain results in an overflow at Ross River Dam.

Bottom: Ross Creek is now a tidal 'creek' rather than a mouth of the Ross River.





The Townsville WQIP area is a mixture of natural areas, agriculture and urban landscapes. Land use and management practices influence catchment condition and the environmental values of waterways.



Catchment Condition and Environmental Values

4

4. CATCHMENT CONDITION AND ENVIRONMENTAL VALUES

4.1 STATE OF THE BLACK RIVER AND ROSS RIVER BASINS

Two primary studies have been undertaken to determine the current condition of the Black River and Ross River Basins. Results of the studies have been incorporated in the WQIP supporting documents, and subsequently in this WQIP.

4.1.1 CONDITION OF RECEIVING WATERS

The first of the studies was undertaken by Connell Wagner to collate available water quality data for the study area. The water quality data was then analysed to provide an indication of the condition of the waterways of the Black Ross (Townsville) WQIP area (see *Water Quality Condition of the Black and Ross River Basins* (Connell Wagner 2008)). A summary of waterway condition by catchment, and a discussion on the condition of marine waters is provided in *Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area* report (Gunn and Manning 2009).

4.1.2 RIPARIAN CONDITION

C and R Consulting prepared the riparian condition report to provide an overview of the 'current' state of the vegetation in the riparian zones of the main waterways in the Black and Ross River Basins.

4.1.3 CATCHMENT CONDITION

Results of the riparian condition assessment; water quality condition report and pollutant load modelling were combined with land use information for the Black Ross (Townsville) WQIP to give an indication of current catchment condition. When this information is cross-referenced with the environmental values results the priority catchments for water quality improvement activities become apparent (see Gunn and Manning 2010).

4.2 DETERMINING ENVIRONMENTAL VALUES

The *National Water Quality Management Strategy* (NWQMS) provides a framework for protecting and enhancing the quality of the nation's waters. The framework (see simplified diagram in Figure 4.1) includes the determination of environmental values of waterways and waterbodies as a starting point to establish the level of protection required.

A detailed description of the process used to determine environmental values for the Black Ross (Townsville) WQIP area is provided in *Environmental Values, Water Quality Objectives and Targets for the Black Ross Water Quality Improvement Plan* (Gunn, Manning and McHarg 2009).

Environmental values (EVs) are those qualities of the waterway that make it suitable to support particular aquatic ecosystems and human uses, also known as beneficial uses. Human use EVs are divided into a variety of categories reflecting the types of human use

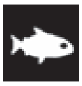
Figure 4.1 Environmental Values in the NWQMS Framework

SECTION 4

while aquatic ecosystem EVs are divided into condition classes reflecting the degree of modification from natural conditions. Definitions of the various environmental values as per the NWQMS are provided in Table 4.1.

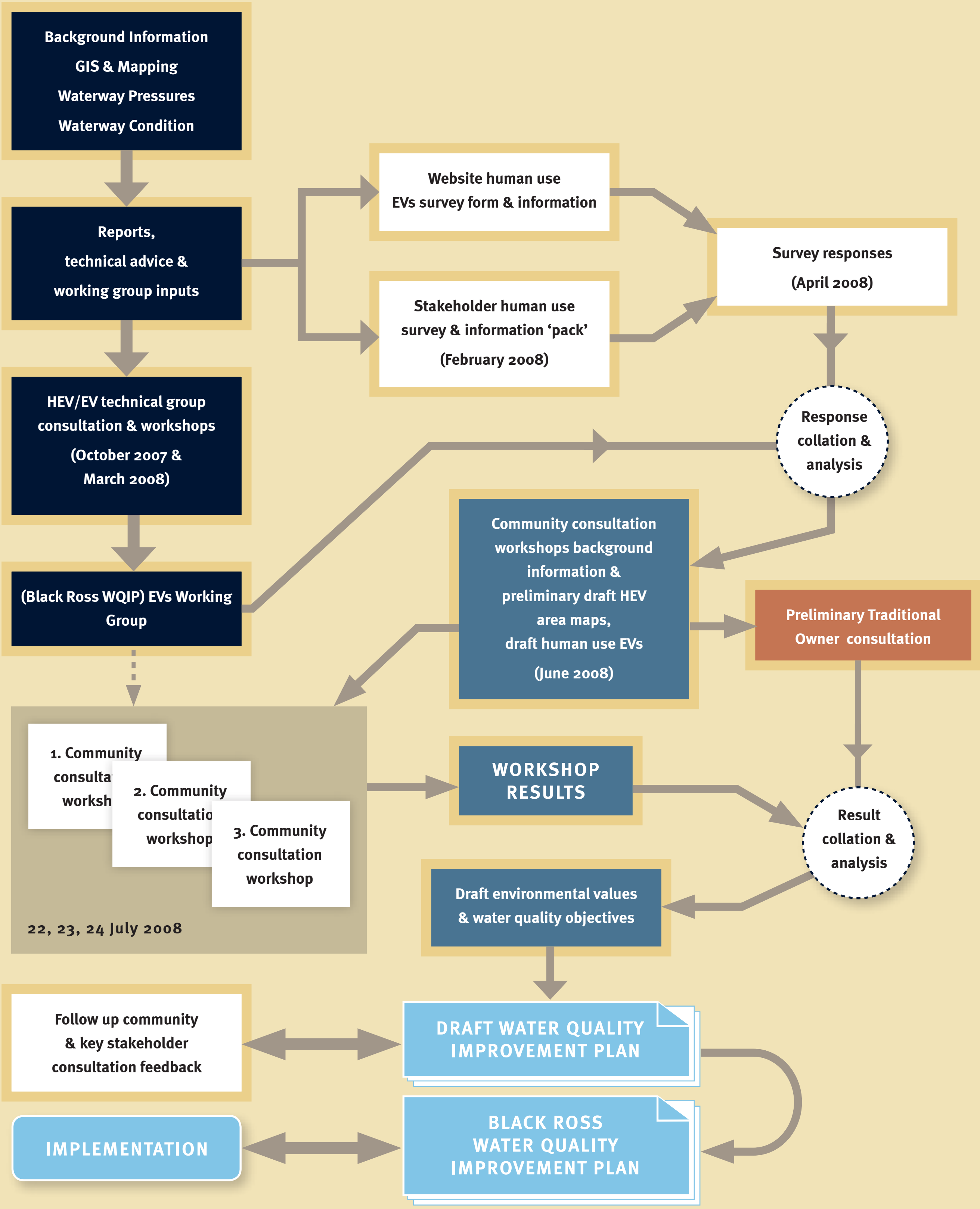
Note: The Black Ross WQIP was prepared with reference to the *Environmental Protection (Water) Policy 1997*. Modifications to the policy and the QWQG in 2009 have divided aquatic ecosystem EVs into four categories. The SMD category has been separated into "Slightly disturbed" and "Moderately disturbed".

Table 4.1 Environmental Values Definitions

EV symbol	Symbol	Interpretation
	Aquatic ecosystems	There are three EV levels (for levels of protection): ▪ High conservation/ecological value systems (HCV or HEV). They are often found within national parks, conservation reserves or inaccessible locations. ▪ Slightly to moderately disturbed systems (SMD). These systems have undergone some changes but are not considered so degraded as to be highly disturbed. ▪ Highly disturbed systems (HD). These are degraded systems likely to have lower levels of naturalness. These systems may still retain some ecological or conservation values that require protecting. Targets for these systems are likely to be less stringent and may be aimed at remediation and recovery or retaining a functional but highly modified ecosystem that supports other environmental values also assigned to it.
Human use (Beneficial use)		
	Irrigation	Irrigating crops such as sugar cane, lucerne, etc.
	Stock watering	Water for stock e.g. cattle, horses, and sheep.
	Farm use	Water for farm use such as in fruit packing or milking sheds, etc.
	Aquaculture	Water for aquaculture such as barramundi or red claw farming
	Human consumption	Human consumption of wild or stocked fish or crustaceans.
	Primary recreation	Primary recreation with direct contact with water such as swimming or snorkelling.
	Secondary recreation	Secondary recreation with indirect contact with water such as boating, canoeing or sailing.
	Visual appreciation	Visual appreciation with no contact with water such as picnicing, bushwalking, sightseeing.
	Drinking	Raw drinking water supplies for human consumption.
	Industrial	Water for industrial use such as power generation, manufacturing plants.
	Cultural & spiritual	Cultural and spiritual values including the cultural values of traditional owners.

The process used to determine environmental values for the Black Ross (Townsville) WQIP is summarised in Figure 4.2. See Gunn, Manning and McHarg (2009) for a full description of the community consultation process including the involvement of Creek to Coral partners.

Figure 4.2 Stakeholder Consultation Process



SECTION 4

4.3 ENVIRONMENTAL VALUES FOR THE BLACK ROSS WQIP AREA

The combined results of the environmental values determination process are provided in Table 4.2 to Table 4.6. The areas identified as containing HEV waters are displayed in Figure 4.3 and Figure 4.4. Refer to *Environmental Values, Water Quality Objectives and Targets for the Black Ross Water Quality Improvement Plan* (Gunn, Manning and McHarg 2009) for more detailed information.

FIGURE 4.3 DRAFT AQUATIC ECOSYSTEM HEV WATERS

FIGURE 4.4 MAGNETIC ISLAND DRAFT AQUATIC ECOSYSTEM HEV WATERS

Note: HEV waters, denoted by hatching in figures, include fresh, estuarine and marine water types.

Table 4.2 Environmental Values for Black Basin

Waterway	Irrigation	Farm supply	Stock watering	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Industrial use	Cultural and spiritual values	Aquatic ecosystems
Black River Basin Freshwaters												
Crystal Creek Sub Basin												
[1] Crystal Creek						L	L	M - H	H		H	HEV
[2] Crystal Creek	M	M	H		M	H	L - M	H	H		H	✔
[1] Ollera, Scrubby and Hencamp Creeks						L	L	L			H	HEV
[2] Lorna, Ollera, Scrubby and Hencamp Creeks	M	M	H		M	H	L - M	H			H	✔
Rollingstone Creek Sub Basin												
[1] Rollingstone Creek						L	L	L			H	HEV
[2] Rollingstone Creek	M	L	H		M	H	L - M	H	L		H	✔
Surveyors and Wild Boar Creeks	L					L	L	L			H	HEV
Station Creek					L	L	L	L			H	HEV
[1] Saltwater and Cassowary						L	L	L			H	HEV
[2] Saltwater Creek	M	L	H		M	H	M	M			H	HEV
[2] Cassowary Creek	M	L	H		M	H	L - M	H			H	HEV
[1] Leichhardt Creek											H	HEV
[2] Leichhardt Creek	M	L	H		M	H	M	M	L		H	✔
Bluewater Creek Sub Basin												
[1] Christmas, Sleeper Log Creek											H	HEV
[2] Christmas, Sleeper Log Creek	L	L	H		M	H	L - M	H			H	✔
Two Mile Creek					L		L				H	✔
[1] Bluewater Creek						L	L	M - H			H	HEV
[2] Bluewater Creek	M - H	M	H		M	H	H	H			H	✔
[1] Althaus Creek						L	L	M - H			H	HEV
[2] Althaus Creek			H		L	H	H	H			H	✔
[1] Deep Creek						L	L	M - H			H	✔
[2] Deep Creek	M - H	M	H		L	H	H	H			H	✔
Healy Creek					L		L	L			H	✔

SECTION 4

... CONTINUED

Waterway	Irrigation	Farm supply	Stock watering	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Industrial use	Cultural and spiritual values	Aquatic ecosystems
Continued												
Black River Sub Basin												
[1] Black River						L	L	L			H	HEV
[2] Black River	L		H		L	L			L	M	H	✔
Alick and Log Creek	L		L								H	✔
[1] Scrubby Creek (Upland)					L	L	L	L			H	✔
[2] Alice River	L		H		L	L					H	✔
Canal Creek	L								L		H	✔

Notes: [1] indicates upland waterways (above the 150 metre contour). [2] indicates lowland waterways (below the 150 metre contour). Otherwise all freshwater reaches are included.

These notes apply to all Environmental Values tables. Most of the human use values have been identified from stakeholder workshops where L = low, M = medium and H = high use/value. The level of human use (recreation and human consumption) was assigned on the basis of input from the community workshops where high use/value was assigned when it was recognised that people travelled from other parts of the region to use the resource, medium use was associated with areas being important locally with less external utilisation i.e. by visitors, and low use was infrequent or seasonal use predominantly by landowners and locals. Low use was also attributed to inaccessibility. Agricultural use was assigned on the local/catchment importance associated with land use and stream size, and in the context of the region. Some use levels were assigned on the basis of water extraction data. Industrial and drinking water use was assigned on the basis of regional importance followed by local importance. Areas designated as developed in the workshop/s have been replaced with Lowland to match water quality guideline divisions.

Additional uses identified through a prior study and not identified at the workshop have also been included; from the preliminary stakeholder survey, the human use study and from DNRW water licencing extraction data (see Human Use EVs Report for more detail). Unless otherwise indicated by the background information a low level of use was assigned to the human uses not identified at the workshops. For Cultural and Spiritual human use a default high value was assigned at workshops. Consultation with Traditional Owners will be undertaken to further define these values (see the report titled *Environmental Values, Water Quality Objectives and Targets for the Black and Ross River Basins Water Quality Improvement Plan* details of Traditional Owner consultation). [Available at www.creektocoral.org]

In some cases future uses, which are different to current uses, have also been identified. These are marked on the appropriate table/s.

Aquatic ecosystem environmental values were initially identified through a desktop review and technical panel workshops. The draft aquatic ecosystem environmental values were then reviewed at stakeholder workshops.

HEV = High ecological value. ✔ indicates aquatic ecosystem environmental values are selected for the waterway and HEV indicates areas contain HEV waters.

Table 4.3 Environmental Values for Ross Basin

Waterway	Irrigation	Farm supply	Stock watering	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Industrial use	Cultural and spiritual values	Aquatic ecosystems
Ross River Basin (Ross River Dam and upstream) Freshwaters												
Bohle River Sub Basin												
Stony, Saunders, Middle Bohle Creeks and Little Bohle River	L		L		L	L	L	M			H	✔
Bohle River (upper)	L	L	L		L	L	L	L			H	✔
Bohle River (lower)	L	L	L		M	M/H	M/H	M/H			H	✔
Louisa Creek					L		L	L			H	✔
Town Common							L - M	H			H	✔
Lower Ross River Sub Basin												
Ross River (below Dam)	M	L			H	H	H	H			H	✔
Black Weir	H				H	H	H	H	H		H	✔
Gleesons and Aplins Weir	L				H	H	H	H			H	✔
Defence land streams					L	L	L	L			H	✔
Campus Creek					L	L	L	M			H	✔
Ross Creek					H	L	L	H			H	✔
Pallarenda					H		H	H			H	✔
Upper Ross River Sub Basin												
Lake Ross (Ross Dam)	L				L	L	L	M	H	M	H	✔
Ross River, Round Mountain, Lagoon, Plum Tree, Ross, Sandy, Deep, Cattle and Leichhardt Creeks	L		M - H			L	L	L			H	✔
Six Mile, Four Mile, Flagstone and Antill Plains Creeks and Jimmys Lagoon	L	L	M					L			H	✔
Toonpan Lagoon	M	L	M					L			H	✔
One Mile, Spring and Lansdowne Creeks	H	L	M					L			H	✔

... CONTINUED

Waterway	Irrigation	Farm supply	Stock watering	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Industrial use	Cultural and spiritual values	Aquatic ecosystems
Continued												
[1] Round Mountain and Sachs Creek, Blacksoil Gully/ Mt Stuart											H	HEV
[2] Sachs Creek	M					L	L	M	L		H	✔
[2] Blacksoil Gully/ Mt Stuart						L	L	L			H	✔
Stuart Creek Sub Basin												
[1] Stuart Creek	L	L	L			L		L			H	✔
[2] Stuart Creek	L	L	L		M	L	M	L - M			H	✔
Sandfly Creek			L			L	L	M			H	✔
Alligator Creek Sub Basin												
[1] Alligator Creek	L					H	H	H	L		H	HEV
[2] Alligator Creek	L - M	M	L		L - M	L	L - M	L - M	L		H	✔
[1] Whites, Slippery Rocks and Killymoon Creeks											H	HEV
[2] Whites and Slippery Rocks Creeks	L		L		L	L	L - M	L - M			H	✔
Crocodile Creek	L		L		L	L	L - M	L - M	L		H	✔
Killymoon Creek	M		L		L	L	L - M	L - M	L		H	✔
Cape Cleveland						L	L	L			H	HEV

[1] indicates upland waterways (above the 150 metre contour). [2] indicates lowland waterways (below the 150 metre contour). Otherwise all freshwater reaches are included. Instream storages (dams, weirs and barrages) have been underlined. Where identified, future human use levels are shown next to current human use levels i.e. now/future.

Note: Notes from Table 4.2 are also relevant to this table.

Table 4.4 Environmental Values for Magnetic Island

Waterway	Irrigation	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Drinking water	Cultural and spiritual values	Aquatic ecosystems
Magnetic Island Sub Basin Freshwaters								
Retreat Creek	H	L	M	H	H	L	H	HEV
Duck Creek	L		M	H	L	L	H	HEV
Chinamans Gully		L	L	L	L		H	HEV
Ned Lee Creek			H	H	H	L	H	HEV
Butler Creek and Picnic Bay west creek		L	L	L	M		H	✔
[2] Gustav Creek		L	L	H	H		H	✔
Hoyer Creek (Nelly Bay)			L	L	H		H	✔
North Nelly Bay creek				L	H		H	HEV
[2] Petersen Creek			M - H	H	H		H	✔
[1] Gustav, Petersen, Gorge and Endeavour Creeks		L	M - H	H	H		H	HEV
[2] Gorge Creek		L	L	L	H		H	✔
[2] Endeavour Creek			M - H	H	H		H	✔
East Horseshoe Bay creek		L	L	L - M	H		H	✔
Five Beach Bay creeks			M - H	H	H		H	HEV

[1] indicates upland waterways (above the 150 metre contour). [2] indicates lowland waterways (below the 150 metre contour). Otherwise all freshwater reaches are included.

For Aquatic Ecosystems HEV values are for upland areas, defined at the community workshop as areas upstream of the break in slope between the coastal plain and the hills/ranges.

Note: Notes from Table 4.2 are also relevant to this table.

SECTION 4

Table 4.5 Environmental Values Mainland Estuaries (Black and Ross Basins)

Waterway	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Industrial use	Cultural and spiritual values	Aquatic ecosystems
Estuarine Waters								
Crystal, Lorna, and Hencamp Creeks		H	M	M - H	H		H	✔
Ollera and Scrubby Creeks		H	M	M - H	H		H	HEV
Rollingstone Creek		H	L	H	H		H	✔
Surveyors, Wild Boar and Station Creeks		H	M	M - H	H		H	HEV
Saltwater Creek	H	H	L	H	H		H	HEV
Cassowary Creek		L	L	L	L		H	HEV
Leichhardt, Christmas, Two Mile, Deep, and Healy Creeks		H	L	H	H		H	✔
Bluewater Creek		H	L	L	H		H	✔
Black River		H	L	M	L		H	✔
Bohle Sub Basin (upper)		M		M	L - M		H	✔
Bohle Sub Basin (lower)		H		H	H		H	✔
Town Common		L					H	✔
Louisa Creek		M		M	M		H	✔
Ross River Sub Basin		H		H	H	M	H	✔
Stuart Creek Sub Basin	L	H	L	H	H		H	✔
Alligator Creek Sub Basin	L	H	L	H	H		H	HEV

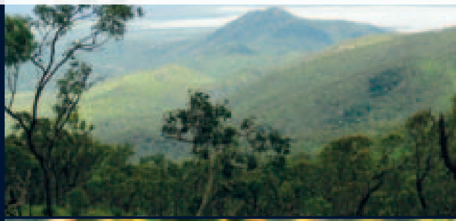
Note: Notes from Table 4.2 are also relevant to this table.

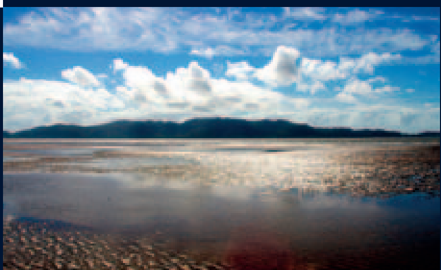
Table 4.6 Draft Environmental Values Magnetic Island Estuaries and Coastal and Marine

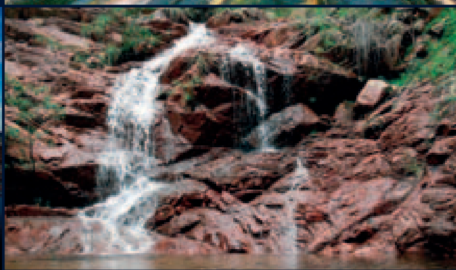
Waterway	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual appreciation	Cultural and spiritual values	Aquatic ecosystems
Estuaries							
All Magnetic Island		H	L	L	H	H	HEV
Butler Creek		L	M	M	H	H	✔
Gustav Creek		L - M	H	H	H	H	✔
East Horseshoe Bay creek		L	L	L	H	H	✔
Near Coastal and Marine Waters							
All near coastal waters Magnetic Island		H	M - H	H	H	H	HEV
Horseshoe Bay	M	H	H	H	H	H	HEV
West Channel		H	H	H	H	H	✔
Cleveland Bay		H	H	H	H	H	HEV
Halifax Bay		H	H	H	H	H	✔
Outer Marine		H	H	H	H	H	HEV

Note: Due to the relatively large areas involved both HEV and SMD aquatic ecosystems have been identified in the Cleveland Bay and Outer Marine areas.

Note: Notes from Table 4.2 are also relevant to this table.







If we meet our water quality objectives and pollutant load reduction targets we will be well on track to improve water quality condition in our streams and marine waters.

Water Quality Objectives and Targets

5

5. WATER QUALITY OBJECTIVES AND TARGETS

5.1 INTRODUCTION

This section summarises some of the information in the report titled *Environmental Values, Water Quality Objectives and Targets for the Black Ross Water Quality Improvement Plan* (Gunn, Manning and McHarg 2009), and is linked closely with the previous section on environmental values (EVs).

5.2 WATER QUALITY CONDITION INDICATORS

A range of indicators can be used when assessing water quality and aquatic ecosystem condition. These are usually divided into physico-chemical indicators and biological indicators. Physico-chemical indicators are most often used, as they are more easily measured using standardised sampling and analysis procedures. Biological indicators are discussed briefly in section 5.10. The physico-chemical water quality indicators considered for use when establishing water quality objectives are listed in Table 5.1. Some of the indicators are specific to urban areas and not all indicators are used in all situations e.g. freshwater versus marine.

Table 5.1 Condition Indicators

WQ indicator	Description	Reason for use
TSS	Total suspended solids (sediment)	Indicator of erosion and transport of sediment to waterbodies. Can be related to vegetation cover/bare ground and management practices. Can result in inhibition of primary production and upon settling, smothering of benthic organisms.
Turbidity	Visual measure of water clarity	Light penetration and subsequent biological activity is impacted by water clarity.
Org N/PN	Organic nitrogen/ particulate nitrogen	Provides an indication of the amount of plant material entering the system. Will become bioavailable in the longer term through decomposition.
DIN	Dissolved inorganic nitrogen	Readily bioavailable and supports a range of biological interactions including algal growth.
Total N	The sum of all forms of nitrogen	More common to have a value for total nitrogen than the different species of nitrogen.
PP	Particulate phosphorus	Can become bioavailable in the longer term and is often related to TSS levels.
FRP	Filterable reactive phosphorus	Readily bioavailable and supports a range of biological interactions including algal growth.
Total P	The sum of all forms of phosphorus	As for total nitrogen, available data sets may only include total phosphorus and not the different P species.
Chlorophyll a	A measure of algal growth	Is an indicator of algal growth and has a close relationship to nutrient concentrations, modified to some extent by water clarity.
DO	Dissolved oxygen (percentage saturation)	Oxygen levels are important for fish and other aquatic organisms to survive. Low oxygen levels can occur naturally but are frequently caused by eutrophication and other disturbances. One of the main water quality issues in tropical Queensland.
pH	Indicator of acidity and alkalinity	pH is important for chemical and biological processes with highly acid and highly alkaline waters resulting in stressful or toxic conditions for many organisms leading to potential changes in biodiversity.
EC	Electrical conductivity is a simple way to measure salt levels	In freshwaters, high levels of salt can impact plant growth and create conditions that are toxic to many organisms leading to habitat and biodiversity changes.
Pesticides	Various types	Inhibits plant and animal growth and may bioaccumulate.

... CONTINUED

WQ Indicator	Description	Reason for use
Urban Specific		
Hydrocarbons	Oil and petroleum based products	Excessive hydrocarbons can result in smothering of aquatic habitats. They can also increase morbidity and mortality in aquatic species and impact reproductive cycles.
Gross pollutants	Debris items often >5mm. Litter including plastics, garden waste and coarse sediment	Organic material can lead to oxygen depletion during decomposition. Litter, especially plastic bags, can be harmful to marine organisms, is unsightly and may contribute to obstructions in stormwater infrastructure.
Metals / heavy metals	Cadmium, Chromium, Copper, Nickel, Lead, Zinc	Excessive levels can be toxic to aquatic organisms and can bioaccumulate and be passed along the food chain (cobalt, selenium, thallium, silver, arsenic, antimony).

5.3 WATER QUALITY GUIDELINES RELEVANT TO THE DRY TROPICS

The *Queensland Water Quality Guidelines 2006* (QWQG), with minor updates in 2007, were developed by the EPA as an extension of the *National Water Quality Management Strategy* (NWQMS) and the *Australian and New Zealand Guidelines for Fresh and Marine Waters Quality* (ANZECC 2000) (AWQG). The Queensland guidelines are designed to be regionally relevant based on regionally collected water quality data. Where no regional information is available the QWQG defaults back to the AWQG. The QWQG focus largely on aquatic ecosystem protection, across three Queensland geographic regions where water quality data was available i.e. Southeast, Central Coast, and the Wet Tropics. Version 3 of the QWQG was released in September 2009.

Local water quality guidelines (WQGs) have not yet been established for the Black Ross (Townsville) WQIP area. In lieu of local guidelines the Queensland guidelines for the Central Coast region have been adopted for freshwaters and estuaries, except for the northern catchments i.e. Crystal Creek and Rollingstone Creek sub basins, where WQGs for the Wet Tropics region have been used.

For marine waters, water quality trigger value guidelines prepared by GBRMPA have been used (see Gunn, Manning and McHarg 2009).

5.4 WATER QUALITY OBJECTIVES

Water quality objectives (WQOs) are defined in relation to the EVs of a waterway or water body.

For high ecological value (HEV) waters the intent is to maintain existing water quality (physico-chemical) relative to the 20th, 50th and 80th percentiles and maintain existing habitat, biota, flow and riparian areas. The generic management intent for HEV waters comes from the AWQG (ANZECC 2000). The physico-chemical WQOs for HEV waters are therefore defined by the existing water quality. Due to the lack of water quality condition data for fresh and estuarine HEV waters, the WQIP does not define specific ambient WQOs for fresh and estuarine HEV waters. This could be further reviewed when locally relevant information is available for HEV waters.

For slightly to moderately disturbed (SMD) and highly disturbed (HD) aquatic ecosystems WQOs are based on the adoption of the most stringent WQGs for the relevant water quality indicators, which will protect and maintain the identified EVs of the waterways and waterbodies in the study area.

As there are currently no locally determined WQGs for the Black Ross (Townsville) WQIP area the WQOs have been determined by reference to the Queensland WQGs. Establishing local WQGs, for both SMD and HD waters, is an implementation action of the WQIP.

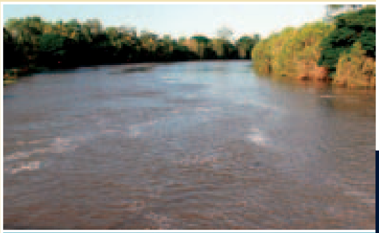
Stream flow in the dry tropics is highly seasonal with potentially high and flood flows during the wet season (December to April) and limited baseflow or no flow, in many of the streams during the drier months (May to November). The amount and concentration of pollutants in waterways will vary depending on rainfall and stream flow so WQOs also need to be tailored to appropriately reflect climatic variations typical of the dry tropics. This is achieved by adopting a set of WQOs for ambient conditions, with separate water quality targets for runoff associated with rainfall events (see section 5.5). Load based WQOs and targets are discussed later in this section.

A set of physico-chemical WQOs for ambient conditions has been adopted for the Black Ross (Townsville) WQIP area based on the *Queensland Water Quality Guidelines* (EPA 2006) and water quality guideline trigger values for the GBRMP (GBRMPA 2009) (see Table 5.3). The WQOs are set to protect the EVs of the Black and Ross Basins as established through stakeholder and community consultation (see Gunn, Manning and McHarg 2009).

5.4.1 FRESHWATER AND ESTUARINE PHYSICO-CHEMICAL (SMD WATERS) WQOS

For freshwaters and estuaries the WQOs (see Table 5.2) are based principally on the guidelines for SMD aquatic ecosystems, which provide a higher level of water quality protection than is required for most human use environmental values i.e. they are more stringent guideline values.

In this way the human use environmental values, with a few exceptions, are protected by default if the aquatic ecosystem water quality guideline values are maintained. Where there is an exception to this generalisation the higher level of protection for human use is adopted where a waterway or water body has been identified as having one or more of those human use environmental values. Exceptions are listed in the table endnotes.



Top: Water quality objectives are determined for waterways such as Ross River to measure and assist with water quality improvement.

Bottom: Waterways are a prominent feature of Townsville's urban landscape.

SECTION 5

Table 5.2 Ambient Physico-chemical WQOs (SMD) Freshwater and Estuaries

Indicator	Freshwater (CC/WT)			Estuarine (CC/WT)	
	Upland	Lowland	Lakes	Mid estuary	Upper estuary
TSS (mg/L)	-	10/nd	10/nd	20/nd	25/nd
Ammonia N (μg/L)	10/6	20/10	10	10/15	30/nd
Oxid – N (μg/L)	15/30	60/30	10	10/30	15/nd
DIN – N (μg/L)	25/36	80/40	20	20/45	45/nd
Organic N (μg/L)	225/125	420/200	330	260/200	400/nd
Total N (μg/L)	250/150	500/240	350	300/250	450/nd
FRP – P (μg/L)	15/5	20/4	5	8/5	10/nd
Total P (μg/L)	30/10	50/10	10	25/20	40/nd
Turbidity (NTU)	25/6	50/nd	1-20/2-200	8/10	25/nd
Chlorophyll a (μg/L)	na/0.6	5/1.5	5/3	4/3	10/nd
Dissolved Oxygen (%)	90-110/100	85-110/120	90-110/120	85/80-105	70-105/nd
pH	6.5-7.5	6.5-8.0	6.5/6.0-8.0	7.0/6.5-8.4	7.0-8.4/nd
EC* (μS/cm)	375/271	375/271	375/271		

Notes: Values are for Slightly to Moderately Disturbed (SMD) waterways using QWQG figures for Central Coast (CC) (on the left) and Wet Tropics (WT) (on the right) i.e. CC/WT, unless figures are the same for both regions.

nd is no data available. Where there is no data available the Central Coast values are adopted for the whole of the Black Ross (Townsville) WQIP area.

Dissolved oxygen is % saturation. DIN is the sum of Ammonia N and Oxid – N (oxidised nitrogen i.e. NO_x).

* Conductivity values (EC) for freshwaters (from the QWQG Appendix G, p.103) for Central Coast North, based on the 75th percentile value, is 375 μS/cm for the Black Basin. The Ross Basin is in the Burdekin-Bowen region and the corresponding value is 271 μS/cm.

Water Quality Guideline values – Human use exception to the aquatic ecosystem WGQ values:

Turbidity - Drinking water (aesthetics) guidelines for turbidity are more stringent for freshwater i.e. 5 NTU (Nephelometric turbidity unit).

The drinking water aesthetic WQG value for turbidity is specific to a particular human use and therefore has not been applied to the whole of the WQIP area. It is however applicable to Paluma Dam, the Crystal Creek catchment, Black Weir (part of the Lower Ross River Sub Basin) and the Upper Ross River Sub Basin as these are sources of Townsville's drinking water supply.

For the majority of the Black Ross (Townsville) WQIP area (other than HEV waters) the Central Coast values for SMD systems from the QWQG (EPA 2006) are adopted as the WQOs. However, Wet Tropics WQG values from the QWQG (EPA 2006) were adopted as WQOs for the Crystal Creek and Rollingstone Creek sub basins due to the closer alignment of these two sub basins with the vegetation, topography, climatic conditions and rainfall patterns of the QWQG Wet Tropics region.

The Crystal Creek and Rollingstone Creek sub basins are also within the Wet Tropics bioregion, which is one of the thirteen bioregions Queensland is divided into for regional ecosystem mapping purposes (Sattler and Williams 1999). While the Bluewater Creek Sub Basin is also within the Wet Tropics bioregion the Wet Tropics WQGs have not been adopted for

SMD waters in this sub basin as initial investigations indicate that the substantial lowland area is more typical of the drier Queensland Central Coast water quality guideline region than the vegetation based Wet Tropics bioregion.

The Alligator Creek Sub Basin is another potential exception to the use of Central Coast WQGs as WQOs. Mt Elliot is a significant part of the Alligator Creek catchment, which includes vegetation communities, and rainfall patterns that may be closer in nature to the Wet Tropics bioregion than the Brigalow Belt bioregion. Additional work is required, including water quality monitoring and analysis of current data, to determine whether the Wet Tropics or Central Coast WQGs are most applicable to the SMD waters in the Alligator Creek Sub Basin. The intention is to develop a set of WQGs specifically for the Townsville region as soon as possible, thereby removing the need to adopt either the Central Coast or Wet Tropics WQGs.

5.4.2 MARINE PHYSICO-CHEMICAL WQOS

The marine WQOs in Table 5.3 are based on the water quality guidelines developed for the GBRMP (GBRMPA 2009) and the QWQG (EPA 2006) for SMD aquatic ecosystems of the Central Coast region.

Table 5.3 Marine Physico-chemical WQOs

Indicator	Marine water type			
	Enclosed Coastal[2]	Open Coastal	Midshelf	Offshore
TSS (mg/L)	15 [2]	2.0 [1]	2.0 [1]	0.7 [1]
[2] Organic N (µg/L)	180 [2]	130 [2]	130 [2]	id
[1] PN (µg/L)	id	20 [1]	20 [1]	17 [1]
DIN – N (µg/L) *	11 [2]	9 [2]	9 [2]	id
Total N	200 [2]	140[2]	140[2]	id
[1] PP – P (µg/L)	id	2.8 [1]	2.8 [1]	1.9 [1]
FRP – P (µg/L)	6 [2]	6 [2]	6 [2]	id
Total P	20 [2]	20[2]	20[2]	id
Turbidity (NTU)	6 [2]	1 [2]	1 [2]	id
Chlorophyll a (µg/L)	2 [2]	0.45 [1]	0.45 [1]	0.4 [1]
Dissolved Oxygen (%)	90-105 [2]	95-105 [2]	95-105 [2]	id
pH	8.15-8.4 [2]	8.15-8.4 [2]	8.15-8.4 [2]	id
Secchi depth	1.5 [2]	10 [1]	10 [1]	17 [1]

Notes: [1] indicates values from the WQ Guideline for the GBRMP (GBRMPA 2009) and [2] indicates values from the Queensland Water Quality Guidelines (EPA 2006). id is insufficient data. There are no Offshore areas in the Black Ross WQIP area and these values are included for information only. Definitions of marine water type can be found in *Environmental Values, Water Quality Objectives and Targets for the Black Ross WQIP* (Gunn, Manning and McHarg 2009).

SECTION 5

5.4.3 PESTICIDE WQOS

The pesticide WQOs in Table 5.4 are a combination of trigger values from the AWQG and the GBRMPA water quality guideline, for both HEV (99% protection) and SMD (95% protection) waters.

Table 5.4 Pesticide WQOs

Pesticides (µg/L)	Freshwater		Marine	
	HEV	SMD	HEV	SMD
Diuron	id	id	0.9	1.6
Atrazine	0.7	13	0.6	1.4
Simazine	0.2	3.2	0.2	3.2
Hexazinone	id	id	1.2	id
Endosulfan	0.03	0.03	0.005	0.005
Malathion	0.002	0.05	id	id
Chlorpyrifos	0.00004	0.01	0.0005	0.009
Ametryn	id	id	0.5	1
2,4-D	140	280	0.8	30.8
Tebuthiuron	0.02	2.2	0.02	id
MEMC	id	id	0.002	id
Diazinon	0.00003	0.01	0.00003	id
Tributyltin[1]	id	id	0.0004	0.006

Source: Freshwater values are from AWQG (ANZECC 2000) Table 3.4.1 Trigger values for toxicants at alternative levels of protection (aquatic ecosystems). Marine values are predominantly from Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA 2009).

Notes: All values are measured in µg/L. id is insufficient data to derive trigger values to establish WQOs.

[1] Tributytlin is a biocide.

5.4.4 URBAN SPECIFIC WQOS

WQOs for heavy metals (Table 5.5), and heavy metals in sediment (Table 5.6) have also been adopted for the 'high urban' catchments (urban land uses comprise ›65% of the catchment).

Table 5.5 Heavy Metal WQOs

Indicator	Freshwater		Marine	
Heavy metal (µg/L)	HEV	SMD	HEV	SMD
Cadmium	0.06	0.2	0.7	0.7
Chromium	0.01	1.0	0.14	4.4
Copper	1.0	1.4	0.3	1.3
Lead	1.0	3.4	2.2	4.4
Nickel	8	11	7	70
Zinc	2.4	8.0	7	15

Source: AWQG Table 3.4.1 Trigger values for toxicants at alternative levels of protection.

Note: Adopted trigger values for toxicants are 99% protection for HEV waters and 95% protection for SMD waters with the exception of Cadmium where the 99% protection level is adopted for both HEV and SMD marine waters.

Table 5.6 Heavy Metals in Sediment WQOs

Metals in sediment	ISQG low (mg/kg)	ISQG high (mg/kg)
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Nickel	21	52
Zinc	200	410

Source: AWQG (ANZECC 2000) Interim Sediment Quality Guidelines (ISQG) Table 3.5.1.

Note: Values are measured as mg/kg (dry weight), which is equivalent to parts per million (ppm). The guideline values/ WQOs apply to slightly to moderately disturbed (ISQG low) and highly disturbed (ISQG high) aquatic ecosystems.

A WQO for hydrocarbons was also considered for urban areas. Hydrocarbon spills may be significant for local waterways or water bodies and could be considered as a type of point source pollution. There was insufficient data to suggest that hydrocarbons are a significant ambient water quality issue from diffuse sources and as a result a WQO has not been set.

Additionally, a water quality design objective has been set for gross pollutants as part of the process for developing the water sensitive urban design guidelines for the Townsville region. This is expressed as a 90 per cent reduction in gross pollutants from current levels. Investigations are required to determine the current levels of gross pollutants entering waterways to provide a baseline for measuring the achievement of this target over time.

5.4.5 COMPARING WATER QUALITY AND AMBIENT WQOS

Where water quality condition data was available, this has been collated and compared with the adopted WQOs for SMD waters to provide an indication of the physico-chemical water quality status of the freshwaters of the Black Ross (Townsville) WQIP area (see Gunn, Manning and McHarg 2009) for sediment and nutrients. The data interpretation is only an initial indication of water quality. It should be noted that the collated data is not consistent with regard to; monitoring timeframe, water quality indicators monitored, monitoring methods, analysis methods and continuity of monitoring. A list of waterways and their water quality condition relative to the WQOs for SMD waters is provided in Table 5.7.

TABLE 5.7 COMPARING WQOS TO WATER QUALITY CONDITION DATA

Sub basin and waterways						
Crystal Creek Sub Basin [2]	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Crystal Creek 1-1	✓ 65%	✓ 53%	✓ 55%	✓ 50%	✓ 60%	✓ 80%
Hencamp Creek 1-5	✓ 13%	✗ 50%	✗ 52%	✗ 25%	✗ 100%	✗ 10%
Crystal Creek Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Crystal Creek 1-1	✓ 83%	✓ 77%	✓ 78%	✓ 90%	✓ 92%	✓ 80%
Hencamp Creek 1-5	✓ 56%	✓ 29%	✓ 32%	✓ 75%	✓ 60%	✗ 10%
Rollingstone Creek Sub Basin [2]	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
[1] Rollingstone Creek 2-1	✓	✗ 100%	✗ 50%	ND	✗ 100%	✓ 20%
[1] Saltwater Creek 2-6	✓ 65%	✓	✓ 7%	✓ 25%	✗ 100%	✗ 40%
[1] Leichhardt Creek 2-8	✓ 25%	✗ 100%	✗ 38%	ND	✗ 100%	✓
Rollingstone Creek Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Rollingstone Creek 2-1	✓ 50%	✓ 29%	✓ 28%	ND	✓ 60%	✓ 20%
Saltwater Creek 2-6	✓ 81%	✓ 52%	✓ 55%	✓ 75%	✓ 60%	✗ 40%
Leichhardt Creek 2-8	✓ 63%	✓ 29%	✓ 34%	ND	✓ 60%	✓
Bluewater Creek Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
[1]Sleeper Log Creek 3-1	✓ 78%	✓ 52%	✓ 52%	✓ 75%	✓ 40%	✗ 70%
[1]Two Mile Creek 3-2	✓ 76%	✓ 52%	✓ 54%	✓ 55%	✓ 20%	✗ 150%
Bluewater Creek 3-3	✗ 109%	✓ *61%	✓ *44%	✓ 70%	✓ *66%	✓ *50%
[1]Deep Creek 3-4	✓ *50%	✓ 29%	✓ *26%	ND	✓ *60%	✗ 40%

SECTION 5

... CONTINUED

Black River Sub Basin	DIN	Org N	TN	FRP	TP	TSS
Black River 4-1	✔ *50%	✔ 28%	✔ *33%	✘ 75%	✔ *36%	✘ 60%
Bohle River Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Bohle R (below Highway) 5-1	✔ *14%	✘ 16%	✘ 24%	✘ 330%	✘ 160%	✘ 110%
Bohle R (above Highway) 5-2	✘ 1,064%	✘ 138%	✘ 264%	✘ 19,900%	✘ 4,900%	✘ 140%
Lower Ross River Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Mundy Creek 6-2	ND	✔ 15%	✘ 28%	✘ 590%	✘ 390%	✘ 50%
[1]Esplanade 6-3	✔ 63%	✔ *29%	✔ *31%	ND	✔ 20%	ND
Ross Creek 6-4	✔ 29%	✔ 33%	✔ 29%	✔	✔ *20%	✘ 40%
Ross River (below Dam) 6-5	✔ *50%	✔ *20%	✔ *14%	✔ 40%	✔ 6%	✘ 40%
Upper Ross River Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Lake Ross (Ross Dam) 7-1	✘ 100%	✘ 52%	✘ 60%	✘ 200%	✘ 200%	✔ *80%
Sachs Creek 7-5	ND	✔ 41%	✘ 13%	✘ 45%	✔	✔ *30%
Stuart Creek Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Stuart Creek 8-1	✔ *50%	✘ 19%	✘ 42%	✘ 295%	✘ 160%	✘ 420%
[1]Sandfly Creek 8-2	✘ 875%	✘ 233%	✘ 308%	ND	✘ 820%	✘ 150%
Alligator Creek Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Alligator Creek 9-1 (Lowland)	✔ 63%	✔ 46%	✔ 34%	✔ 25%	✔ 40%	✔ 20%
Alligator Creek 9-1 (Mid estuary)	✘ 50%	✘ 15%	✘ 10%	ND	✘ 17%	✔ 50%
Magnetic Island Sub Basin	**DIN**	**Org N**	**TN**	**FRP**	**TP**	**TSS**
Cockle Creek 10-1	ND	ND	✘ 26%	✔ *100%	✘ 110%	✘ 70%
Butler Ck (Picnic Bay) 10-2	ND	ND	✘ 14%	✔ *100%	✘ 140%	✘ 100%
Gustav Creek 10-3	ND	ND	✔ *55%	✔ *50%	✔ *60%	✔ *30%
Endeavour Creek 10-6	✘ 13%	ND	✘ 90%	✔ *100%	✘ 100%	✘ 590%

Notes: Tick/cross denotes if the WQO is met (✔) or not (✘) for the waterway based on the median value for the water quality indicator. The percentage indicates the amount by which the WQO is met or not met (the difference between the WQO and water quality condition median as a percentage of the WQO). No % is listed if the water quality condition is the same as the WQO. ND is no data.

DIN is dissolved inorganic nitrogen, Org N is organic nitrogen, TN is total nitrogen, FRP is filterable reactive phosphorus, TP is total phosphorus and TSS is total suspended solids (sediment).

* indicates inconsistency or a wide variation in the data, or insufficient data to calculate percentiles.

[1] indicates data is dated and may not reflect current condition.

[2] indicates that WQGs for the Wet Tropics were used to derive the WQOs for these sub basins. WQOs for all other sub basins are based on WQGs for the Central Coast

As can be seen from the comparison of water quality monitoring data with the WQOs in Table 5.7, there is significant variation in the achievement of WQOs between waterways for the various indicators as well as from catchment to catchment and within sub basins. It should be noted that a true comparison is difficult to make as not all waterways have water quality data for all indicators and not all data sets are current, or equally reliable.

This comparison highlights the need for both up-to-date and consistently reliable water quality data. Without a comprehensive monitoring program it is difficult to assess the actual condition of waterways or trends in water quality. Appropriate water quality monitoring is also required to enable the establishment of local water quality guidelines and, subsequently, the determination of locally relevant WQOs. In the absence of the required data the adopted WQOs will be retained as an interim measure.

5.4.6 CURRENT WQO ACHIEVEMENT

Based on the available water quality data for the Black Ross (Townsville) WQIP area (with the recognised limitations as discussed above), a summary of the waterways within the sub basins that meet the WQOs for SMD waters adopted for the Black Ross (Townsville) WQIP are shown in Table 5.8.

Of the 66 waterways, tributaries and waterbodies identified and included in the Black Ross (Townsville) WQIP there are 24 waterways that have some water quality data that has been used for comparison with the WQOs for SMD waters.

Of the 24 waterways with water quality data only four (17% of waterways with water quality data) met all the WQOs. Ten of the waterways (42%) met 80 per cent of the WQOs while thirteen (54%) met 50 per cent of the WQOs.

In terms of the main pollutants to be addressed as part of the WQIP, 50 per cent of the waterways achieved the total nitrogen (TN) WQO, 50 per cent achieved the total phosphorus (TP) WQO while only 33 per cent achieved the total suspended solids (TSS) WQO. TSS is therefore likely to be the main focus for water quality improvement with nutrient reduction also being important. Given that water quality data is available for only 36 per cent of the Black Ross (Townsville) WQIP waterways, additional monitoring is required to identify and confirm priority areas and pollutants.

Top: Black River is flanked by rural residential properties forming part of the peri-urban zone on the outskirts of Townsville.

Bottom: The 'new' Ross River rail bridge stands along side the old structure.

SECTION 5

Table 5.8 Water Quality and WQOs Summary

Descriptor	Sub Basins									
	[2] Crystal Creek	[2] Rollingstone Creek	Bluewater Creek	Black River	Bohle River	Lower Ross River	Upper Ross River	Stuart Creek	Alligator Creek	Magnetic Island
* Catchments (number)	5	8	4	2	2	5	6	2	4	7
* Waterways (number)	5	8	7	2	5	5	10	2	7	15
[1] Water quality (WQ) data	2	3	4	1	1	4	2	2	1	4
Waterways with WQ data	40%	38%	57%	50%	20%	80%	20%	100%	14%	27%
Waterways meet all WQOs	1/1	0/2	0	0	0	1	0	0	1	1
Waterways meet 80% of WQOs	1/2	0/3	4	0	0	3	0	0	1	1
Waterways meet 50% of WQOs	1/2	1/3	4	1	0	3	1	0	1	1
Waterways meet TN WQO	1/2	1/3	4	1	0	3	0	0	1	1
Waterways meet TP WQO	1/2	0/3	4	1	0	3	1	0	1	1
Waterways meet TSS WQO	1/1	2/2	1	0	0	0	2	0	1	1

Notes: * denotes the main catchments delineated (total of 45), and major freshwater and estuarine waterways, tributaries and waterbodies (total of 66) identified and included in the Black Ross WQIP.

[1] indicates the number of freshwater waterways and waterbodies with some water quality data (total of 24), which has been included in the water quality database and subsequent Water Quality Condition Report (Connell Wagner 2008). 36% of the identified waterways, tributaries and waterbodies have some available water quality data. Not all waterways have a complete set of data for all water quality indicators used for the comparison (DIN, Organic N, TN, FRP, TP and TSS). Not all water quality data is current and/or considered reliable in terms of assessing existing condition or setting targets for all waterways in the Black Ross WQIP area.

'Waterways with WQ data' indicates the percentage of waterways in the sub basin with available water quality data either current or historic.

[2] Wet Tropics water quality guideline (WQG) values were used for these sub basins. The first number in the "Waterways meet .... WQOs" rows relates to compliance with WQOs based on Wet Tropics WQGs. The second number denotes compliance with Central Coast WQOs, which are based on Central Coast WQGs.

If the Central Coast water quality guideline based WQOs were used for all sub basins i.e. including Crystal Creek and Rollingstone Creek, then six (25%) of the waterways would meet all the WQOs, fourteen (58%) of the waterways would meet 80 per cent of the WQOs and sixteen (67%) of the waterways would meet 50 per cent of the WQOs. Additionally 63 per cent (15) of the waterways would achieve the TN WQO and 67 per cent (16) would achieve the TP WQO. The number of waterways achieving the TSS WQO would remain unchanged at 33 per cent (8).

As can be seen from the above example the nomination of appropriate water quality guidelines and WQOs is an important step in determining the relative condition of waterways and further emphasises the need to establish local water quality guidelines, WQOs and water quality targets that are relevant to the coastal catchments of the Black Ross (Townsville) WQIP area.

This lack of local water quality guidelines for HEV and SMD waters should not be seen as an impediment to water quality improvement efforts. Rather, it is an indication of the type of actions that need to be included in the water quality monitoring program as part of the Black Ross (Townsville) WQIP implementation process.

5.5 SUSTAINABLE LOADS

The WQOs adopted for ambient conditions are concentration based and are compared to ambient water quality data to determine the relative health of aquatic ecosystems (see section 5.4.5) at baseflow (ambient) conditions. We also want to know the amount of the main pollutants of concern i.e. sediment and nutrients, that can be discharged from a catchment each year while still maintaining the ecological health of the receiving waters. This figure is referred to as the *sustainable load*.

Determining sustainable load levels requires the linking of pollutant runoff from catchments with the condition of receiving waters, generally through a receiving waters model. The information and resources required to develop a receiving waters model for the Black Ross (Townsville) WQIP were not available so an alternative approach was taken to determine end of catchment load targets for the catchments of the Black Ross (Townsville) WQIP area. Future studies are required to establish the relationship between catchment run off and receiving waters (marine) ecosystem health.

In order to determine end of catchment loads for TSS and nutrients, a modelling study was undertaken using input from the ACTFR water quality event monitoring and other local water quality and climatic data. A summary analysis of the results of the modelling study can be found in *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010). This report and the full report titled *Black and Ross River Water Quality Improvement Plan Catchment and Water Quality Modelling* (BMT WBM 2010) are available at www.creektocoral.org.

5.5.1 MODEL INPUT

Event water quality data was collected and analysed by the ACTFR over the 2006/2007 and 2007/2008 'wet seasons' to provide a preliminary set of event mean concentration (EMC) values for a suite of land uses in the Black Ross (Townsville) WQIP area. This local event water quality monitoring data, including EMC values, was used as input to a catchment model (WaterCAST) to derive end of catchment sediment and nutrient loads, and flow volumes, for the Black Ross (Townsville) WQIP area.

The preliminary EMC values from the event monitoring are displayed in Table 5.9 for urban land use (developing and developed), peri-urban, rural and minimal use. Minimal use EMC values were estimated for 'wet' catchments, typical of the Wet Tropics region, to compare with the 'dry' catchment values calculated from the event monitoring.

Table 5.9 EMC Values from Event Water Quality Monitoring

Indicator	Developing	Developed	Peri-urban	Rural	Minimal use
TSS (mg/L)	476	63	75	75	25/4
PN – N (µg/L)	198	235	167	149	125/45
DIN – N (µg/L)	160	132	125	75	58/58
Total N (µg/L)	747	716	578	426	383/193
PP – P (µg/L)	125	93	57	33	20/8
FRP – P (µg/L)	130	147	83	20	25/3
Total P (µg/L)	277	299	167	59	51/15

Source: ACTFR event water quality monitoring data 2006-2008.

Notes: Minimal use figures are for; dry catchments/ wet catchments

SECTION 5

5.5.2 MODEL OUTPUTS

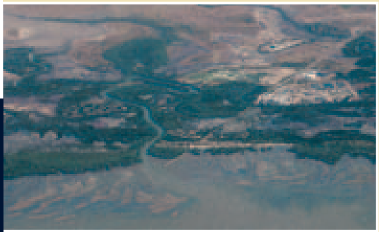
The initial output of the WaterCAST model was the 2005 (baseline using updated land use mapping) end of catchment pollutant loads, calculated with and without wastewater treatment plant discharges. The 1850 (pre-settlement) and 2045 end of catchment loads were also calculated with the 1850 loads based on pollutant run off coefficients from a 'forested' catchment, and 2045 loads based on anticipated land use change between 2005 and 2045, and the associated pollutant load change.

The 2005 and 2045 outputs assumed 'business as usual', with no specific management interventions. The model was then rerun for 2045 with management intervention scenarios in place.

The following sections contain the results of the catchment modelling for point sources and diffuse sources, along with load reduction targets and assumptions based on the model outputs.

5.6 POINT SOURCE LOADS

Three sub basins in the Black Ross (Townsville) WQIP area are impacted by point source discharges to waterways i.e. Black River, Bohle River and Stuart Creek. Table 5.10 shows the modelled combined nutrient loads from diffuse sources and point sources for the sub basins impacted by point source discharges i.e. wastewater treatment plants (WWTPs).



Top: Cleveland Bay Wastewater Treatment Plant is situated in a coastal wetland near Sandfly Creek.

Bottom: The Stuart area has a concentration of industrial activities.

Table 5.10 Modelled Nutrient Loads for Sub Basin With WWTPs (at 2007)

Sub Basin	Flow ML/year	TN kg/year	TP kg/year
Black River	114,396	70,591	11,063
Bohle River	131,708	191,753	29,795
Stuart Creek (pre upgrade)	47,483	200,020	58,400
Stuart Creek (post upgrade)	47,483	61,320	20,039

Note: Blue shaded row shows loads prior to the Cleveland Bay WWTP upgrade i.e. 2005 diffuse source baseline year.

Based on the modelled loads with and without nutrient contributions from WWTPs, the relative contributions from WWTPs by sub basin, basin and WQIP area have been calculated and are shown in Table 5.11. WWTP contributions are based on WWTP discharge figures for 2007 while diffuse source contributions are based on the 2005 baseline modelled loads.

Table 5.11 WWTP Nutrient Load Contributions

Sub Basin	TN (kg/yr)		TN difference		TP (kg/yr)		TP difference	
	Point and diffuse	Diffuse only	kg/yr	%	Point and diffuse	Diffuse only	kg/yr	%
Black River	70,591	69,178	1,413	2.0	11,063	10,022	1,041	9.4
Black Basin total	**293,861**	**292,448**	**1,413**	**0.5**	**29,108**	**28,067**	**1,041**	**3.6**
Bohle River	191,753	78,328	113,425	59.2	29,795	14,146	15,649	52.5
Stuart Creek	61,320	18,956	42,364	69.1	20,039	2,959	17,080	85.2
Ross Basin total	**429,353**	**273,565**	**155,788**	**36.3**	**74,409**	**41,680**	**32,729**	**44.0**
Black Ross Total	**729,500**	**572,299**	**157,201**	**21.5**	**104,461**	**70,690**	**33,771**	**32.3**

Notes: Only the sub basins with contributions from WWTPs at 2007 have been included in the table. “Point and diffuse” is the total load from WWTP discharge (at 2007) and diffuse sources (at 2005) for the sub basins and “Diffuse only” is modelled diffuse source loads using 2005 land use figures. Load contribution totals for Black Basin and Ross Basin are from all sub basins in the Black Basin and Ross Basin respectively and the Black Ross Total is for all sub basins in the Black Ross WQIP area. For a list of all load contributions see Table 5.13 (diffuse only) and Table 5.10 (point source and diffuse source). TN is total nitrogen and TP is total phosphorus. The Difference columns indicate the modelled contributions from WWTPs with % being the percentage contribution of WWTPs to the total load of the sub basin, basin and WQIP area.

Point source loads will be reduced over the next three years as a result of upgrades to existing WWTPs. Expected load reductions from WWTPs along with post upgrade increases associated with population growth are listed in Table 5.12. The trend for nitrogen is illustrated in Figure 5.1 and the trend for phosphorus is illustrated in Figure 5.2.

Table 5.12 Point Source Load and Flow Figures

Upgrade status	Years	Total flows (ML/day)	Total TSS loads (t/yr)	Total TN loads (t/yr)	Total TP loads (t/yr)
WWTP upgrade scenario data	Pre 2006	41.54	91.03	296.32	72.08
	2008	41.54	91.03	157.41	33.83
	2010	43.24	94.77	163.29	36.68
	2012	48.43	106.14	70.02	23.92
	2021	55.65	121.97	92.10	28.67
	2045	74.43	163.12	124.64	37.06

Note: Loads are in tonnes per year. Flows are daily discharge flows based on expected population growth

Figure 5.1 Modelled Nitrogen Loads from Point Sources

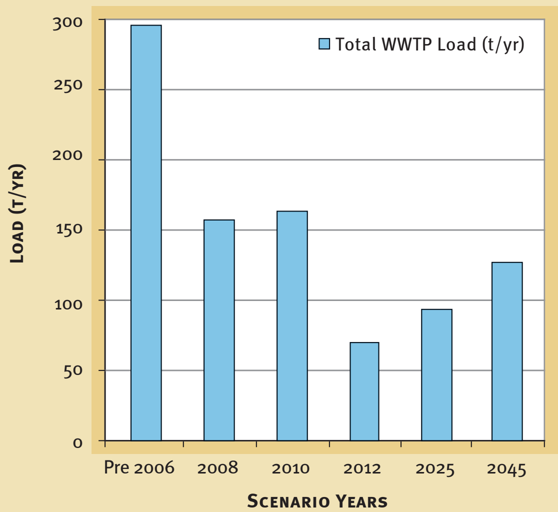
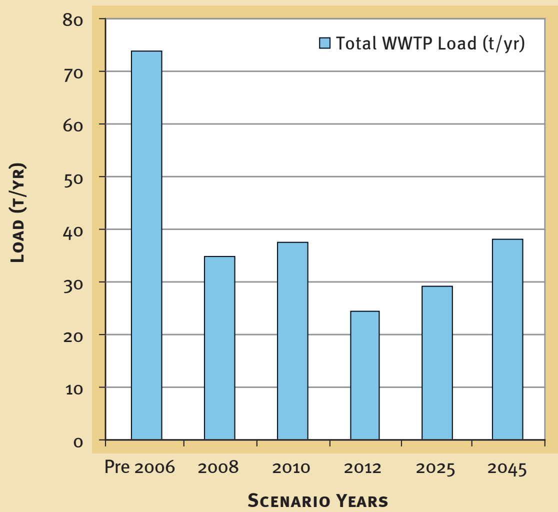


Figure 5.2 Modelled Phosphorus Loads from Point Sources



5.7 DIFFUSE SOURCE LOADS AND TARGETS

Modelled baseline pollutant loads (using 2005 land use) from diffuse sources for the Black Ross (Townsville) WQIP sub basins are shown in Table 5.13.

Table 5.13 Modelled Loads by WQIP Sub Basin at 2005

		Area	Flow	TSS	TN	TP
Sub Basin	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,443	5,513,449	90,122	9,383
Rollingstone Creek	2	21,822	144,387	1,603,046	40,448	4,021
Bluewater Creek	3	28,872	145,698	2,806,946	92,700	4,641
Black River	4	29,539	114,396	7,195,425	69,178	10,022
Black Basin total		**105,291**	**643,925**	**17,118,866**	**292,448**	**28,067**
Bohle River	5	33,194	131,708	9,295,613	78,328	14,146
Lower Ross River	6	13,244	53,714	4,205,854	33,120	6,981
Upper Ross River	7	74,929	196,870	8,108,550	100,444	12,784
Stuart Creek	8	11,024	47,483	1,650,930	18,956	2,959
Alligator Creek	9	27,490	104,834	2,104,936	42,716	4,811
Ross Basin total		**159,882**	**534,608**	**25,365,882**	**273,565**	**41,680**
Magnetic Island	10	4,815	27,390	342,217	6,286	944
Black Ross Total		**267,559**	**1,205,923**	**42,826,965**	**572,299**	**70,690**

Note: Alligator Creek Sub Basin has been grouped with the Ross River AWR Basin. It is part of the Haughton River AWR Basin. Areas are those used for modelling. Upper Ross River loads are delivered to Ross Dam, not end of catchment.

Load increases to 2045 were modelled based on expected land use changes associated with population growth. Loads at 2021 were interpolated from the 2005 and 2045 modelled loads.

Anticipated diffuse sources load reductions from 'business as usual' at 2045, resulting from improved management practices, have been modelled using three initial management practice scenarios:

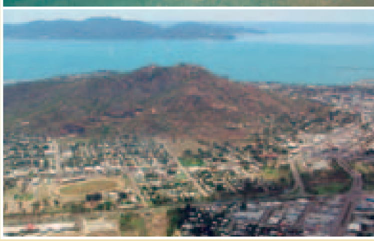
1. Water sensitive urban design (WSUD) applied to all new urban (greenfield) development;
2. WSUD applied to all urban areas (greenfield and retrofit into established urban); and
3. Best management practice principles applied to rural areas i.e. grazing and intensive agriculture.

Load increases, land use changes associated with the modelled load increases and management intervention scenarios to reduce loads are discussed in more detail in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* report (Gunn and Manning 2010).

5.7.1 DIFFUSE SOURCE LOAD REDUCTION TARGETS

Potential diffuse source load reductions from the modelled 2045 management practice scenarios have been used to establish indicative load reduction targets for diffuse sources at 2021 (interpolated) and 2045 (see Table 5.14 and Table 5.15 respectively). The required management practice adoption rates to achieve the load reduction targets are listed in Table 5.16.

These initial load reduction targets have been set conservatively based on anticipated improvements that are achievable without the commitment of significant additional external resources for retrofitting existing urban areas (Retro WSUD), and developing a rural best management practice (BMP) extension program. If additional resources are secured then reduction targets can be amended commensurate with resources. At the time of printing it is unlikely that additional external funds will be made available to implement all of the priority management actions outlined in the Black Ross (Townsville) WQIP.



Top: Sediment is stirred up in the shallow waters of Cleveland Bay.

Bottom: Townsville has an idyllic coastal setting.

SECTION 5

Table 5.14 Indicative Load Reduction Targets for 2021

Sub Basin	BAU loads		Load reduction targets				
	2005 (t/yr)	2021 (t/yr)	WSUD (t/yr)	Retro (t/yr)	Rural (t/yr)	Total target 2021 (t/yr)	% of 2021 BAU
Total Suspended Solids							
Crystal Creek	5,513	6,516	69	0	560	629	9.7
Rollingstone Creek	1,603	2,169	71	8	163	242	11.2
Bluewater Creek	2,807	2,807	2	2	129	132	4.7
Black River	7,195	7,409	0	24	389	412	5.6
Bohle River	9,296	9,495	329	136	344	809	8.5
Lower Ross River	4,206	5,081	70	197	201	468	9.2
Upper Ross River	8,109	10,154	0	0	754	754	7.4
Stuart Creek	1,651	2,430	0	2	209	211	8.7
Alligator Creek	2,105	3,792	0	0	398	398	10.5
Magnetic Island	342	399	40	14	0	54	13.5
Black Basin	**17,119**	**18,900**	**141**	**34**	**1,241**	**1,416**	**7.5**
Ross Basin	**25,366**	**30,952**	**398**	**336**	**1,906**	**2,639**	**8.5**
Black Ross	**42,827**	**50,252**	**580**	**383**	**3,147**	**4,110**	**8.2**
Total Nitrogen							
Crystal Creek	90	98	0.07	0.00	1.4	1.5	1.55
Rollingstone Creek	40	46	0.07	0.02	0.5	0.6	1.4
Bluewater Creek	93	95	0.01	0.00	1.4	1.4	1.5
Black River	69	71	0.00	0.06	0.8	0.8	1.2
Bohle River	78	78	0.37	0.35	0.6	1.3	1.7
Lower Ross River	33	37	0.08	0.36	0.4	0.8	2.2
Upper Ross River	100	110	0.00	0.00	1.3	1.3	1.2
Stuart Creek	19	24	0.00	0.01	0.4	0.4	1.6
Alligator Creek	43	53	0.00	0.00	0.7	0.7	1.4
Magnetic Island	6	6	0.05	0.03	0.0	0.1	1.4
Black Basin	**292**	**309**	**0.16**	**0.09**	**4.1**	**4.3**	**1.4**
Ross Basin	**274**	**302**	**0.45**	**0.72**	**3.3**	**4.5**	**1.5**
Black Ross	**572**	**618**	**0.66**	**0.84**	**7.4**	**8.9**	**1.4**
Total Phosphorus							
Crystal Creek	9.4	10.4	0.04	0.00	0.1	0.14	1.4
Rollingstone Creek	4.0	4.6	0.05	0.01	0.0	0.09	2.0
Bluewater Creek	4.6	4.5	0.00	0.00	0.0	0.05	1.2
Black River	10.0	10.2	0.00	0.03	0.1	0.15	1.5
Bohle River	14.1	14.2	0.21	0.19	0.1	0.50	3.5
Lower Ross River	7.0	7.8	0.04	0.21	0.0	0.28	3.6
Upper Ross River	12.8	14.7	0.00	0.00	0.2	0.23	1.6
Stuart Creek	3.0	3.8	0.00	0.01	0.0	0.05	1.3
Alligator Creek	4.8	6.6	0.00	0.00	0.1	0.07	1.0
Magnetic Island	0.9	1.0	0.03	0.02	0.0	0.05	4.8
Black Basin	**28**	**29.7**	**0.09**	**0.05**	**0.3**	**0.44**	**1.5**
Ross Basin	**42**	**47.1**	**0.25**	**0.40**	**0.5**	**1.13**	**2.4**
Black Ross	**70.7**	**77.8**	**0.37**	**0.47**	**0.8**	**1.61**	**2.1**

Notes: Load reductions are based on 100% adoption rate for "WSUD" in Greenfield (GF) developments, a 20% adoption rate for "Retro" i.e. WSUD in existing urban areas, and a 30% adoption rate for "Rural" BMP.

Table 5.15 Indicative Load Reduction Targets for 2045

Sub Basin	BAU loads		Load reduction targets				
	2005 (t/yr)	2045 (t/yr)	WSUD (t/yr)	Retro (t/yr)	Rural (t/yr)	Total target 2045 (t/yr)	% of 2045 BAU
Total Suspended Solids							
Crystal Creek	5,513	8,019	172	0	3,736	3,907	48.7
Rollingstone Creek	1,603	3,017	176	52	1,089	1,318	43.7
Bluewater Creek	2,807	2,807	4	12	857	874	31.1
Black River	7,195	7,729	0	148	2,592	2,740	35.5
Bohle River	9,296	9,794	822	852	2,290	3,965	40.5
Lower Ross River	4,206	6,395	174	1,230	1,343	2,747	43.0
Upper Ross River	8,109	13,222	0	0	5,026	5,026	38.0
Stuart Creek	1,651	3,598	0	15	1,394	1,409	39.2
Alligator Creek	2,105	6,323	0	0	2,651	2,651	41.9
Magnetic Island	342	485	101	85	0	186	38.4
Black Basin	**17,119**	**21,572**	**352**	**212**	**8,274**	**8,839**	**41.0**
Ross Basin	**25,366**	**39,331**	**996**	**2,097**	**12,703**	**15,796**	**40.2**
Black Ross	**42,827**	**61,389**	**1,450**	**2,394**	**20,978**	**24,823**	**40.4**
Total Nitrogen							
Crystal Creek	90	109.7	0.2	0.0	9.6	9.7	8.9
Rollingstone Creek	40	53.4	0.2	0.1	3.4	3.7	7.0
Bluewater Creek	93	99.0	0.1	0.0	9.1	9.2	9.3
Black River	69	72.9	0.0	0.4	5.1	5.5	7.5
Bohle River	78	78.3	0.9	2.2	3.9	7.0	8.9
Lower Ross River	33	42.1	0.2	2.3	2.5	4.9	11.7
Upper Ross River	100	125.0	0.1	0.0	8.5	8.6	6.9
Stuart Creek	19	30.5	0.0	0.0	2.5	2.6	8.6
Alligator Creek	43	69.0	0.0	0.0	4.9	4.8	7.0
Magnetic Island	6	6.5	0.1	0.2	0.0	0.3	4.6
Black Basin	**292**	**335.1**	**0.5**	**0.5**	**27.3**	**28.3**	**8.4**
Ross Basin	**274**	**344.9**	**1.2**	**4.5**	**22.4**	**28.0**	**8.1**
Black Ross	**572**	**686.0**	**1.2**	**5.2**	**49.3**	**55.7**	**8.1**
Total Phosphorus							
Crystal Creek	9.4	11.80	0.10	0.00	0.64	0.7	6.3
Rollingstone Creek	4.0	5.40	0.12	0.07	0.21	0.4	7.4
Bluewater Creek	4.6	4.30	+0.02	0.02	0.31	0.3	6.9
Black River	10.0	10.60	0.02	0.20	0.81	1.0	9.7
Bohle River	14.1	14.30	0.47	1.20	0.64	2.3	16.1
Lower Ross River	7.0	8.90	0.06	1.29	0.18	1.5	17.1
Upper Ross River	12.8	17.70	0.02	0.00	1.57	1.6	9.0
Stuart Creek	3.0	5.00	0.00	0.04	0.29	0.3	6.4
Alligator Creek	4.8	9.20	+0.05	0.00	0.40	0.4	3.9
Magnetic Island	0.9	1.10	0.09	0.12	0.01	0.2	20.1
Black Basin	**28**	**32.10**	**0.22**	**0.29**	**1.97**	**2.5**	**7.7**
Ross Basin	**42**	**55.20**	**0.60**	**2.52**	**3.15**	**6.3**	**11.4**
Black Ross	**70.7**	**88.40**	**0.91**	**2.93**	**5.13**	**9.0**	**10.1**

Notes: Load reductions are based on 100% adoption rate for "WSUD" in Greenfield (GF) developments, a 50% adoption rate for "Retro" i.e. WSUD in existing urban areas, and an 80% adoption rate for "Rural" BMP.

Table 5.16 Adoption Rates for Load Reductions

Management practice	Adoption rate (%)		
	Current (2005)	2021	2045
Greenfield WSUD (WSUD)	15*	100	100
Existing urban WSUD (Retro)	10*	20	50
Rural best management practice (Rural)	15*	30	80

Note: * indicates that Current (2005) adoption rates are anecdotal estimates and have not been derived from rigorous investigations. Descriptions in (brackets) refer to the abbreviations used in Table 5.14 and Table 5.15.

Additional information on load targets, including potential reductions in relation to pre-settlement (1850) and baseline (2005) loads, is available in Gunn and Manning (2010).

The adoption of water sensitive urban design (WSUD) principles for new developments (greenfield) is achievable in the shorter term through policy and regulatory interventions and explains the 100% adoption rate used for both the 2021 and 2045 load reduction targets. In the short term a 50% voluntary adoption rate by 2014 may be achievable.

Further investigations are required to determine current adoption rates of Greenfield WSUD and Rural BMP, and to determine the extent and effectiveness of WSUD measures in established urban areas. Some urban developments have incorporated WSUD in more recent years, however there is no quantitative information available to verify the estimated current adoption rate shown in Table 5.16, or the effectiveness of the measures. In conjunction with determining baseline management practice adoption rates a detailed analysis of implementation costs and available resources is required to add sufficient rigour to establish a more meaningful set of load reduction targets for the Black Ross (Townsville) WQIP area, especially within the short term i.e. to 2014.

Preliminary work on costs and benefits has been carried out and the results are included in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* report (Gunn and Manning 2010). Additional investigations with partner organisations, and through stakeholder consultation, are planned as part of the WQIP implementation process.

5.8 WATER SENSITIVE URBAN DESIGN (STORMWATER)

The introduction of water sensitive urban design (WSUD) to Townsville is one of the main water quality improvement options planned for the Black Ross (Townsville) WQIP urban areas. The modelled improvements associated with WSUD, shown in section 5.7.1, are based on a set of draft stormwater quality design objectives determined during the preparation of the draft *Water Sensitive Urban Design Technical Design Guidelines for Stormwater Management for the Coastal Dry Tropics (Townsville)* (EDAW 2008). This document along with *Water Sensitive Urban Design for the Coastal Dry Tropics (Townsville): Design Objectives for Stormwater Management* (EDAW 2009), are available at www.creektocoral.org.

WSUD for stormwater addresses the amount and concentration of pollutants that are discharged from ‘established’ urban areas. While soil erosion and sediment movement is the main water quality issue in developing urban areas it is also relevant to the installation of WSUD elements to ensure they function properly after they have been installed. WSUD stormwater quality design objectives come into play, and are expected to be met; only after the WSUD measures are established and operational.

The urban stormwater quality management design objectives adopt a pollutant load reduction approach consistent with the approach recommended in Australian Runoff Quality (Engineers Australia 2005, p1-7) and ANZECC (2000, p 3.3.2) (EDAW 2009), i.e. a load reduction relative to conventional developed areas with no WSUD measures in place.

The draft WSUD stormwater quality management design objectives for Townsville, expressed as a minimum reduction in pollutant loads discharged from developed sites, are:

- Suspended solids (TSS) 80% (less than the site with no WSUD measures),
- Total phosphorus (TP) 65% (less than the site with no WSUD measures),
- Total nitrogen (TN) 40% (less than the site with no WSUD measures),
- Gross pollutants (> 5mm) 90% (less than the site with no WSUD measures).

Calculating the load reductions that can be achieved by installing WSUD elements requires knowledge of the loads that are generated from developed urban catchments without any WSUD elements in place. This generic body of knowledge exists and is used as input to an appropriate catchment model e.g. Model for Urban Stormwater Improvement Conceptualisation (MUSIC); to assess the potential effectiveness of proposed WSUD elements. However, further work is required to determine the most appropriate pollutant runoff coefficients for the Townsville region.

Modelling to determine stormwater quality improvement as a result of inclusion of WSUD elements is carried out during the pre-construction design phase, with the results included in the information submitted as part of the development approval process. Post-construction verification of the effectiveness of in-situ WSUD elements relies on water quality monitoring where both the pollutant concentration and the volume of runoff are measured to calculate the pollutant load (pollutant concentration x volume = pollutant load).

Further information on WSUD options can be found in *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010).

Top: Vegetated swale drains are a water sensitive urban design alternative to concrete pipes.

Bottom: Urban stormwater management starts at the source i.e. our homes and workplaces.

5.9 STORMWATER DESIGN OBJECTIVES FOR DEVELOPING AREAS

The WQOs and load reduction targets described previously relate primarily to developed areas. Developing areas are a different scenario with the potential for significant levels of sediment to be discharged over relatively short timeframes, generally associated with rainfall events (see section 3.7.1).

Neither the ambient WQOs (see section 5.4), nor the load reduction targets associated with the adoption of WSUD and rural management practices (see section 5.7.1), directly address the acute sediment loads generated during the development and construction phases.

A draft event mean concentration (EMC) target for sediment has been defined for developing urban areas for use in addressing the water quality issues associated with erosion and sediment movement (see Table 5.17). While the EMC target is based on local water quality monitoring data (flow events over two wet seasons) ongoing monitoring is required to confirm the target. EMCs for nutrients from the event monitoring are provided in Table 5.17, however targets have not yet been defined.

Table 5.17 Event Mean Concentrations and Sediment Target for Developing Areas

	TSS (mg/L)	Total N (µg/L)	DIN – N (µg/L)	PN – N (µg/L)	Total P (µg/L)	PP – P (µg/L)	FRP – P (µg/L)
Average EMC	476	747	160	198	277	125	130
EMC target	285	-	-	-	-	-	-

Notes: The EMC target for developing urban areas was derived by summing and averaging three of four event mean concentrations derived from event water quality monitoring samples taken from waterways of the developing coastal plains in Townsville (the highest value outlier was discarded). The average EMC value was then reduced by 40% to arrive at the event mean concentration water quality target. The 40% reduction is an approximation of theoretic potential reductions based on current best management practice incorporated in existing regulations for erosion and sediment control (pers. comm. Tony Weber – BMT WBM).

TSS is total suspended solids (sediment), N is nitrogen, P is phosphorus, DIN is dissolved inorganic nitrogen, PN is particulate nitrogen, PP is particulate phosphorus, and FRP is filterable reactive phosphorus.

5.10 AQUATIC ECOSYSTEM HEALTH

While physico-chemical properties are important for waterway health there are a number of other physical and biological factors that impact aquatic ecosystem health that can be readily measured and contribute to our understanding of water quality issues and areas for improvement.

A draft water quality report card has been developed as part of the Black Ross (Townsville) WQIP and includes a number of indicators that are relevant to aquatic ecosystem health. The key indicators for the report card are grouped into the following categories:

1) Water quality (physico-chemical);
2) Freshwater fish (aquatic ecosystem);
3) Aquatic invertebrates (aquatic ecosystem);
4) Aquatic vegetation (aquatic ecosystem);
5) Riparian vegetation (catchment condition);
6) Channel and floodplain features (catchment condition).

While all groupings can be related to aquatic ecosystem health, the three principal indicator groups are freshwater fish, aquatic invertebrates and aquatic vegetation. Flow regime modification is also a critical factor for aquatic ecosystem health particularly in perennial streams. Aquatic ecosystems of ephemeral streams are probably less susceptible to impacts of flow modification as they are adapted to the seasonal variations of high and no flow. This is of course a generalisation and flow modification can also be detrimental to ephemeral systems.

While some studies have been done that are relevant to aquatic ecosystem health the range of available information has not been collated for the Black Ross (Townsville) WQIP area as yet. In the absence of current condition information and local aquatic ecosystem health guidelines the generic aquatic ecosystem health target, for waterways not already at the top grade, is to improve the current condition of waterways by at least one report card grade (see Connell Wagner 2009) for a minimum of one out of the six indicator groups by 2014. For waterways already at the top grade, the intent is to maintain the grade.

5.10.1 ENVIRONMENTAL FLOW

Environmental flow is a term used to express the amount/proportion of the natural flow of a watercourse required to maintain aquatic habitat health and ecological function in waterways and waterbodies. While environmental flow is usually related to regulated waterways where there are impoundments, environmental flow also applies to unregulated waterways where water entitlements allow landowners to extract water for irrigation and other purposes.

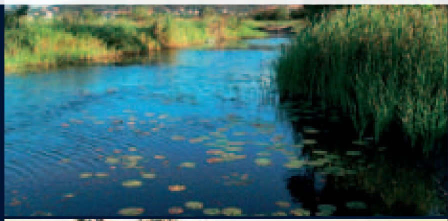
There are two regulated systems in the Black Ross (Townsville) WQIP area: Ross River and Crystal Creek. Both systems are the subject of an Interim Resource Operations Licence (IROL) under the *Water Act 2000* (Qld), which provide for the release of water for environmental purposes (see Gunn, Manning and McHarg 2009 for more detail).

The remainder of the Black Ross (Townsville) WQIP area is subject to the general provisions of the Water Act with regard to taking water from a watercourse or other waterbody. If a landowner wants to take water from a stream, lake or other waterbody they are required to apply to DERM (formerly the Department of Natural Resources and Water) for a water licence. These water licences are now subject to conditions whereby the stream must have a certain flow before water can be extracted.

For unregulated systems the aquatic ecosystem health target is to maintain stream flow at greater than 80 per cent of natural flow. Flow related objectives are also included in the WSUD stormwater management design objectives.

Top: While dams disrupt natural environmental flows they also reduce the impacts of flooding in urban areas.

Bottom: Water can be drawn from unregulated streams as long as there is more than enough water to meet environmental flows (Crystal Creek).



Many of the management actions associated with Townsville's WQIP focus on urban areas and reducing the impacts of development. Supporting communities of interest is the key to successful implementation.

SECTION 6

Water Quality Improvement Management Actions

6

6. WATER QUALITY IMPROVEMENT MANAGEMENT ACTIONS

6.1 INTRODUCTION

Management options were identified that have the potential to improve water quality in line with the environmental values identified by the community, and to work towards achievement of the water quality objectives and load reduction targets identified in the previous section. The options were considered on the basis of:

- Likely water quality improvement outcomes (based on previous experiences, scientific evidence and catchment modelling results);
- Potential for integration with existing programs and projects;
- Value for money;
- Social acceptability; and
- Practicality of implementation i.e. available resources and timeframes.

Information about the management options considered including associated costs and benefits can be found in the report titled *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010).

To better facilitate land based management practice improvements, the Black Ross (Townsville) WQIP area has been grouped by land use and development stage (see section 3). It became apparent during the development of the WQIP that the peri-urban 'zone', including rural residential areas in close proximity to the urban areas, should be classified as a separate major land use category so that peri-urban specific issues could be addressed using appropriate measures.

While many of the management actions are directed at specific land uses and stages of development, some of the management actions will be common to the whole of the Black Ross (Townsville) WQIP area. This section provides an overview of the management areas and management action targets selected for urban, peri-urban and rural areas as well as supportive and enabling, cross-catchment and cross-land use activities. The specific management actions selected to achieve the management outcomes and management action targets are included in Appendix 1.

SECTION 6

6.2 PRIORITY MANAGEMENT ACTIONS

Priority actions have been selected to address the issues that have the most impact on water quality in the urban, peri-urban and rural environments. The priority actions have been proven to be effective locally or in other parts of Australia, are based on available sound science and are considered to be the best value in terms of benefits for water quality improvement (see Gunn and Manning 2010). Priority management actions are listed in Appendix 1 (Implementation actions) under their respective management outcomes, management action targets and associated management areas.

Where there was a moderate to high uncertainty about the potential benefit or practicality of implementing management options initial WQIP implementation actions have been based on:

Top: Industrial and commercial sites require different management actions to residential areas.

Bottom: A combination of 'hard' and 'soft' infrastructure is required to manage stormwater runoff.

- Gathering additional data to determine the magnitude of the issue and the potential benefits of interventions in relation to the issue,
- Feeding 'new' information into models such as the Bayesian Belief Network to identify the best management interventions on a catchment basis,
- Undertaking socio-economic studies to determine the most effective course of action to achieve a particular behaviour change i.e. the uptake of water quality improvement management practices, and
- Determining the effectiveness of interventions through pilot programs and demonstration studies.

Priority management actions have been initially grouped to coincide with the major land use categories (urban, peri-urban and rural) they influence with further divisions based on development stage and more specific land use e.g. water supply catchment.

The main enabling actions, designed to increase capacity to undertake on-ground actions and influence behaviour change, have been listed separately as the actions are generally not specific to a particular land use. The priority management action topics are discussed below with reference to the main land use categories. An action priority and relevance rating for each major land use is provided in Table 6.1.

Table 6.1 Priority Management Action Areas

No.	Action area	Rural and Peri-urban: Grazing	Rural and Peri-urban: Intensive agriculture	Rural and Peri-urban: Natural areas	Rural and Peri-urban: Ross Dam catchment	Rural and Peri-urban: Peri-urban	Urban: Urban (diffuse)	Urban: Urban (point source)
1	Erosion and sediment control (ESC) for development	O	L	O	H	H	H	O
2	Site based stormwater management plans (SBSMP) for development	O	O	O	H	H	H	O
3	Water sensitive urban design (WSUD) guideline finalisation and adoption	O	O	O	M	H	H	L
4	Total water cycle management plan (TWCMP) and urban stormwater quality management plan integration	O	O	O	L	M	H	O
5	Urban stormwater treatment trains	O	O	O	O	L	H	O
6	WSUD retrofit	O	O	O	O	H	H	O
7	Develop peri-urban catchment management guidelines and implementation activities	M	M	L	H	H	L	O
8	Water resource catchment management (Ross River Dam)	H	M	L	H	H	M	O
9	Promote "Managing for WQ within grazing lands of the Burdekin Catchment" (NQ Dry Tropics)	H	O	L	H	M	O	O
10	Promote management practice ABCD framework for sugar cane and horticulture (approach to be determined)	O	H	O	M	M	L	O
11	Legislation and governance	L	L	L	H	H	H	M
12	Policy investigations and development	L	M	L	H	H	H	M
13	Planning scheme studies and instruments review (for the new Townsville planning scheme)	M	M	M	H	H	H	L
14	Strategic landscape mapping and habitat prioritisation	H	H	H	H	H	H	L
15	Population growth and climate change considerations	M	M	M	H	H	H	H
16	Condition assessment and prioritisation	H	H	M	H	H	H	L
17	Community based education and involvement (CBEI) (awareness and capacity building)	M	M	L	H	H	H	L
18	Reef Guardian Councils implementation	O	O	O	L	H	H	H
19	Social learning and behaviour change studies (for determining effective management interventions)	M	M	L	H	H	H	L
20	Market based instruments investigation	L	L	L	H	H	H	L
21	Riparian zone rehabilitation	H	M	M	M	H	H	O
22	Wetland restoration and construction	M	M	M	M	H	H	O
23	Aquatic ecosystem health improvement	H	H	M	H	H	H	L
24	Integrated water quality monitoring and modelling (IWQM and M) including local WQGs	H	H	H	H	H	H	H
25	Integration, communication, monitoring, evaluation and adaptive management	M	M	M	H	H	H	M

Notes: H is high priority activity, M is medium priority activity ( ), L is low priority activity, O is not relevant or very low priority. Colour coding denotes the principal land use 'style' associated with high priority activity (= rural, = peri-urban, = urban). There will be overlap into peri-urban areas from rural and urban land uses

SECTION 6

A diagram of the conceptual relationships between the main WQIP management actions is provided as Figure 6.1.

6.2.1 PROJECT MANAGEMENT

Project management and coordination, communications and information management are overarching enabling 'administrative' actions required for implementation of the WQIP. Creek to Coral (Townsville City Council) will manage the implementation of the Black Ross (Townsville) WQIP using an integrative and assimilative approach similar to that used to prepare the WQIP.

To make project management of the WQIP more effective, an adaptive management and planning approach (continuous improvement) will be used to implement this WQIP. This approach will be closely linked to the communication strategy and management system to assist with data and information management to enhance the overall adaptive management framework.

6.2.2 PROJECT FINANCE

While the preparation of the Black Ross (Townsville) WQIP received considerable financial support from the Australian Government through the Coastal Catchments Initiative program, the implementation phase has not received funding through the 'new' Caring for Our Country (CFOC) program or the CFOC Reef Rescue sub-program. As a result, the ability to implement the Black Ross (Townsville) WQIP in a reasonable timeframe has been reduced and water quality targets have been revised to reflect the forecast level of support provided for the implementation stage.

Top: The Lakes are an urban water 'feature' requiring management to maintain water quality.

Bottom: Urban wetlands are important in filtering water quality pollutants.

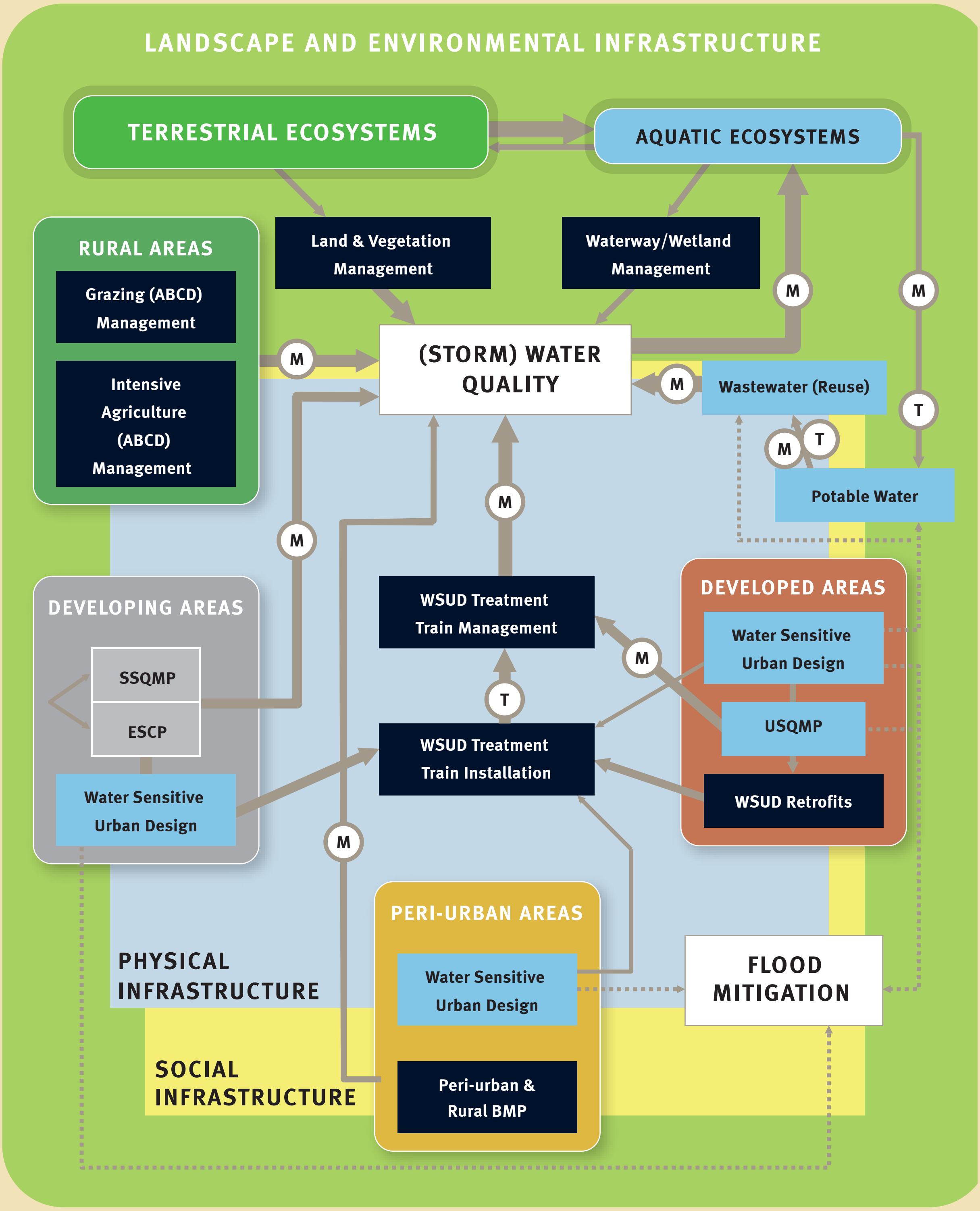
Townsville City Council will proceed with implementation of priority Black Ross (Townsville) WQIP management actions at a pace commensurate with available core funding, while continuing to explore co-funding opportunities.

The emphasis will be on improving internal program coordination to achieve integrated water quality and aquatic ecosystem health outcomes across all Council departments and areas of responsibility. Additional efforts will be made to strengthen partnerships with Queensland and Australian government agencies, industry and community groups to deliver water quality improvement outcomes in a coordinated and cooperative approach, as with other Creek to Coral initiatives.

In the event that funds are secured to implement unresourced elements in the Black Ross (Townsville) WQIP then the water quality targets will be reviewed in terms of the resources available for implementation and amended accordingly.

For more detail on management options and costs of implementation see *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010).

Figure 6.1 WQIP Components Relationships



Notes: Solid lines indicate physical linkages between components with the thickness indicating the assumed or potential magnitude of the influence. Broken lines indicate conceptual linkages between components i.e. policy and planning. SBSMP is site based stormwater management plan. ESCP is erosion and sediment control plan and measures. BMP is best (available at the time) management practice. ABCD is a management practice framework for identifying, implementing and measuring BMP and BMP uptake. WSUD is water sensitive urban design. (M) indicates potential water quality monitoring points. (T) is human instigated water treatment e.g. raw water to potable water. Natural water 'treatment' e.g. riparian zone filtering, which occurs in natural systems and peri-urban and rural areas has not been noted on the diagram.

6.3 URBAN WATER QUALITY MANAGEMENT

Management of urban water quality can firstly be separated into issues associated with point sources and diffuse sources.

Point source pollutants are reasonably easy to address in terms of management actions as the issue is relatively well defined and management options are also well known. As with most infrastructure based solutions one of the main considerations is cost. The subject has been comprehensively studied and reviewed by the current and past Councils so point source pollutants are only discussed briefly.

The Townsville urban setting is enhanced by its water features.

Diffuse sources of urban water pollutants are more diverse and consequently involve a wider range of management interventions, including a greater emphasis on people based solutions. Therefore urban diffuse management actions often include communication and training as key components for behaviour change.

The priority management actions for reducing urban diffuse water quality pollutant loads are based on the stage of development, or level of 'maturity', of urban areas and are designed to address:

- The short-term sediment load 'spikes' from developing areas; and
- The longer-term leakage of sediment and nutrients from developed urban areas.

A brief introductory discussion is included with each set of management action targets below. The management actions associated with the management action targets are listed in Appendix 1.

For more detail on management options and costs of implementation see the background report titled *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010).

6.3.1 POINT SOURCE

Wastewater treatment plants are the main point source contributor of water quality pollutants in the Black Ross (Townsville) WQIP area with direct discharge of treated effluent to the Black River, Bohle River and Stuart Creek sub basins. The management actions to reduce point source pollutant loads are listed in the text box below along with any relevant reduction targets associated with treatment plant upgrades.

For additional information on point source pollutant emitters in the Black Ross (Townsville) WQIP area refer to *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan* (Gunn and Barker 2009).

Management of point source pollution (wastewater treatment plants)

To ensure pollutants from point sources in Townsville are managed appropriately to reduce the impact on receiving waters to acceptable levels, the following management actions will be undertaken.

Wastewater treatment plant upgrades

As a result of plant upgrades and associated measures, by 2012 total wastewater treatment plant pollutant loads will be reduced from 2006 loads by:

- 75% for total nitrogen (225 tonnes/yr)
- 65% for total phosphorus (48 tonnes/yr).

This will ensure that all wastewater treatment plants in Townsville meet DERM (EPA) revised permit requirements.

Reuse

Other options for 'fit for purpose' uses of treated wastewater are investigated through Townsville's Integrated Water Supply Strategy (IWSS) and implemented as appropriate.

(For additional information on wastewater treatment strategies and future actions refer to GHD 2009, *Townsville Integrated Water Supply Strategy Stage 1 Assessment*, Townsville City Council (Townsville Water), Townsville.)

Maintenance

All water quality improvement devices are managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained.

Sewer system management

Sewer networks are managed appropriately and infrastructure is upgraded in order to minimise wet weather overflows and to achieve zero dry weather overflows.

Treatment plant residue management

Options to reduce the potential impact of wastewater concentrates, toxicants, disinfection residuals, biosolids and salt loads are investigated and implemented where appropriate.

Other point sources

Ensure new and emerging point source issues are identified and addressed in a timely manner.

6.3.2 DEVELOPING URBAN AREAS

The main water quality pollutant issue associated with developing areas is soil erosion and the subsequent movement of sediment to waterways. This is particularly relevant to development on sloping sites; however, it is also an issue on floodplains and flat sites especially in close proximity to waterways.

The other essential component for developing urban areas is to ensure pre-development design i.e. water sensitive urban design (WSUD), incorporates water quality improvement measures for post-development outcomes.

As an adjunct to the preparation of the Black Ross (Townsville) WQIP, a set of draft WSUD products were developed for the Townsville region. These products include:

- WSUD Strategy Roadmap - a web based navigation tool to assist access to information and resources relevant to the application of WSUD in the coastal dry tropics;
- WSUD draft design objectives for the dry tropics;
- Draft *WSUD Technical Design Guidelines for the Coastal Dry Tropics*; and
- Factsheets;
    - Factsheet - Concepts and Terms,
    - Factsheet - WSUD in the Dry Tropics,
    - Factsheet - Site Planning and Urban Design,
    - Factsheet - Industrial and Commercial Sites,
    - Factsheet - Car parks,
    - Factsheet - Porous Pavement, and
    - Factsheet - Best Management Practices.

The management action targets (MATs) for developing areas are listed in Table 6.2. The priority management actions to achieve the MATs, including the testing and implementation of the WSUD components, are listed in Appendix 1. The management actions may also be relevant to 'urban' style development in rural and peri-urban areas, as the general principles are the same.

Table 6.2 Urban Diffuse Developing Areas

Management of development in urban and peri-urban areas **MANAGEMENT OUTCOME 1:**	
To ensure all new development in Townsville is managed appropriately to achieve agreed water quality improvement outcomes including sediment load reductions	
MAT 1.1	Erosion and sediment control principles and measures implemented across all new development by 2011
MAT 1.2	Locally specific guidelines and associated tools developed to support the implementation of best practice stormwater management in Townsville by 2013
MAT 1.3	Water sensitive urban design (stormwater) principles and actions are progressively incorporated in the design of all new development reaching a 100 per cent adoption rate by 2021
MAT 1.4	By 2014 locally specific water sensitive urban design guidelines and associated tools developed and tested to support the implementation of best practice stormwater management in Townsville

6.3.3 DEVELOPED URBAN AREAS

Developed urban areas have the same water quality pollutants as developing areas i.e. sediment and nutrients, although the relative contribution of nutrients is greater and sediment generation rates are lower on an areal basis for developed areas. In comparison to rural areas, developed urban areas also have additional issues and pollutants specific to these more heavily populated and intensive land use environments e.g. 'backyard' nutrients, residential and industrial waste and transport infrastructure.

The key strategic management approach to water quality improvement applied to developed urban areas is urban stormwater quality management (USQM). This is a broad action area and includes the incorporation of WSUD principles into existing urban areas.

Mature developed urban areas often don't have WSUD features, as the main intent of 'older' stormwater management systems was to remove rainfall runoff from urban areas as quickly as possible as part of flood mitigation measures. The space available to retrofit established stormwater management systems with water quality treatment measures is often limited in mature urban areas and the cost of land acquisition can be prohibitive. It may be more cost effective to investigate and develop actions that target the source of pollutant loads rather than invest in expensive retrofits that may have limited ability to address the issues.

Management action targets associated with mature urban areas are listed in Table 6.3. Much of the subsequent management action detail associated with these urban areas will result from the preparation of a new city-wide urban stormwater quality management plan (USQMP) and associated investigations and studies. Management actions to achieve the MATs are listed in Appendix 1.

Along with the requirements under the *Environmental Protection (Water) Policy 2009* to prepare a USQMP for Townsville, the water policy also requires Councils with more than 10,000 residents to prepare a total water cycle management plan (TWCMP). USQMPs are included as a sub component of the TWCMP.

Table 6.3 TWCMP, USQMP and Retrofits

Management of existing urban areas MANAGEMENT OUTCOME 2:	
To ensure the existing urban areas of Townsville are managed appropriately in order to achieve agreed water quality improvement outcomes including sediment, nutrient and other pollutant load reductions	
MAT 2.1	One waterway management and rehabilitation plan for priority urban waterways developed annually commencing in 2010 with implementation actions underway by 2011
MAT 2.2	Best practice erosion and sediment control principles and actions being implemented across all infill and retrofit development by 2011
MAT 2.3	Options investigated, areas prioritised and implementation plan developed for retrofit of appropriate water quality improvement devices into community infrastructure by 2012
MAT 2.4	An integrated draft urban stormwater quality management plan for the Townsville City Council LGA prepared by 2013, as a sub component of a Total Water Cycle Management Plan for Townsville
MAT 2.5	All water quality improvement devices managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained
MAT 2.6	Stormwater quality service levels agreed and incorporated into strategic infrastructure planning (Priority Infrastructure Plan) by 2012

For more detail on the USQMP process as well as management options and costs of implementation see the background report titled *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010).

6.4 PERI-URBAN MANAGEMENT ACTIONS

While being strategically important from both the short and long-term water quality perspective there is a paucity of information associated with local peri-urban areas, which comprise around 30 per cent of the Black Ross (Townsville) WQIP area.

Along with application of the relevant management actions for developing urban areas, the main management actions associated with the peri-urban landscape involve the quantification and prioritisation of water quality issues, behaviour change investigations and the development of guidelines and programs based on knowledge acquired from investigations. The principal peri-urban specific management action targets are listed in Table 6.4. Associated management actions are included in Appendix 1.

Table 6.4 Peri-urban Management Action Targets for Water Quality Improvement

Management of peri-urban areas **MANAGEMENT OUTCOME 3:**	
To ensure all peri-urban areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment, nutrients and pesticide load reductions	
MAT 2.5	All water quality improvement devices managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained
MAT 3.1	A locally relevant catchment management plan and/or guidelines for managing peri-urban land use for water quality improvement prepared by 2012
MAT 3.2	Peri-urban diffuse source pollutant loads reduced through cost effective approaches to the management of priority pollutant source areas
MAT 3.3	All on-site wastewater treatment facilities (including septic tanks) managed according to approved best management practice over the life cycle of the asset
MAT 3.4	Best practice management actions being implemented within the catchment of the Ross Dam to ensure the improvement in the quality of water draining into Lake Ross

While not entirely comprised of peri-urban land uses the Ross River Dam catchment is heavily influenced by peri-urban activities especially in the vicinity of the water storage area. The main actions associated with protecting the water quality of the Ross Dam to meet management action target MAT 3.4 (see Table 6.4) are listed in Appendix 1. Where appropriate rural management practice actions will be adopted as for other rural land uses in the Black Ross (Townsville) WQIP area.

Lake Ross catchment has a combination of rural and peri-urban land uses requiring special management measures to protect the quality of Townsville's water supply.

Rural management primarily for grazing

6.5 RURAL MANAGEMENT ACTIONS

Rural management actions are based on the predominant land use activity i.e. grazing, sugar cane and horticulture. The main management actions involve adaptation and/or promotion of the management practices that have been identified in the preparation of rural based WQIPs in the Burdekin, Mackay-Whitsunday and Tully regions. Rural management action targets are listed in Table 6.5 with the associated implementation actions listed in Appendix 1.

Table 6.5 Rural Management Action Targets for Water Quality Improvement

Management of rural areas **MANAGEMENT OUTCOME 4:**	
To ensure all rural areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment load reductions from grazing lands and nutrient and pesticide load reductions from intensive agricultural land use	
MAT 4.1	Grazing best practice programs being implemented in the rural areas of Townsville
MAT 4.2	Intensive agriculture (horticulture and sugar cane cropping) best practice management actions being implemented within rural and peri-urban catchments across Townsville
MAT 4.3	Non-urban diffuse source pollutant loads reduced through cost effective approaches to erosion prevention and property management in priority sediment source catchments

6.6 ENABLING MANAGEMENT ACTIONS

Enabling management actions consist of a number of interrelated tasks, which can be implemented sequentially if necessary but would be most effective if implemented in parallel.

6.6.1 POLICY AND STRATEGIC PLANNING

The first set of enabling management actions involve some form of policy or governance arrangements, which in terms of local government often overlap with regulatory roles and functions through planning schemes and the development assessment process.

Policy, governance arrangements and regulatory functions all need to have access to the most relevant information from the biophysical and socio-economic realms. The policy and governance management actions (see Appendix 1) to achieve the strategic planning management action targets (see Table 6.6) include strategic planning studies and integration of natural asset assessment. The actions are closely linked to condition assessment and behaviour change investigations in subsequent sections.

Table 6.6 Policy and Governance Management Action Targets

Strategic planning **MANAGEMENT OUTCOME 5:**	
To ensure relevant water quality improvement initiatives, information and activities are investigated and integrated where appropriate into Council strategic policy and planning instruments	
MAT 5.1	Appropriate water quality improvement actions integrated with the draft Townsville City Council Planning Scheme by 2014
MAT 5.2	Regulatory, policy and land use planning frameworks across all levels of government support the enhanced adoption of water quality improvement actions in Townsville
MAT 5.3	A Total Water Cycle Management Plan (TWCMP) developed for Townsville linking stormwater, wastewater, potable water and waterway management

6.6.2 CONDITION ASSESSMENT AND MAPPING

Natural asset condition assessment and mapping, combined with socio-economic data, underpins appropriate decision making and policy development. During the preparation of the Black Ross (Townsville) WQIP, a number of information gaps were identified along with areas where greater coordination and integration of information resources could result in more cost effective outcomes. The management actions (see Appendix 1) revolve around filling the information gaps to enable the management action targets in Table 6.7 to be achieved.

Table 6.7 Condition Assessment and Mapping

Ecosystem health improvement MANAGEMENT OUTCOME 6:	
On-ground actions are prioritised for improving water quality and ecosystem health	
MAT 6.1	Condition assessment studies progressed by 2011 to enable prioritisation of on-ground works
MAT 6.2	Traditional Owner waterway and water quality values are incorporated into planning and implementation of management actions
MAT 6.3	Priority (no regrets) on-ground works for water quality and ecosystem health improvement underway by 2010

6.6.3 ON-GROUND ACTIONS

While the largest gains in water pollutant load reductions are likely to be realised from improved management practices, there are also potential gains from on-ground actions, which stabilise waterways, increase groundcover and assist with erosion prevention. There may also be some water quality benefits derived from rehabilitated riparian zones and the subsequent natural filtering of sediment and nutrients. Prior to any on-ground works, a rigorous prioritisation process needs to be undertaken to ensure the benefits derived will be worthwhile. On-ground actions are listed in Appendix 1 to meet MAT 6.3 in Table 6.7.

Top: Wetlands require management and maintenance.

Bottom: Behaviour change reduces End of Pipe Solutions.

6.6.4 SOCIO-ECONOMIC AND BEHAVIOURAL ACTIONS

In the realm of energy use and waste management it is less expensive to reduce demand or the need for disposal facilities than to construct new infrastructure. The same concept applies to water pollutant load reduction i.e. reduction at the source through behaviour change is less costly than installing physical infrastructure.

Townsville City Council has a range of community based education and involvement (CBEI) initiatives in place, which promote catchment management outcomes and people based solutions to environmental issues. More recently a number of behaviour change approaches have been added to the CBEI toolkit to accelerate the uptake of sustainability practices.

Behaviour change strategies can be used in most situations where people are involved including in the mature urban environment to reduce the need for expensive infrastructure retrofits. In developing environments behaviour change strategies would be used as a precursor to the development of effective strategies and programs to encourage the uptake of erosion and sediment control and WSUD measures (see Gunn 2010). The main behaviour change targets are listed in Table 6.8.

Table 6.8 Socio-economic and Behavioural Actions

Community involvement and capacity **MANAGEMENT OUTCOME 7:**	
All sectors of the Townsville community have access to the information and training required to contribute to implementation of relevant water quality improvement actions in the Black Ross WQIP area	
MAT 7.1	Community involvement in water quality improvement is supported through continuation of Townsville's community based education and involvement program
MAT 7.2	Locally relevant training and information provision programs developed and delivered to relevant sector groups based on the identified and agreed priority actions
MAT 7.3	Best practice management and measures being implemented in the home and workplace as a result of programs developed using behaviour change study results
MAT 7.4	Best practice market based incentive options investigated for water quality improvement in Townsville by 2011

6.6.5 WATER QUALITY MONITORING AND MODELLING

Water quality monitoring and modelling is used not only for measuring success but also to guide management actions as a key component of the adaptive management strategy. Additional information is provided in section 7.2 with priority actions listed in Appendix 1 to achieve management action target MAT 8.1 (see Table 6.9).

Table 6.9 Water Quality Monitoring and Modelling Actions

Monitoring, evaluation and reporting **MANAGEMENT OUTCOME 8:**	
To ensure water quality improvement actions are effective in improving water quality and results are communicated appropriately to the Townsville community	
MAT 8.1	A comprehensive monitoring, modelling and evaluation program developed and being implemented as part of the ongoing adaptive planning and management framework of the Black Ross (Townsville) WQIP (includes Integrated Water Quality Monitoring and Modelling Program)
MAT 8.2	Knowledge and information requirements are identified and prioritised for major sector groups by 2010
MAT 8.3	Opportunities identified to invest in research to develop and assess the performance of water quality improvement actions in the Townsville region
MAT 8.4	An integrated report card developed to communicate the progressive outcomes from the implementation of the Black Ross (Townsville) WQIP, including achievement of water quality improvement targets
MAT 8.5	An effective cross regional Reef urban water quality improvement group contributes to water quality improvement outcomes for all local governments in the Great Barrier Reef Catchment

6.6.6 COMMUNICATION PLUS

Good communications and management systems along with coordinated and integrated actions are critical to the success of the Black Ross (Townsville) WQIP. The main strategic actions are listed in Appendix 1 to achieve the management action targets listed in Table 6.9. Additional information is provided in the following section (section 7 Progress Reporting and Adaptation).

There are many forms of communication for different purposes.

6.7 MANAGEMENT ACTION TARGETS SUMMARY

A summary of all the diffuse source water quality pollutant management outcomes and management action targets from the sections above is provided in Table 6.10.

TABLE 6.10 MANAGEMENT ACTION TARGETS

Management of development in urban and peri-urban areas **MANAGEMENT OUTCOME 1:** *To ensure all new development in Townsville is managed appropriately to achieve agreed water quality improvement outcomes including sediment load reductions*	
MAT 1.1	Erosion and sediment control principles and measures implemented across all new development by 2011
MAT 1.2	Locally specific guidelines and associated tools developed to support the implementation of best practice stormwater management in Townsville by 2013
MAT 1.3	Water sensitive urban design (stormwater) principles and actions are progressively incorporated in the design of all new development reaching a 100 per cent adoption rate by 2021
MAT 1.4	By 2014 locally specific water sensitive urban design guidelines and associated tools developed and tested to support the implementation of best practice stormwater management in Townsville
Management of existing urban areas **MANAGEMENT OUTCOME 2:** *To ensure the existing urban areas of Townsville are managed appropriately in order to achieve agreed water quality improvement outcomes including sediment, nutrient and other pollutant load reductions*	
MAT 2.1	One waterway management and rehabilitation plan for a priority urban waterways developed annually commencing in 2010 with implementation actions underway by 2011
MAT 2.2	Best practice erosion and sediment control principles and actions being implemented across all infill and retrofit development by 2011
MAT 2.3	Options investigated, areas prioritised and implementation plan developed for retrofit of appropriate water quality improvement devices into community infrastructure by 2012
MAT 2.4	An integrated draft urban stormwater quality management plan for the Townsville City Council LGA prepared by 2013, as a sub component of a Total Water Cycle Management Plan for Townsville
MAT 2.5	All water quality improvement devices managed and maintained appropriately over the life cycle of the asset to ensure treatment efficiencies are maintained
MAT 2.6	Stormwater quality service levels agreed and incorporated into strategic infrastructure planning (Priority Infrastructure Plan) by 2012
Management of peri-urban areas **MANAGEMENT OUTCOME 3:** *To ensure all peri-urban areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment, nutrients and pesticide load reductions*	
MAT 3.1	A locally relevant catchment management plan and/or guidelines for managing peri-urban land use for water quality improvement prepared by 2012
MAT 3.2	Peri-urban diffuse source pollutant loads reduced through cost effective approaches to the management of priority pollutant source areas
MAT 3.3	All on-site wastewater treatment facilities (including septic tanks) managed according to approved best management practice over the life cycle of the asset
MAT 3.4	Best practice management actions being implemented within the catchment of the Ross Dam to ensure the improvement in the quality of water draining into Lake Ross

Management of rural areas **MANAGEMENT OUTCOME 4:**	
To ensure all rural areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment load reductions from grazing lands and nutrient and pesticide load reductions from intensive agricultural land use	
MAT 4.1	Grazing best practice programs being implemented in the rural areas of Townsville
MAT 4.2	Intensive agriculture (horticulture and sugar cane cropping) best practice management actions being implemented within rural and peri-urban catchments across Townsville
MAT 4.3	Non-urban diffuse source pollutant loads reduced through cost effective approaches to erosion prevention and property management in priority sediment source catchments
Strategic planning **MANAGEMENT OUTCOME 5:**	
To ensure relevant water quality improvement initiatives, information and activities are investigated and integrated where appropriate into Council strategic policy and planning instruments	
MAT 5.1	Appropriate water quality improvement actions integrated with the draft Townsville City Council Planning Scheme by 2014
MAT 5.2	Regulatory, policy and land use planning frameworks across all levels of government support the enhanced adoption of water quality improvement actions in Townsville
MAT 5.3	A Total Water Cycle Management Plan (TWCMP) developed for Townsville linking stormwater, wastewater, potable water and waterway management
Ecosystem health improvement **MANAGEMENT OUTCOME 6:**	
On-ground actions are prioritised for improving water quality and ecosystem health	
MAT 6.1	Condition assessment studies progressed by 2011 to enable prioritisation of on-ground works
MAT 6.2	Traditional Owner waterway and water quality values are incorporated into planning and implementation of management actions
MAT 6.3	Priority (no regrets) on-ground works for water quality and ecosystem health improvement underway by 2010
Community involvement and capacity **MANAGEMENT OUTCOME 7:**	
All sectors of the Townsville community have access to the information and training required to contribute to implementation of relevant water quality improvement actions in the Black Ross WQIP area	
MAT 7.1	Community involvement in water quality improvement is supported through continuation of Townsville's community based education and involvement program
MAT 7.2	Locally relevant training and information provision programs developed and delivered to relevant sector groups based on the identified and agreed priority actions
MAT 7.3	Best practice management and measures being implemented in the home and workplace as a result of programs developed using behaviour change study results
MAT 7.4	Best practice market based incentive options investigated for water quality improvement in Townsville by 2011
Monitoring, evaluation and reporting **MANAGEMENT OUTCOME 8:**	
To ensure water quality improvement actions are effective in improving water quality and results are communicated appropriately to the Townsville community	
MAT 8.1	A comprehensive monitoring, modelling and evaluation program developed and being implemented as part of the ongoing adaptive planning and management framework of the Black Ross (Townsville) WQIP (includes Integrated Water Quality Monitoring and Modelling Program)
MAT 8.2	Knowledge and information requirements are identified and prioritised for major sector groups by 2010
MAT 8.3	Opportunities identified to invest in research to develop and assess the performance of water quality improvement actions in the Townsville region
MAT 8.4	An integrated report card developed to communicate the progressive outcomes from the implementation of the Black Ross (Townsville) WQIP, including achievement of water quality improvement targets
MAT 8.5	An effective cross regional Reef urban water quality improvement group contributes to water quality improvement outcomes for all local governments in the Great Barrier Reef Catchment

The management action targets (MATs) listed in the tables above are often associated with a number of "Action areas" (see Table 6.1). The associations, or linkages, between the MATs and the Action areas are shown in Table 6.11.

Table 6.11 Action Area and MAT Associations

Target	Action area																								
	1 ESC	2 SBSMP	3 WSUD	4 TWCMP and USQMP	5 Treatment trains	6 WSUD retrofit	7 Peri-urban Guide	8 Ross Dam catchment	9 Grazing BMP	10 Agriculture BMP	11 Governance	12 Policy	13 Planning Scheme	14 Landscape mapping	15 Population and CC	16 Condition assessment	17 CBEI	18 Reef Guardians	19 Behaviour change	20 MBI	21 Riparian rehabilitation	22 Wetland restoration	23 Aquatic ecosystems	24 IWQ M and M	25 Communication plus
MAT 1.1	✔																								
MAT 1.2		✔																							
MAT 1.3			✔	✔		✔					✔	✔	✔	✔	✔										
MAT 1.4			✔																						
MAT 2.1													✔	✔		✔					✔	✔	✔		
MAT 2.2	✔			✔																					
MAT 2.3					✔	✔																			
MAT 2.4	✔	✔	✔	✔	✔	✔					✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
MAT 2.5			✔	✔	✔	✔	✔																		
MAT 2.6			✔	✔								✔	✔										✔		
MAT 3.1							✔																		
MAT 3.2							✔									✔					✔	✔	✔	✔	✔
MAT 3.3							✔																		
MAT 3.4							✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
MAT 4.1									✔								✔		✔	✔	✔	✔	✔	✔	✔
MAT 4.2										✔							✔		✔	✔	✔	✔	✔	✔	✔
MAT 4.3							✔	✔	✔	✔						✔	✔		✔	✔	✔	✔	✔	✔	✔
MAT 5.1	✔	✔	✔	✔			✔	✔			✔	✔	✔	✔	✔	✔		✔							
MAT 5.2											✔	✔	✔	✔	✔										
MAT 5.3	✔	✔	✔	✔	✔	✔	✔	✔			✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
MAT 6.1																✔									
MAT 6.2											✔	✔	✔	✔	✔	✔	✔	✔			✔	✔	✔	✔	
MAT 6.3																✔					✔	✔	✔		
MAT 7.1																	✔								
MAT 7.2	✔	✔	✔				✔	✔	✔	✔							✔	✔	✔		✔	✔	✔	✔	
MAT 7.3																		✔		✔					
MAT 7.4																	✔	✔	✔	✔					
MAT 8.1																								✔	✔
MAT 8.2																	✔		✔					✔	
MAT 8.3																								✔	✔
MAT 8.4																✔								✔	✔
MAT 8.5	✔	✔	✔															✔						✔	✔

There is significant overlap between the MATs and the Action areas illustrating the integrated nature of water quality improvement activities and the potential for achieving a number of objectives, at least in part, through a variety of actions. Delivering the Black Ross (Townsville) WQIP to achieve the proposed targets would work best through a systematic approach, which takes all the Action areas into consideration. A key component of the implementation strategy is adaptive planning and management to ensure the most effective outcomes are achieved with available resources.

6.8 COST OF IMPROVED WATER QUALITY AND ECOSYSTEM HEALTH

The actions associated with the Black Ross (Townsville) WQIP can be roughly divided into two primary groups:

1. Actions that can be implemented with confidence of results being achieved;
2. Actions designed to establish priority areas for future action and the most effective methods of water quality improvement beyond the known.

A summary of estimated costs to deliver the WQIP for the period 2009 to 2014 is provided in Table 6.12. These are indicative costs only and do not reflect the funding available for implementation. The majority of the actions are not funded or only partly funded at this stage.

For further information on costs and benefits refer to *Black Ross Water Quality Improvement Plan Options, Costs and Benefits* (Gunn and Manning 2010).

Table 6.12 Preliminary Costing

No.	Action areas	Cost $
1	Erosion and sediment control for development [2009-2014]	311,000
2	Site based stormwater management plans for development [2009-2014]	269,000
3	Water sensitive urban design (WSUD) guideline adoption and additional products [2009-2014]	566,000
4	Total Water Cycle Management Plan and Urban Stormwater Quality Management Plan integration [2009-2014]	515,000
5	Urban stormwater treatment trains [2009-2014]	1,618,000
6	WSUD retrofit [2010-2014]	500,000
7	Develop peri-urban catchment management guidelines and implementation activities [2010-2014]	455,000
8	Water resource catchment management (Ross River Dam) [2010-2014]	35,000
9	Promote *Managing for WQ within grazing lands of the Burdekin Catchment* developed by NQ Dry Tropics [2010-2014]	50,000
10	Promote management practice ABCD framework for sugar cane and horticulture developed by Mackay Whitsunday NRM [2010-2014]	14,000
11	Legislation and governance [2009-2014]	51,000
12	Policy investigations and development [2010-2014]	40,000
13	Planning scheme studies and instruments review [2009-2014]	188,000
14	Strategic landscape mapping and habitat prioritisation [2010-2013]	418,000
15	Population growth and climate change considerations [2010-2013]	95,000
16	Condition assessment and prioritisation [2009-2014]	638,000
17	Community Based Education and Involvement (CBEI) (awareness and capacity building) [2009-2014]	2,222,000
18	Reef Guardian Councils implementation [2009-2014]	90,000
19	Social learning and behaviour change studies (for determining effective management interventions) – urban and peri-urban [2010-2014]	296,000
20	Market based instruments investigation [2010-2011]	13,000
21	Riparian zone rehabilitation [2010-2014]	1,370,000
22	Wetland restoration and construction prioritisation [2010-2011]	40,000
23	Aquatic ecosystem health improvement [2009-2014]	1,250,000
24	Integrated water quality monitoring and modelling [2010-2014]	1,213,000
25	Integration, communication (includes Reporting), monitoring (including behaviour change), evaluation and adaptive management [2009-2014]	1,186,000
	Total	**$13,443,000**

Notes: Figures are preliminary estimates and will be refined following further identification of priority areas for action. Dates in square brackets indicate the completion time of a task or the length of a program if funds were immediately available. Includes the cost of existing funded programs and activities. More detail can be found in Gunn and Manning (2010).

6.9 ROLES AND RESPONSIBILITIES

Roles and responsibilities are the subject of ongoing discussions with relevant stakeholders including internally throughout Townsville City Council. Roles and responsibilities will be defined as part of any program or project delivery arrangements agreed with Creek to Coral. In the interim it can be assumed that Townsville City Council, through Creek to Coral, is responsible for the implementation of internally funded actions and that it is the role of Creek to Coral to investigate funding options and coordinate activities to progress Action areas that are not yet resourced.

6.10 INTEGRATION WITH OTHER PROCESSES

There are a number of NRM initiatives that have direct relevance to the Black Ross (Townsville) WQIP with a variety of other activities that are indirectly related and/or synergistic. A selection of the key programs, projects and initiatives considered when developing the Black Ross (Townsville) WQIP are described briefly in Gunn and Manning (2010). This includes consideration of relevant components of the Burdekin WQIP (NQ Dry Tropics 2009).

The process of developing and implementing a WQIP is both incremental and iterative as new information is accumulated and incorporated. Other planning processes need to be taken into account and integrated, as appropriate, into the WQIP development process. In the context of an 'urban' catchment incorporation of elements of the WQIP in council planning schemes under the *Planning Act 2016*, development assessment processes and construction guidelines and codes is particularly important.

Top: Just as Ross River links the city the WQIP links actions across the region.

Bottom: Integrating WSUD with development assessment and other processes is a key action.

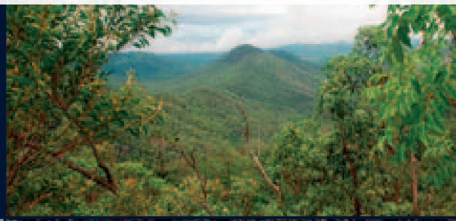
The adaptive management strategy, which is an integral part of this WQIP, makes allowance for the transitional nature of local government in Queensland, NRM funding programs, partners and partnerships, evolving science and socio-economic influences. This ensures the uncertainty inherent in the system is accounted for and enables appropriate adaptation measures to be incorporated in the implementation phase of the Black Ross (Townsville) WQIP.

6.10.1 COMMUNICATION STRATEGY

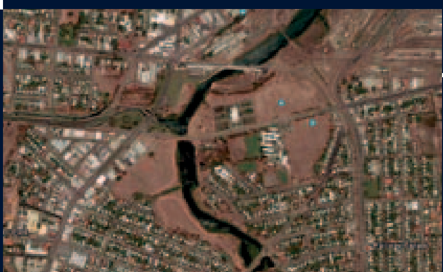
Reporting to the community and stakeholders is to be integrated into relevant and existing reporting mechanisms including TCC, Townsville SOE, Creek to Coral, NQ Dry Tropics and Reef Plan websites. The communication strategy will be developed as part of the implementation phase of this WQIP when resources become available.

6.10.2 PARTNERSHIPS

Organisations such as NQ Dry Tropics (formerly Burdekin Dry Tropics NRM) and Terrain NRM are regional NRM bodies funded principally by the Australian Government to implement NRM activities within their region and, with other NRM bodies and partners, across regions. Creek to Coral may partner with NQ Dry Tropics to deliver the rural components of the Black Ross (Townsville) WQIP and in return will provide assistance to NQ Dry Tropics with the urban and peri-urban components of their WQIP area. There is scope for future collaborative projects to jointly deliver WQIP components as well as broader biodiversity and catchment management outcomes.



Planning where we are going, looking at where we have been and seeing what works is critical in addressing old issues and adapting to new challenges.



SECTION 7

Progress Reporting and Adaptation

7

7. PROGRESS REPORTING AND ADAPTATION

7.1 WQIP MONITORING AND EVALUATION

There are two key monitoring and evaluation components associated with the Black Ross (Townsville) WQIP:

1. WQIP implementation effectiveness (management practice adoption); and
2. Water quality monitoring and modelling.

7.1.1 WQIP EFFECTIVENESS

The main method for determining the effectiveness of the WQIP will be through the measurement of recommended management practice adoption rates. To assist with the task of determining current management practice status and then measuring adoption rates, an ABCD framework for urban and peri-urban areas is being developed. Initially, a coarse survey of a range of land managers for different land uses may be required to feed into the ABCD framework (see section 7.1.3).

7.1.2 MANAGEMENT PRACTICE UPTAKE

Evaluating management practice uptake needs to commence by determining the current status of management practice in the various areas of interest for the different land uses across the WQIP area. Of particular interest are management practices in the established urban areas as well as the near urban developing areas and peri-urban fringe. As yet, a data collection system has not been devised as the proposed management practices are related to a number of other processes within Townsville City Council, including regulatory processes associated with State legislation and policy. Any data collection system proposed may have implications for the monitoring and enforcement role of Council and therefore needs to be designed in consultation with relevant Council departments and linked with the associated processes and existing systems.

Each individual action component of the Black Ross (Townsville) WQIP will involve a design that incorporates monitoring of behaviour change, social learning and management practice uptake. In addition specific social studies will be undertaken to determine the most appropriate methods to communicate water quality improvement messages and motivate land managers to adopt management practices aimed at improving water quality and ecosystem health.

7.1.3 ABCD MANAGEMENT PRACTICE FRAMEWORK

A tool to assist with the promotion and measurement of management practice uptake is the ABCD management practice framework for urban areas. This was initially developed in conjunction with the management team of the Mackay Whitsunday WQIP and Mackay City Council (now Mackay Regional Council). The framework has a number of functional uses including:

- To set targets for water quality management practice improvement;
- To provide land managers with a range of water quality improvement options;
- To relate the management action improvements to pollutant load reductions;
- To measure improvement in management practice on an ascending grouped scale;
- To provide discreet management classes for inclusion in probability based modelling programs e.g. Bayesian Belief Network (BBN);
- To investigate the most effective, and most cost effective, management interventions for water quality improvement using probability based modelling;
- To provide a level of certainty, through modelling of probability distribution, of the potential effectiveness of management interventions for reasonable assurance;
- To inform the adaptive management strategy.

Creek to Coral has continued to work on the framework with the latest urban drafts (developing areas, developed areas and point sources) included in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2010).

In addition to the urban areas, a draft framework for peri-urban areas has been developed and this will be ‘road-tested’ as part of the WQIP implementation process. The peri-urban areas do not neatly fit into the urban or rural land use categories and require separate consideration. The peri-urban areas are under the most pressure from a development perspective and also have a relatively large number of land managers with different levels of land management experience and expertise.

7.2 WATER QUALITY MONITORING AND MODELLING

Water quality monitoring and modelling is essential for determining the current condition of waters, trends in water quality condition and measurable improvements associated with management practice change. The WQIP development and implementation process is being used to integrate water quality monitoring in the study area to achieve more effective outcomes including calibrating and verifying water quality models used to inform the adaptive management strategy for the WQIP, Townsville WSUD design objectives and Urban Stormwater Quality Management Plans (USQMP).

An integrated water quality monitoring and modelling strategy has been prepared by the ACTFR (Bainbridge et al 2008) for the Black Ross (Townsville) WQIP area. Since the main aim of the Black Ross (Townsville) WQIP is to reduce sediment, nutrient and pesticide export to the Great Barrier Reef, a coupled monitoring and modelling approach has been designed to measure, assess and report on the effectiveness of the Black Ross (Townsville) WQIP and in particular, the impact of improved land management practices on receiving waters associated with WQIP implementation actions.

The ACTFR report provides a monitoring and modelling strategy for the Townsville region, as well as an outline for future detailed water quality monitoring and modelling plan development. The strategy is presented in three sections:

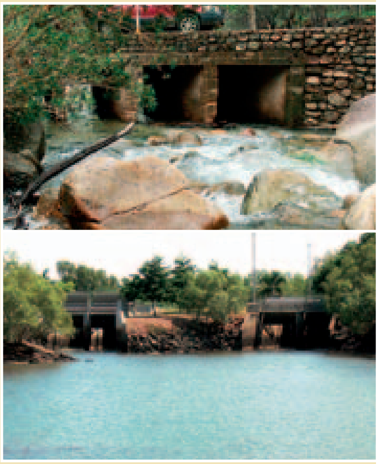
1. Catchment Ecosystem Health Framework, *relating to instream waterways and wetlands* (see Figure 7.1);
2. Marine Ecosystem Health Framework, *linking catchment management actions to marine ecosystem health* (see Figure 7.2); and
3. Social and Economic Framework, *linking socio-economic indicators and management action uptake to water quality outcomes*.

Further integration of ambient and event water quality monitoring within the Black and Ross Basins is proposed as part of the implementation of the Black Ross (Townsville) WQIP. Similarly, the coupled monitoring and modelling approach described in the strategy (Bainbridge et al 2008) will be progressed as a WQIP implementation action.

In particular the process for assessing management practice effectiveness and the water quality improvement implications for marine ecosystem health (see Figure 7.2) will be extended. This process started with the event monitoring and subsequent modelling undertaken during the preparation of the Black Ross (Townsville) WQIP.

While the coupled modelling and monitoring approach will provide managers with a better understanding of the water quality improvement signals associated with various land uses over time, improvement in management practices also need to be audited. Such auditing will be an integral part of the Black Ross (Townsville) WQIP, particularly during the first phase of implementation where water quality monitoring data will be limited and management practice auditing will be the primary means of feedback.

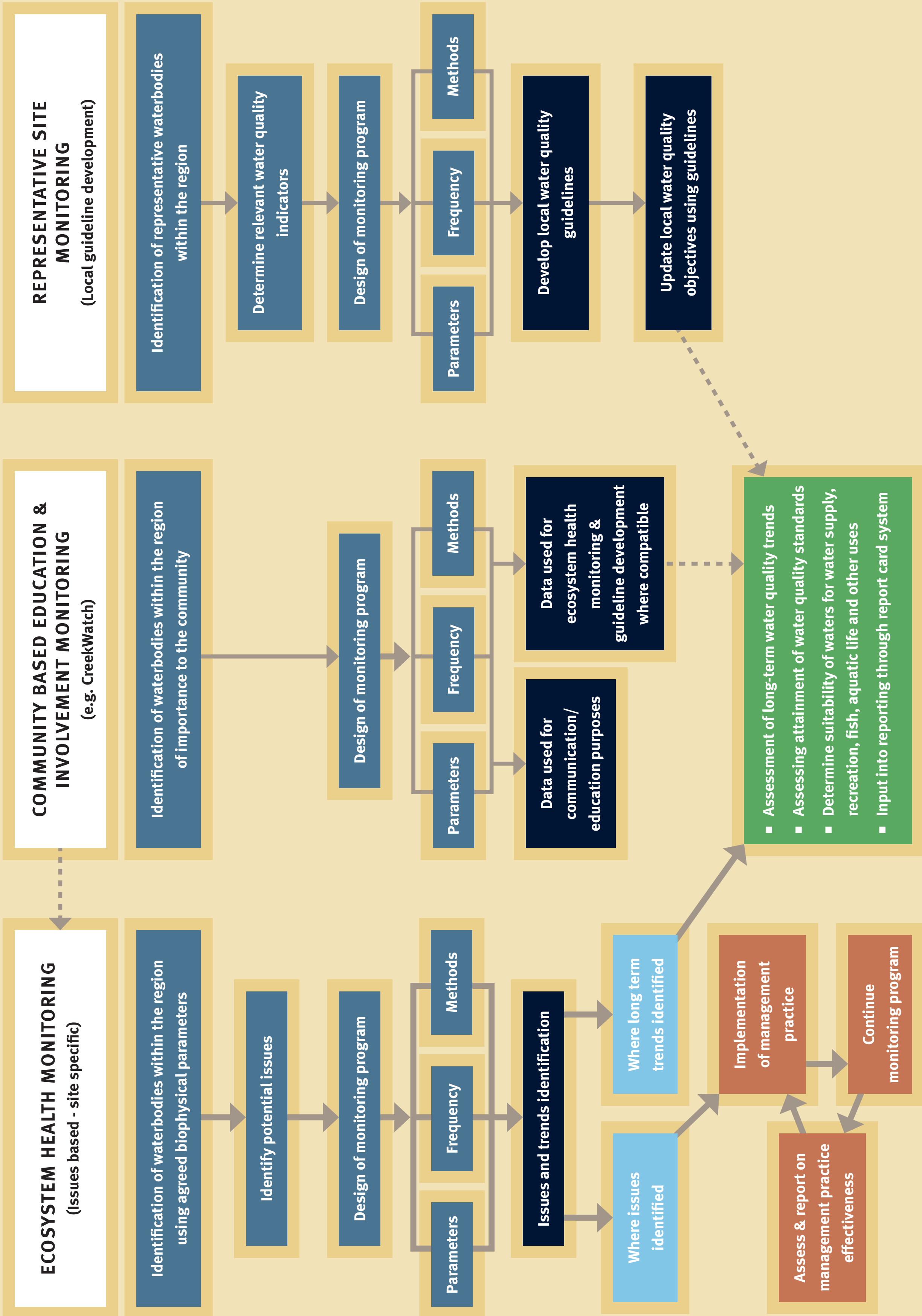
In the interim existing Council ambient water quality monitoring programs will continue with available resources.



Top: Bluewater Creek retains natural values in the face of human intervention.

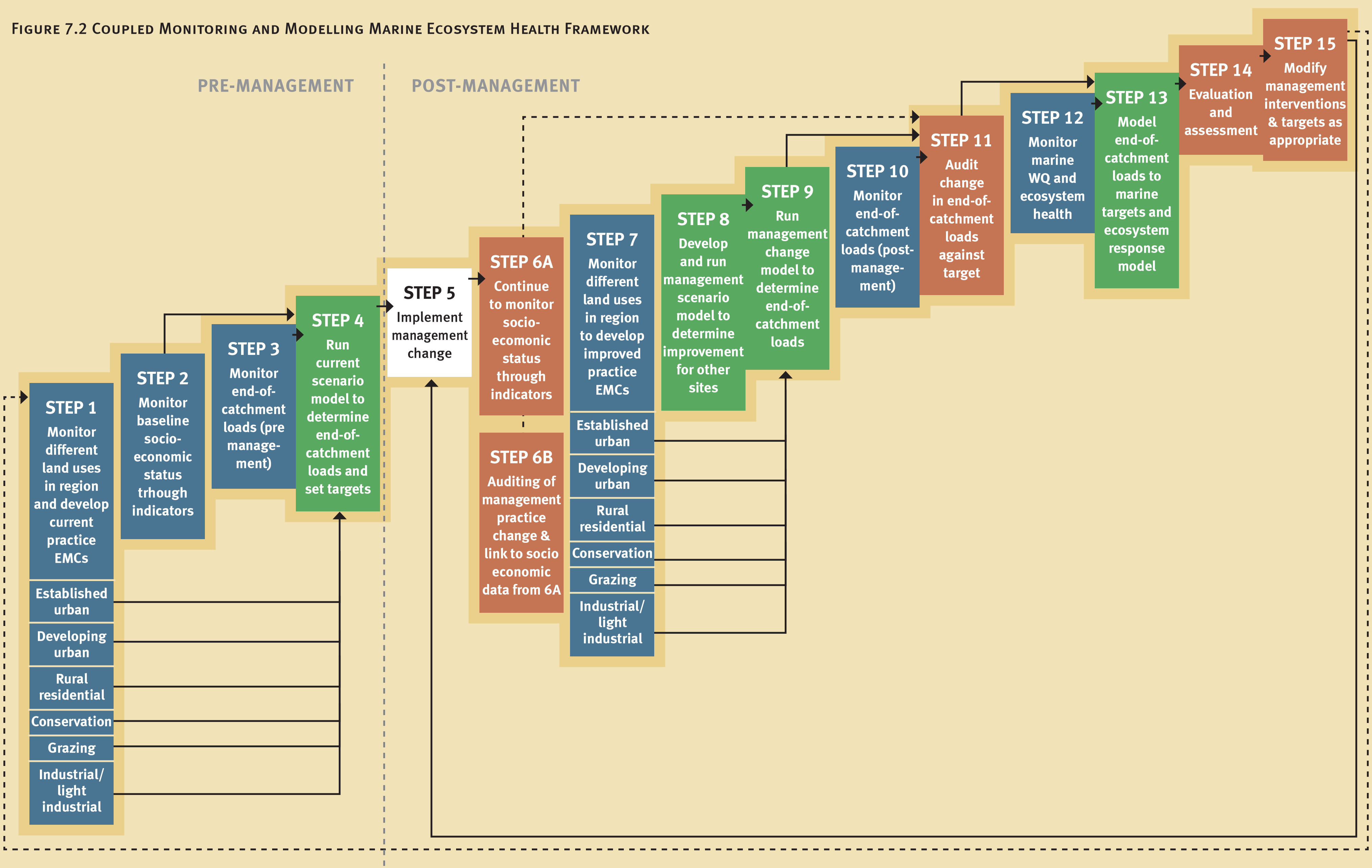
Bottom: Significant infrastructure is often required to manage urban stormwater issues.

Figure 7.1 Catchment Ecosystem Health Framework



Source: Bainbridge et al (2008) Figure 5 (p.11)

Figure 7.2 Coupled Monitoring and Modelling Marine Ecosystem Health Framework



Source: Adapted from Bainbridge et al (2008) Figure 6 (p.13). Notes: Monitoring processes shown in blue, modelling in green and auditing in red.

7.2.1 IMPROVING WATER QUALITY DATA

Creek to Coral, through its CCI/WQIP project, commissioned:

- The collation of available water quality monitoring data and preparation of a water quality condition report;
- The development of a draft report card format for water quality, ecosystem and catchment health;
- Event water quality monitoring for the 2006/07 and 2007/08 wet seasons; and
- Catchment and water quality modelling for the Black Ross (Townsville) WQIP area.

Prior to these studies there had been limited modelling efforts specific to the smaller coastal catchments of the region and appropriate to the altered catchment processes of urbanised landscapes. Virtually no event monitoring had been done with the majority of existing data being from ambient water quality monitoring. Further improvements in the collection, collation and interpretation of water quality monitoring data are planned as an implementation component of the WQIP to complement the coupled modelling and monitoring approach described previously.

7.2.2 SCALES OF WATER QUALITY MONITORING

Top: Rural estuaries provide a contrast to the built form of urban creeks.

Bottom: Modification of waterways and wetlands is a common feature in urban settings.

Improvement in water quality as a result of management action change is only likely to be measured at the 'paddock' scale in the short-term. Catchment 'noise' and lag times associated with particular management actions limit the detection of water quality changes or trends at the catchment scale (Stow et al 2001 and Osidele et al 2003 in Bainbridge et al 2008). For this reason the most effective form of monitoring to determine improvements in water quality at the end of catchment will necessarily be long-term and strategically focused.

Short-term improvements may be detected through a well planned program based around 'isolated' reaches (urban paddock scale) and water bodies associated with smaller sub catchments that have relatively uniform land uses. Without this level of specificity there are too many variables and too much background 'interference' to derive any meaningful cause and effect information from water quality monitoring.

7.2.3 CONNECTING MANAGEMENT PRACTICE TO WATER QUALITY

Verification of the effectiveness of water quality improvement management practices will be through water quality monitoring at the urban 'paddock' scale. The information gained at this scale can then be used as input to catchment models to determine 'downstream' improvements and to justify broader introduction of measured effective management practices. Catchment scale monitoring at strategic nodes will also be used to verify modelled outputs and assist with recalibration of models (Bainbridge et al 2008).

Creek to Coral has been working in conjunction with CSIRO to develop a water quality based Bayesian Belief Network (BBN) to explore the relationships between management practice, land use and water quality (pollutant loads) as a probability based decision support system. The BBN has been designed to assist with setting or verifying direction for potential management interventions and subsequently, redirecting management interventions as part of the adaptive management approach to catchment management and water quality improvement in the Black and Ross Basins. BBN and their application to the Black Ross (Townsville) WQIP are explained in more detail in a report prepared by the BBN project team leader, Tim Lynam (Lynam et al 2008).

Information derived from event water quality monitoring and modelling studies feeds into the BBN to provide pollutant coefficients for the various land uses within a sub catchment (management unit). The ABCD management practice framework (see section 7.1.3) is being developed, in part; to provide some form of delineation of the pollutant generation rates associated with different management practices for various land uses.

The intention is to use the BBN to determine the most effective management interventions for each land use based on potential water quality improvement associated with various management practices. A significant amount of testing and calibration of the BBN model is required to attain greater levels of certainty associated with modelled outputs.

7.2.4 CONNECTING MANAGEMENT PRACTICE TO ECOSYSTEM HEALTH

Making the connection between ecosystem health and management practices requires the collection of baseline data, prior to the commencement of ‘new’ practices; with follow up monitoring after management interventions have been put in place. Available water quality monitoring data has been collated and this needs to be further analysed and combined with as yet to be collated and collected condition assessment data. Ecosystem health relates to all receiving waters and requires different assessment methods and models for freshwaters, estuaries and marine systems (Bainbridge et al 2008).

Making direct connections between marine ecosystem health and catchment land use and management practices is a difficult task and requires a well planned and appropriately resourced monitoring program combining and coordinating local and regional monitoring efforts. The Black Ross (Townsville) WQIP focuses on local level monitoring i.e. in the Black and Ross Basins, and will link to regional monitoring undertaken by GBRMPA as well as any other relevant whole of GBR catchment monitoring programs and activities e.g. the Paddock to Reef program.

7.2.5 LEARNING AND DOING

A parallel and integrated component of the BBN project involves the observation of the BBN development process as part of a social learning study. Alternatively referred to as collective or collaborative learning, social learning in the natural resource management context is a process for improving the effectiveness of adaptive management strategies. Creek to Coral in partnership with CSIRO is investigating a range of adaptive management approaches and tools, as recommended by the former Reef Water Quality Partnership (Eberhard et al 2008).

The BBN social learning study seeks to understand the role of social learning in complementing and enhancing approaches and tools currently being trialled in the WQIP process. The social learning component of the BBN project will provide a social learning conceptual framework as well as a set of processes and tools to maximise the capacity of Townsville City Council staff (and associated partners) to ‘learn by reflection and doing’. BBN and social learning are included in the Decision Support components of the adaptive management framework (see Figure 7.4).

Additional information on the BBN social learning project is provided in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2010).

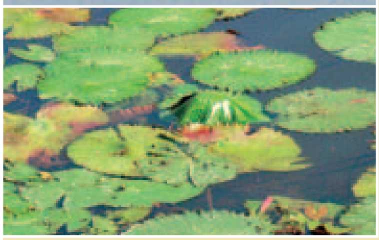
7.3 ADAPTIVE MANAGEMENT

Eberhard et al (2008) state *"Adaptive management is particularly appropriate in dynamic and complex systems that result in high levels of uncertainty in delivery of actions and achievement of outcomes. These characteristics typify environmental management systems, in both biophysical and socio-economic aspects, and are strong features of the GBR system"* (Eberhard et al 2008, p.4). The preparation of an adaptive management strategy is, therefore, an important part of the WQIP development and implementation process.

Furthermore, environmental and catchment management takes place in the context of human activity systems (social, economic and political). In essence we are not managing the environment so much as guiding and influencing the people that impact the environment through their everyday behaviour. Adaptive management needs to be mindful of the human activity systems operating in the particular area of influence and be tailored to enable behaviour change in the relevant context.

Adaptive management is an approach that involves learning from management actions, and using that learning to improve the next stage of management (Holling 1978). It is *"learning to manage by managing to learn"* (Bormann et al 1993).

In simple terms, adaptive management applies learning from experience to the management process. We start by managing the preparation of our strategic plan (e.g. a water quality improvement plan) and associated action plans, and then manage the plan implementation process (project management). We implement actions designed as part of the WQIP and we review the outputs and outcomes of the actions. We learn from observation and evaluation of the results and we then incorporate the lessons into the action plans and continue to implement the actions.



Top: Keeping an eye on things is crucial to effective adaptive management.

Bottom: Tranquil places exist in the urban setting.

In some cases the learning may lead to the discontinuation of an action, project or program due to low levels of success i.e. inability to reach targets or achieve outcomes. In reality this is not a failure of the plan, as plans are built using the best available information at the time including opinions, untested assumptions and often, limited science. Rather this is an example of the successful use of adaptive management. The result is that an ineffective action is prevented from continuing along an unproductive path. In terms of the overall plan this may lead to a revision of 'unrealistic' targets, investigation of innovative options or the creation of new focus areas.

7.3.1 ADAPTIVE MANAGEMENT AND PLANNING

Eberhard et al (2008) describe a double loop model of adaptive management where the inner loop of the cycle represents feedback and adaptive implementation of the current action management of the WQIP. The outer loop represents the review and revision of the overall WQIP.

The adaptive management strategy for the Black Ross (Townsville) WQIP follows the general principles proposed in the double loop model with some modification (see Figure 7.3), which allows for greater flexibility in the WQIP implementation process by recognising that the implementation process includes on-going planning.

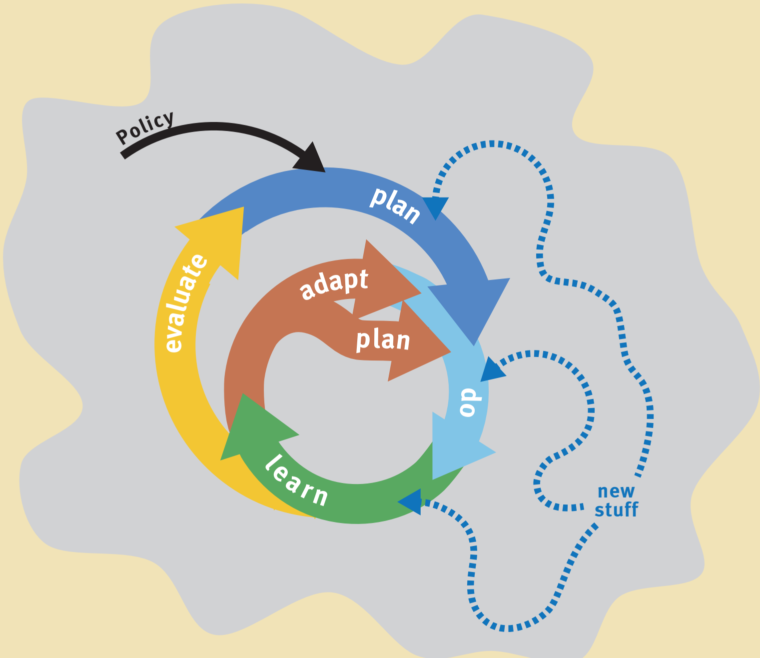
The WQIP is in effect an implementation and planning framework. We therefore have an adaptive management and planning process, which recognises the review of the overall WQIP as the outer loop with an additional inner loop component that includes adaptive planning as part of Black Ross (Townsville) WQIP implementation process.

The modified double loop model incorporates the additional element in the inner loop i.e. the linkage between planning, doing and adapting, as well as being an open loop system to enable 'new stuff' to be infused into the adaptive management cycle at various points in the loops. In terms of the Black Ross (Townsville) WQIP 'new stuff' includes social learning, behaviour change studies, maturing partnerships and project concepts, funding arrangements, coupled monitoring and modelling results, Bayesian Belief Network results, new science, legislative change, management practice updates, modified trend reporting and climate change, amongst other things.

The adaptive management and planning approach is particularly pertinent to the peri-urban land use zone of the Black Ross (Townsville) WQIP area, which has received little attention in the past in terms of catchment management and water quality while containing a relatively large number of land managers in a relatively small area with varying levels of land management capability.

Peri-urban areas can't be readily classed as part of the 'mainstream' agricultural land use area due to the diversity of activities taking place. In reality peri-urban areas have a mixture of both types of agriculture (intensive and grazing) along with lifestyle farmers, urban escapists and absentee owners.

Figure 7.3 Double Open Loop Adaptive Management and Planning Model



Note: The amorphous grey cloud is the context of uncertainty which adaptive management works within. It is an open loop system so new material (stuff) can be introduced into the loops as a natural part of the change and innovation process.

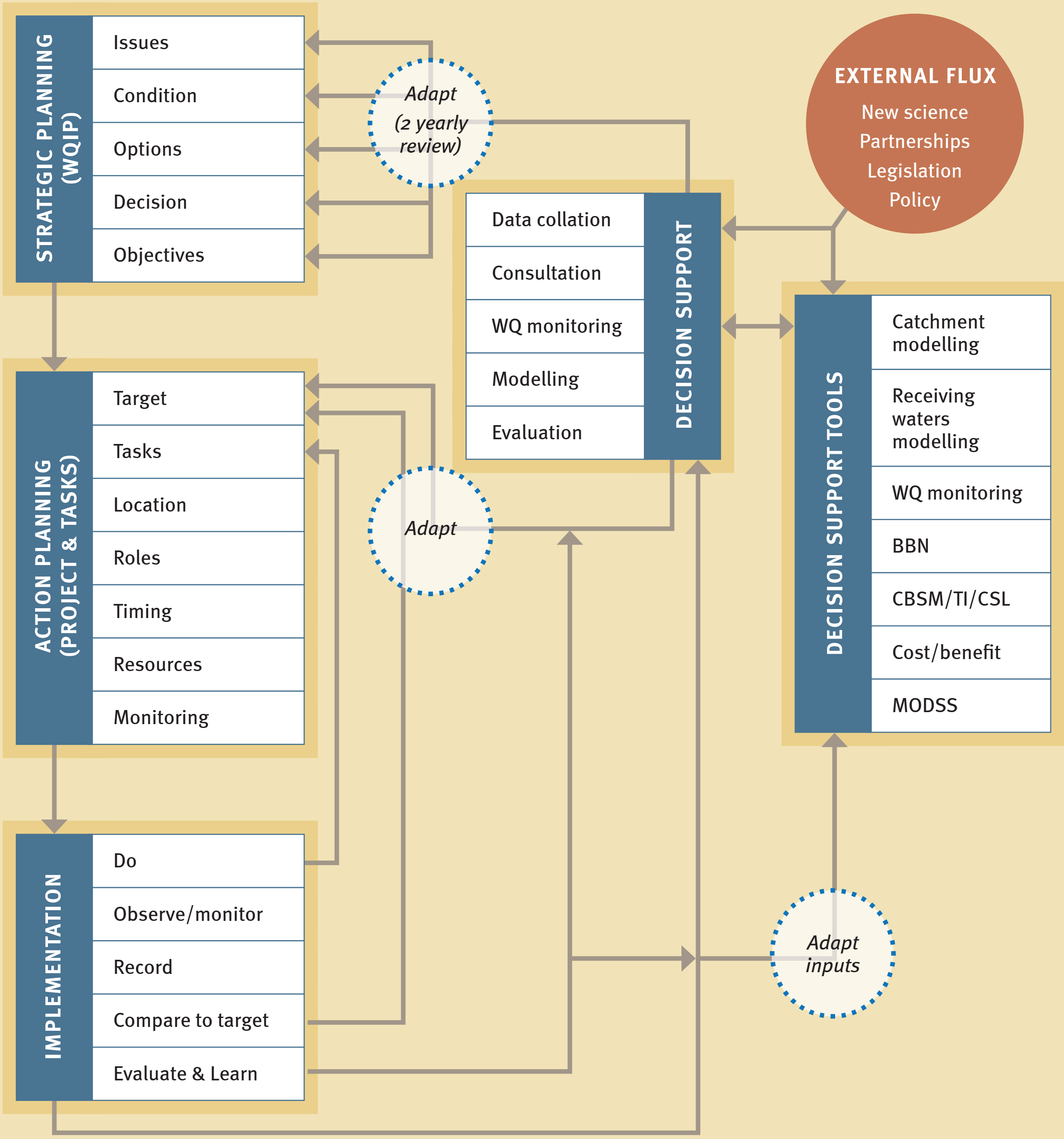
Peri-urban areas have probably been too diverse a mix for 'conventional' rural/agricultural programs to address without the benefit of a robust adaptive management and planning approach incorporating social learning and behaviour change tools. The Black Ross (Townsville) WQIP includes these approaches and tools as integral components of the adaptive management framework.

7.3.2 BLACK ROSS ADAPTIVE MANAGEMENT COMPONENTS

The main components and pathways for delivery of the adaptive management strategy for the Black Ross (Townsville) WQIP are illustrated in Figure 7.4.

A review of the WQIP will take place on a two year cycle and will focus on 'higher' level strategic program adaptation, based on the information gathered and analysed through the decision support processes. Examples could include the introduction of 'new' legislation or a rerun of catchment models revealing different priority areas.

Figure 7.4 Adaptive Management Strategy Main Pathways



Note: WQ monitoring and modelling fits into the Decision Support and Implementation 'boxes' simultaneously (i.e. doing decision support) with Steps 14 and 15 (see Figure 7.2) comprising the adaptive management component.

Adaptation will be part of an ongoing process for action planning and implementation with details of monitoring and assessment of each project or task to be built into each action plan as part of the monitoring component. This will include a set of decision rules to revise targets and actions (tasks), including timeframes.

7.4 CONCLUSION

The Black Ross (Townsville) Water Quality Improvement Plan has been designed as a catchment management based systematic approach to improving water quality by improving the human behaviours and management practices that influence water quality in a modified environment. In this respect, it is a logical progression of the healthy waterways approach launched by Creek to Coral in 2003 and includes a number of existing Creek to Coral and Townsville City Council initiatives.

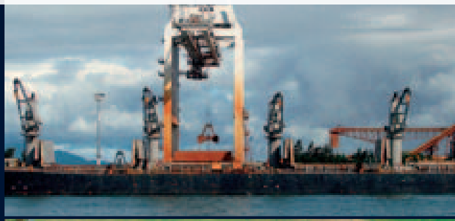
While the Great Barrier Reef lagoon is the eventual destination of runoff from the catchments of the Black Ross (Townsville) WQIP area and improvement of marine water quality was the driver for the development of the WQIP, these are not the only receiving waters of importance in Townsville. Creek to Coral places as much importance on the health of local waterways as it does on the receiving water of the Great Barrier Reef. The logic is simple. If water quality can be improved at the local waterway level then the waters of the Great Barrier Reef will also benefit.

The water quality improvement management actions proposed in this WQIP are a mixture of actions that have been proven to work e.g. erosion control, and emerging actions that require testing to determine their effectiveness. To ensure that the most suitable water quality improvement actions are implemented an adaptive planning and management approach will be incorporated in the WQIP implementation process to allow new ideas and technologies to be tested and implemented.

Measuring the success of the WQIP will be based primarily on the observation of behaviour change and management practice adoption along with paddock scale water quality monitoring and catchment modelling. The most suitable place to measure water quality improvement is at the source of the improvement where management practice changes can be directly related to water quality changes. While broad scale catchment monitoring has a long-term purpose it is unlikely to detect any small scale water quality improvements in the short-term.

For Townsville's WQIP to achieve any significant outcomes a collaborative effort by government, industry and the wider community is required. A significant commitment to water quality improvement has already been made by Townsville City Council through its Creek to Coral initiative and the preparation of the Black Ross (Townsville) WQIP.

Council is committed to the ongoing pursuit of environmental outcomes to benefit the local and regional communities while encouraging responsible development that supports water quality improvement and ecosystem health. Townsville City Council recognises that the social and economic well being of the Townsville region is reliant on the protection of the natural assets that support our existence. Townsville City Council, through Creek to Coral, will continue to support water quality improvement with the community at the local level while working collaboratively with partner organisations at all levels to ensure that the Great Barrier Reef stays great.



Bibliography and Abbreviations

8

8. BIBLIOGRAPHY AND ABBREVIATIONS

BIBLIOGRAPHY

Alberti, M. 2008, *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems*, Springer-Verlag.

Alluvium 2007, *Burdekin Dry Tropics NRM Region Fish Passage Study: Final Report*, BDT NRM, Townsville.

ANZECC and ARMCANZ 1992, *National Water Quality Management Strategy: Australian Water Quality Guidelines for Fresh and Marine Waters*, Agriculture and Resource Management Council of Australia and Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC and ARMCANZ 1994, *National Water Quality Management Strategy: Policies and Principles, a Reference Document*, Agriculture and Resource Management Council of Australia and Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC and ARMCANZ 1996, *National Principles for the Provision of Water for Ecosystems*, Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC ARMCANZ 1998, *National Water Quality Management Strategy Implementation Guidelines*. Agriculture and Resource Management Council of Australia, and Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC and ARMCANZ 2000, *National Water Quality Management Strategy Australian and New Zealand Guidelines for Fresh and Marine Waters Quality, Draft Guidelines Volume 1*. Prepared under the auspices of the Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ARMCANZ and ANZECC 2000, *Australian Guidelines for Urban Stormwater Management*, National Water Quality Management Strategy, Canberra.

Aurecon 2009, *Legislation, Institutional Arrangements and Planning Instruments Review for Water Quality Improvement*, Townsville City Council, Townsville.

Australian Institute of Engineers (Pilgrim and Canterford) 1987, *Australian Rainfall and Runoff; a guide to flood estimation*, Canberra, Institute of Engineers, Australia.

Bailey, B 2009, Unpublished internal report – Townsville population model.

Bainbridge, Z., Brodie, J., Waterhouse, J., Manning, C. and Lewis, S. 2008, *Integrated Monitoring and Modelling Strategy for the Black Ross Water Quality Improvement Plan*, ACTFR Report No. 08/17, Creek to Coral/Townsville City Council, Townsville.

BMT WBM 2009, *Draft Black and Ross River Water Quality Improvement Plan Catchment and Water Quality Modelling*, Townsville City Council - Creek to Coral, Townsville.

BMT WBM 2010, *Black and Ross River Water Quality Improvement Plan Catchment and Water Quality Modelling*, Townsville City Council - Creek to Coral, Townsville.

Bormann, B.T., Cunningham, P.G., Brookes, M.H., Manning, V.W. and Collopy, M.W. 1993, *Adaptive ecosystem management in the Pacific Northwest*, USDA Forestry Services General Technical Report PNW-GTR-341. Available at: www.connectedwater.gov.au/framework/adaptive_management.html).

Brodie, J., Binney, J., Fabricius, K., Gordon, I., Hoegh – Guldberg, O., Hunter, H., O'Reagain, P., Pearson, R., Quirk, M., Thorburn, P., Waterhouse, J., Webster, I. and Wilkinson, S. 2008, *Synthesis of evidence to support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef*, The State of Queensland (Department of Premier and Cabinet), Brisbane.

SECTION 8

creektocoral

Brodie, J. (comp.) 2007, *Nutrient management zones in the Great Barrier Reef catchment: a decision system for zone selection*, ACTFR Report No. 06/07, Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Brodie, J., McKergow, L.A., Prosser, I.P., Furnas, M., Hughes, A., and Hunter, H. 2003, *Sources of Sediment and Nutrient Exports to the Great Barrier Reef World Heritage Area*, ACTFR Report No. 03/11, ACTFR Townsville.

Butler, B. 2008, *Metal Concentrations in the Benthic Sediments of Ross River: Post Wet Season 2008*, ACTFR Report 08/20, ACTFR, Townsville.

C and R Consulting 2007, *Assessment of Selected Riparian Systems of the Ross and Black River Basins Townsville / Thuringowa Region*, Townsville City Council – Creek to Coral, Townsville.

C and R Consulting 2008, *Assessment of Selected Riparian Systems of the Ross and Black River Basins and Selected Other Drainage Within the Townsville / Thuringowa Region (Stage 2)*, Townsville City Council - Creek to Coral, Townsville.

Cardiff, J. 2009, *Black Ross Water Quality Improvement Plan – Socio-Demographic Profile*, Townsville City Council, Townsville.

Connell Wagner 2008, *Water Quality Condition of the Black and Ross River Basins*, Townsville City Council, Townsville.

Connell Wagner 2009, *Development of a Report Card Format for the Waterways of the Black/Ross Basins*, Townsville City Council, Townsville.

Cooperative Research Centre for Catchment Hydrology 1997, *Best Practice Environmental Management Guidelines for Urban Stormwater — Background Paper*, Prepared for Environment Protection Authority, Melbourne Water Corporation and Department of Natural Resources and Environment, Victoria.

Coughlin, T., O'Reagan, P., Nelson, B., Butler, B. and Burrow, D. 2008, *Managing for water quality within grazing lands of the Burdekin Catchments – Guidelines for land managers*, Burdekin Solutions Ltd, Townsville.

Dight, I. 2009, *Draft Burdekin Water Quality Improvement Plan*, Burdekin Solutions Ltd, Townsville.

Drewry, J., Higham, W. and Mitchell, C. 2008, *Water Quality Improvement Plan Final report for Mackay Whitsunday region*, Mackay Whitsunday Natural Resource Management Group, Mackay.

Earth Environmental 2006, *Stormwater Quality Management Framework for Townsville*, Citiworks Townsville City Council, Townsville.

Eberhard, R., Waterhouse, J., Robinson, C., Taylor, B., Hart, B., Parslow, J. and Grayson, R. 2008, *Adaptive Management Strategies for Great Barrier Reef Water Quality Improvement Plans: Draft Final Report*, Reef Water Quality Partnership, Brisbane.

EDAW 2008, *Water Sensitive Urban Design Technical Design Guidelines for Stormwater Management for the Coastal Dry Tropics (Townsville)*, Townsville City Council, Townsville.

EDAW 2009, *Water Sensitive Urban Design for the Coastal Dry Tropics (Townsville): Design Objectives for Stormwater Management*, Townsville City Council, Townsville.

Environmental Protection Agency 2001, *Model urban stormwater quality management plans and guideline*, EPA, Queensland.

Environmental Protection (Water) Policy 1997, Queensland Government.

Environmental Protection (Water) Policy 2009, Queensland Government.

Environmental Protection Agency 2005, *Establishing draft environmental values and water quality objectives: Guideline v1.1*, EPA.

Furnas, M. 2003, *Catchments and Corals: Terrestrial Runoff to the Great Barrier Reef*, Australian Institute of Marine Science, Townsville.

GHD 2002, *Ross River Dam Catchment: Land Use Management Framework Report*, NQ Water, Townsville.

GHD 2006, *Ross River Dam Catchment Water Quality Monitoring Plan*, NQ Water, Townsville.

GHD 2009, *Townsville Integrated Water Supply Strategy Stage 1 Assessment*, Townsville City Council (Townsville Water), Townsville.

Gooch, M., Cullen, L., Manning, C. and Butler, J. 2008, *'Developing indicators of social resilience to changes in water quality – Townsville case study'*, paper presented to the MTSRF Annual Conference, Cairns, April 29, 2008.

Great Barrier Reef Marine Park Authority 2006, *The Current Status of the Great Barrier Reef, GBRMPA*, Townsville (available online at www.gbrmpa.gov.au/corp_site/info_services/publications/sotr).

Greiner, R., Herr, A., Brodie, J., Haynes, D., Audas, D., and Roth, C. 2003, *Profiling and assessment of basins with respect to the sediment, nutrient and other diffuse-source loads they export to the Great Barrier Reef WHA*, CSIRO, Townsville.

Gunn, J. 2006, (Draft) *Framework for Townsville Stormwater Quality Management*, Citiworks-Townsville City Council, Townsville.

Gunn, J. and Barker, G. 2008, (Draft) *Water Quality Pollutant Types and Sources for the Black and Ross River Basins Water Quality Improvement Plan*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J. and Barker, G. 2009, *Water Quality Pollutant Types and Sources Report: Black Ross Water Quality Improvement Plan*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J., Manning, C. and Connolly, N. 2009, (Draft) *Basins, Catchments and Receiving Waters of the Black and Ross River Basins Water Quality Improvement Plan Area*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J. and Manning, C. 2009, *Basins, Catchments and Receiving Waters of the Black Ross Water Quality Improvement Plan Area*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J., Manning, C., McHarg, A., Moulton, D., Connolly, N., Bennett, J., Watson, F. and Kelton, M. 2009, (Draft) *Environmental Values, Water Quality Objectives and Targets for the Black and Ross River Basins Water Quality Improvement Plan*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J., Manning, C. and McHarg, A. 2009, *Environmental Values, Water Quality Objectives and Targets for the Black Ross Water Quality Improvement Plan*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J. and Manning, C. 2010, *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report*, Townsville City Council - Creek to Coral, Townsville.

Gunn, J. 2010, (Draft) *Social Approaches to Water Quality Improvement in the Black Ross WQIP Area*, Townsville City Council - Creek to Coral, Townsville.

Holling, C.S. 1978, *Adaptive environmental management and assessment*, Wiley, Chichester.

Johnson, J.E., and Marshall, P.A. (editors) 2007, *Climate Change and the Great Barrier Reef*, Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia.

Kinsey-Henderson, A., Sherman, B., Bartley, R. 2007, *Improved SedNet Modelling of Grazing Lands in the Burdekin Catchment*, CSIRO Land and Water (Science Report 63/07).

Liessmann, L., Lewis, S., Bainbridge, Z., Butler, B., Brodie, J., Faithful, J. and Maughan, M. 2007, *Event-based water quality monitoring of the Ross and Black River Basins during the 2006/07 wet season Volume 1 – Main Report*, ACTFR Report No. 07/09, Australian Centre for Tropical Freshwater Research (ACTFR), Townsville.

Liessmann, L., Lewis, S., Bainbridge, Z., Butler, B., Brodie, J., Faithful, J. and Maughan, M. 2007, *Event-based water quality monitoring of the Ross and Black River Basins during the 2006/07 wet season Volume 2 – Appendices*, ACTFR Report No. 07/09, ACTFR, Townsville.

Lewis, S., Brodie, J., Ledee, E., and Alewijnse, M. 2006, *The Spatial Extent of Delivery of Terrestrial Materials from the Burdekin Region in the Great Barrier Reef Lagoon*, ACTFR Report No. 06/02, ACTFR, Townsville.

Lewis, S., Bainbridge, Z., Brodie, J., Butler, B., and Maughan, M. 2008, *Water Quality Monitoring of the Black Ross Basins: 2007/08 Wet Season*, Report No. 08/04, ACTFR, Townsville.

Lynam, T., Stone-Jocovich, S., Blanco-Martin, B., Gunn, J., and Manning, C. 2008, (Draft) *Bayesian belief network modelling and social learning for water quality management in the Bohle catchment*, Townsville, Queensland, CSIRO, Townsville.

Maughan, M., Brodie, J. and Waterhouse, J. 2008, *Reef Exposure model for the Great Barrier Reef Lagoon*, DRAFT ACTFR Report No. 07/19, ACTRF, Townsville.

Maunsell McIntyre 2000, *Ross River Dam Catchment Management Plan Report*, NQ Water, Townsville.

Maunsell McIntyre 2001, *Ross River Dam Catchment Water Quality Strategy*, NQ Water, Townsville.

Maunsell Australia 2008, *Wastewater Upgrade Program Planning Report*, Townsville City Council, Townsville.

Mitchell, A., Lewis, S., Brodie, J., Bainbridge, Z., and Maughan, M. 2007, *Water Quality Issues in the Burdekin Region*, ACTFR Report No. 07/03.

Moss, Rayment, Reilly and Best 1992, *A Preliminary Assessment of Sediment and Nutrient Exports from Queensland Coastal Catchments*, Queensland Department of Primary Industries, Brisbane.

Prange, J., Haynes, D., Schaffelke, B., and Waterhouse, J. 2007, *Great Barrier Reef Water Quality Protection Plan (Reef Plan) - Annual Marine Monitoring Report: Reporting on data available from December 2004 to April 2006*, Great Barrier Reef Marine Park Authority, Townsville.

Queensland Institute of Engineers (Witheridge, G. & Walker, R.) 1996, *Soil Erosion & Sediment Control, Engineering Guidelines for Queensland Construction Sites*, Institute of Engineers, Qld Division, Brisbane.

Reef Water Quality Partnership 2007, *Water quality monitoring in Great Barrier Reef catchments*, State of Queensland (Department of Natural Resources and Water), Brisbane.

Scaf, J., Corbett, L. and Grier, N. 2009, (Draft) *Storm Water Quality Improvement Devices in Townsville*, Townsville City Council - Creek to Coral, Townsville.

SEA02 2008, *Climate change in Townsville and potential impacts on water quality*, Townsville City Council – Creek to Coral, Townsville.

Sinclair Knight Merz 2001, *Urban Stormwater Quality Management Plan: USQMP Water Quality Objectives*, Townsville City Council, Townsville.

Schaffelke, B., Thompson, A., Carleton, J., Cripps, E., Davidson, J., Doyle, J., Furnas, M., Gunn, K., Neale, S., Skuza, M., Uthicke, S., Wright, M. and Zagorskis I. 2008, *Water Quality and Ecosystem Monitoring Programme Reef Water Quality Protection Plan: Final Report 2007/08*, Australian Institute of Marine Science, Townsville.

Townsville City Council 1998, *Urban Stormwater Quality Management Plan: Stage 1 Atlas of Environmental Values*, Townsville City Council, Townsville.

Townsville City Council 1999, *Urban Stormwater Quality Management Plan: Stage II Review of Status and Condition of Priority Sites, Stage III Assessment of Environmental Threats and Risks at Priority Sites, Stage IV Concept Engineering of Stormwater Quality Management* Townsville City Council, Townsville.

Trezise, D.L., and Stephenson, P.J. 1990, *Rocks and Landscapes of the Townsville District*, Department of Resource Industries, Queensland.

Trezise, D.L., Holmes, K.H., and Cooper, W. 1989, *Townsville Sheet 8259 1:100000 Geological Map Commentary*, Queensland Department of Mines, Brisbane.

Turner, L., Tracey, D., Tilden, J., and Dennison, W. 2004, *Where river meets sea: Exploring Australia's estuaries*, Cooperative Research Centre for Coastal Zones, Estuary and Waterway Management.

ABBREVIATIONS

A	**ABS**	Australian Bureau of Statistics
	ACTFR	Australian Centre for Tropical Freshwater Research (James Cook University)
	ANZECC	Australian and New Zealand Environment and Conservation Council
	ARI	Annual recurrence interval
	ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
	AWQG	*Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*
	AWR	Australian Water Resources (Council) – River basins
B	**BAU**	Business as usual
	BBN	Bayesian Belief Network
	BDT	Burdekin Dry Tropics
	BMP	Best management practice
	BOD	Biochemical oxygen demand
C	**CC**	Climate change
	CCI	Coastal Catchments Initiative
	CBEI	Community based education and involvement
	CBSM	Community based social marketing
	CFOC	Caring for Our Country
	CQSS	Central Queensland Strategy for Sustainability
	CSIRO	Commonwealth Scientific and Industrial Research Organisation
	CSL	Collective social learning
	CVA	Conservation Volunteers Australia
D	**DEEDI**	Department of Employment, Economic Development and Innovation
	DERM	Department of Environment and Resource Management
	DIN	Dissolved inorganic nitrogen
	DIP	Department of Infrastructure and Planning
	DNRW	Department of Natural Resources and Water (Queensland Government)
	DPIF	Department of Primary Industries and Fisheries (Queensland Government)
E	**EC**	Electrical conductivity (a measure of salinity)
	EMC	Event mean concentration
	EOC	End of catchment
	EPA	Environmental Protection Agency (Queensland Government)
	EP Act	*Environmental Protection Act 1994*
	EPP Water	*Environmental Protection (Water) Policy* 1997 and 2009
	ERA	Environmentally relevant activity
	ERP	Estimated resident population
	ESC	Erosion and sediment control
	ESCP	Erosion and sediment control plan
	ESD	Ecologically Sustainable Development
	EVs	Environmental values
F	**FRP**	Filterable reactive phosphorus

G ...	**GBR**	Great Barrier Reef
	GBRC	Great Barrier Reef catchment
	GBRMP	Great Barrier Reef Marine Park
	GBRMPA	Great Barrier Reef Marine Park Authority
	GIS	Geographic information system
H	**HD**	Highly disturbed (aquatic ecosystems)
	HEV	High ecological value (aquatic ecosystems)
I	**ID**	Insufficient data
	IDAS	Integrated Development Assessment System
	IPA	*Integrated Planning Act 1997*
	IROL	Interim Resource Operations Licence
	IWQM and M	Integrated water quality monitoring and modelling
J	**JCU**	James Cook University
K	**kg/ha/yr**	Kilograms per hectare per year
	km	Kilometres
	km^2	Square kilometres
L	**LGA**	Local government area
	LGAQ	Local Government Association of Queensland
M ...	**MAT**	Management action targets
	MBI	Market based instruments
	MEMC	Methoyetholmercuric chloride
	MODSS	Multiple objective decision support system
	MTSRF	Marine and Tropical Sciences Research Facility
	MUSIC	Model for Urban Stormwater Improvement Conceptualisation
N	**N**	Nitrogen
	ND	No data
	NH_4	Ammonia
	NO_2	Nitrogen dioxide/nitrite
	NO_3	Nitrate
	NOx	Oxides of nitrogen
	NPI	National Pollutant Inventory
	NQ	North Queensland
	NQDT	NQ Dry Tropics
	NRM	Natural resource management
	NRW	Department of Natural Resources and Water (Queensland Government)
	NTU	Nephelometric turbidity unit
P	**P**	Phosphorus
	PAH	Polycyclic aromatic hydrocarbons
	PCB	Poly chlorinated biphenyl
	PIFU	Population Information Forecasting Unit (Department of Infrastructure and Planning)
	PM	Particulate matter
	PM_{10}	Particulate matter less than 10 micro metres in size

	PN	Particulate nitrogen
	PO_4	Phosphate
	PP	Particulate phosphorus
	ppm	Parts per million
Q ...	**QA**	Quality assurance
	QLUMP	Queensland Land Use Mapping Program
	QWQG	Queensland Water Quality Guidelines
R	**Reef Plan**	Reef Water Quality Protection Plan
S	**SBSMP**	Site based stormwater management plan
	SEN	Sustainable education network
	SEQ	South East Queensland
	$Si(OH)_4$	Silicate
	SMD	Slightly to moderately disturbed (aquatic ecosystems)
	SO_2	Sulphur dioxide
	SPP	State Planning Policy
	SQID	Stormwater quality improvement device
	SS	Suspended solids
T	**TBL**	Triple bottom line
	TBT	Tributyltin
	TCC	Townsville City Council
	TI	Thematic interpretation
	TN	Total nitrogen
	TP	Total phosphorus
	TPA	Townsville Port Authority
	TSS	Total suspended solids
	t/yr	Tonnes per year
U ...	**UDIA**	Urban Development Institute of Australia
	USQM	Urban stormwater quality management
	USQMP	Urban Stormwater Quality Management Plan
V	**VOC**	Volatile organic compounds
W ...	**WaterCAST**	Water and Contaminant Analysis and Simulation Tool
	WG	Working group
	WQ	Water quality
	WQG	Water quality guideline
	WQIP	Water Quality Improvement Plan
	WQOs	Water quality objectives
	WSUD	Water sensitive urban design
	WWTP	Wastewater treatment plant
µ	**µg/L**	Micro grams per litre
	µm	Micro metres
	µS/cm	Micro siemens per centimetre

APPENDIX 1 IMPLEMENTATION ACTIONS

Implementation actions associated with each of the management outcomes to achieve the management outcome and management action targets (see section 6) are listed below.

Developing urban areas (Management of development in urban and peri-urban areas)

MANAGEMENT OUTCOME 1:

To ensure water quality improvement actions are effective in improving water quality and results are communicated appropriately to the Townsville community

Management actions to achieve: MAT 1.1, MAT 1.2, MAT 1.3 and MAT 1.4

Action area and tasks (urban some peri-urban overlap)

1 Erosion and sediment control for development and construction

- Review the effectiveness of current measures (especially through the development assessment process) including;
  - TCC erosion and sediment control course and accreditation requirements,
  - Planning scheme provisions and use of Best Practice Erosion and Sediment Control guidelines (IECA Australasia 2008)
  - Monitoring and enforcement,
  - Council requirements under state legislation and especially the EP Act.
- Link with the WSUD implementation process and the development of a new planning scheme for Townsville;
- Incorporate risk management for climate change in all new policy settings and measures;
- Develop generic guidelines for developers/construction industry;
  - General principles about erosion and sediment movement,
  - Linkage with stormwater management planning,
  - Staged clearing commensurate with the progress of development.
- Monitoring and enforcement.

2 Site based stormwater management plans for development

- Review the effectiveness of current measures embedded in the development assessment process including;
  - Planning scheme provisions,
  - Linkages with erosion and sediment control provisions,
  - Monitoring and enforcement,
  - Council requirements under state legislation and especially the EP Act.
- Link with the WSUD implementation process and the development of a new planning scheme for Townsville;
- Incorporate risk management for climate change in all new policy settings and measures;
- Develop generic guidelines for developers/construction industry;
  - General principles about stormwater management,
  - Linkage to erosion and sediment control.
- Monitoring and enforcement.

3 Water Sensitive Urban Design (WSUD) guideline finalisation and adoption

- Strategic framework for integrating WSUD with:
  - The development assessment process in existing planning schemes,
  - The 'new' planning scheme for Townsville City,
  - Development and construction industry standard design and work practices.
- Develop or adapt additional material as required including:
  - The socio-economic case for WSUD
  - Concept design guidelines,
  - Construction and establishment guideline,

... CONTINUED

  - Asset management guideline,
  - Deemed to comply and standard drawings,
  - MUSIC auditing tool (to assist with the development assessment process).
- Investigate market based incentives to assist WSUD adoption;
- Prepare an education and training strategy (Council, developers/construction industry, consultants, community);
- Prepare a communication strategy including;
  - Website platform incorporating the 'Roadmap' (TCC and Creek to Coral websites),
  - Internal reporting,
  - Consultation with key stakeholders,
  - Community consultation.
- Adaptive management;
  - Incorporation of amendments and updates to initial guidelines and documents, and development of an ongoing improvement/learning process.
- WSUD components i.e. stormwater, potable water and wastewater, to be considered in the total water cycle management plan (TWCMP) scoping.
- Identification of WSUD linkages to the development assessment process through the *Environmental Protection (Water) Policy 2009* and state planning policies (SPPs);
- Develop monitoring and enforcement strategies and processes to complement the inclusion of WSUD in the development assessment process;
- Model subdivisions project - monitoring 'new' subdivisions from greenfields stage to test WSUD effectiveness (uptake, and WQ monitoring and modelling).

Developed urban areas (Management of existing urban areas)

MANAGEMENT OUTCOME 2:

To ensure the existing urban areas of Townsville are managed appropriately in order to achieve agreed water quality improvement outcomes including sediment, nutrient and other pollutant load reductions

Management actions to achieve: MAT 2.1, MAT 2.2, MAT 2.3, MAT 2.4, MAT 2.5 and MAT 2.6

Action area and tasks (urban with some peri-urban overlap)

4 Total Water Cycle Management Planning (TWCMP) incorporating the Urban Stormwater Quality Management Plan (USQMP)

Coordinate the preparation of a TWCMP including:

- Convene a TWCMP steering group;
- Review of existing 'water' plans and policies;
- Prepare a TWCMP framework incorporating component plans and integrative processes;
- Scope the activities and prepare a work plan framework for TWCMP component plan adaptation and/or preparation;
- Identify common requirements of TWCMP components e.g. population growth estimates and land use mapping, and allocate responsibilities for actions and define timeframes;
- Allocate resources for TWCMP component preparation, including common components;
- Prepare TWCMP components as per allocations and in conjunction with TWCMP coordination strategy.

USQMP activities include:

Stage 1 Preliminary activities

Step 1 Initial scoping of the project

Step 2 Confirming support for USQMP development

Step 3 Information gathering and collation

Step 4 Review of management practices and processes

... CONTINUED

Stage 2 Risk assessment

Step 1 Compilation of available data to determine draft Environmental Values (human use and aquatic ecosystem) for waterways and waterbodies impacted by urban stormwater

Step 2 Identification of appropriate WQOs for corresponding EVs

Step 3 Comparison of water quality data with WQOs

Step 4 Identify threats to receiving waters from stormwater

Step 5 Rate threats to EVs

Step 6 Site assessments

Step 7 Risk assessment

Step 8 Stakeholder workshop/s to review findings and amend EVs and threat ratings

Step 9 Follow up and resolve any significant disagreements

Stage 3 Development of USQMP management options and actions

Step 1 Identify the range of available management options to address issues / threats identified in Stage 2

Step 2 Align potential management options with functional management units, waterways and catchments as appropriate

Step 3 Evaluate cost effectiveness of options and prioritise management actions

Step 4 Document USQ strategies and management actions

Step 5 Prepare an Implementation Plan. The implementation plan should specify:

- Priority actions,
- Funding and resources,
- Responsibilities,
- Timeframes,
- Reporting requirements and processes,
- Monitoring, evaluation and review processes,
- Communication approach and processes.

5 Urban stormwater treatment trains

- Use the USQMP process (Stage 3) to prioritise areas for infrastructure upgrades;
- Within available funding allocations, upgrade existing systems where additional water quality benefits can be gained at ‘reasonable’ cost;
- Pilot innovative soil amelioration techniques to increase carbon content, nutrient retention and water infiltration in TCC managed sites;
- Investigate (using MUSIC modelling and other techniques) property scale WSUD options that have the potential to reduce pollutant loads without compromising flood management measures.

6 WSUD retrofit

- Expand the SQID Report (Scaf et al 2009) to include all levels of WSUD measures in place in the Townsville urban footprint, and categorise previous developments/neighbourhoods using the ABCD urban management practice framework;
- Prioritise areas where WSUD retrofits can be undertaken in a cost effective way for water quality improvement to meet WSUD objectives for sediment, nutrients and gross pollutants. These can be included in USQMP (Stage 3) for ‘local’ areas.

Peri-urban management actions for water quality improvement (Management of peri-urban areas)

MANAGEMENT OUTCOME 3:

To ensure all peri-urban areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment, nutrients and pesticide load reductions

Management actions to achieve: MAT 3.1, MAT 3.2, MAT 3.3 and MAT 2.5

Action area and tasks

7 Peri-urban catchment management

- Delineate key peri-urban areas through internal/external stakeholder focus group meeting/s and aerial photograph and cadastral interpretation to develop a GIS layer;
- Identify and prioritise catchment management, water quality and socio-economic issues associated with peri-urban areas;
- Develop biophysical BMP guidelines for peri-urban areas (soil, land, water and biodiversity management) incorporating fire management for catchment health and water quality;
- Refine the ABCD framework for peri-urban areas in line with BMP guidelines;
- Undertake behaviour change studies (Thematic Interpretation and/or Community Based Social Marketing) in selected catchments e.g. Alligator Creek, Stuart Creek, Ross River, Bohle River, Black River and Bluewater Creek, to determine the most effective programs for water quality and catchment management initiatives (does not include Ross Dam catchment study);
- Develop and cost programs based on results of studies;
- Incorporate social findings in biophysical BMP guidelines and ABCD framework;
- Implement peri-urban land and water management program.

Water resource catchment management actions (Management of peri-urban areas)

MANAGEMENT OUTCOME 3:

To ensure all peri-urban areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment, nutrients and pesticide load reductions

Management actions to achieve: MAT 3.4

Action area and tasks (peri-urban and rural)

8 Ross River Dam water resource catchment management

- Integrate the dam catchment water quality monitoring program with the Black Ross (Townsville) WQIP WQ Monitoring and Modelling Strategy;
- Review planning scheme provisions in terms of what has worked and what needs to be amended for the information of the new planning scheme for Townsville City;
- Catchment planning for water quality improvement in higher risk land use areas/sub catchments;
- Include Oak Valley in peri-urban management actions and subject to a combination of appropriate management interventions;
- Include Ross River Dam catchment peri-urban areas in the development of the peri-urban BMP guidelines as a specific case study;
- Partner with NQ Dry Tropics to extend grazing Reef Rescue BMP incentives to the larger grazing properties of the Upper Ross River Sub Basin;
- Review previous catchment plans and studies and provide further recommendations for catchment management and WQIP actions;
- Conduct CBSM / Thematic Communication and Social Learning studies for implementation of peri-urban BMP in dam catchment communities e.g. Oak Valley;
- Develop an extension program based on behaviour change findings and the peri-urban BMP guidelines and implement the program.

Rural management actions (Management of rural areas)

MANAGEMENT OUTCOME 4:

To ensure all rural areas in Townsville are managed appropriately to achieve agreed water quality improvement outcomes including sediment load reductions from grazing lands and nutrient and pesticide load reductions from intensive agricultural land use

Management actions to achieve: MAT 4.1, MAT 4.2 and MAT 4.3

Action area and tasks (rural with some peri-urban overlap)

9 Promote "Managing for WQ within grazing lands of the Burdekin Catchment"

- Investigate the need for 'wet coastal catchment' additions to Burdekin rangeland management practices;
- Modify Burdekin rangeland grazing management practices as appropriate to suit local conditions;
- Work with NQ Dry Tropics to develop and roll out BMP adoption programs for rural areas;
- Incorporate grazing BMP components in the peri-urban catchment management guidelines.

10 Promote management practice improvement as per the ABCD framework for sugar cane and horticulture

- Discuss with NQ Dry Tropics, Reef Catchments (Mackay Whitsunday), and Terrain (Tully) WQIP managers the possibility of including the sugar cane and horticultural lands of the Black Ross (Townsville) WQIP area in their Reef Rescue programs;
- Liaise with the Department of Employment, Economic Development and Innovation (DEEDI) (includes the former Department of Primary Industries and Fisheries) to determine potential actions associated with Nutrient Management Zones and linkages with WQIPs and Reef Rescue programs;
- Work with the appropriate organisation/s to develop and roll out BMP adoption programs for the northern sections of the Black Basin;
- Incorporate intensive agriculture BMP components in the peri-urban catchment management guidelines for the sub basins and catchments from Bluewater Creek to Alligator Creek.

Policy and strategic planning (Strategic planning)

MANAGEMENT OUTCOME 5:

To ensure relevant water quality improvement initiatives, information and activities are investigated and integrated where appropriate into Council strategic policy and planning instruments

Management actions to achieve: MAT 5.1, MAT 5.2 and MAT 5.3

Action area and tasks (enabling and cross catchment)

11 Legislation and Governance

- Facilitate the incorporation of WSUD guidelines and measures in the current planning schemes where possible, and as an integral part of the new Townsville City Planning Scheme;
- Assist with the inclusion of water quality objectives in the planning framework to reflect the appropriate level of protection of the environmental values of Townsville's waterways and waters;
- Make recommendations for amendments to planning control measures based on the erosion and sediment control and site based stormwater management plans review findings;
- Provide advice on potential development control measures and landscape protection mechanisms through the new Townsville City Planning Scheme based on findings from condition assessment studies and strategic landscape mapping;
- Assist with the development of Codes associated with 'environmental' Overlays as part of the review process and development of the new Townsville City Planning Scheme;
- Further investigate the identified potential mechanisms available to Council for water quality improvement associated with State and Commonwealth legislation and governance arrangements.

12 Policy investigations and development

- Investigate the potential for development of an integrated water management policy for total water cycle management across the Townsville local government area;
- Investigate the potential for developer contributions to LGA wide water quality monitoring;

... CONTINUED

- Investigate the potential and benefits of establishing an environment infrastructure levy to be used exclusively for protecting and managing natural resources such as waterways and wetlands;
- Investigate options for the establishment of a beneficial rating system based on the level of environmental services installed and maintained in Townsville sub catchments.

13 Planning Scheme studies and instruments review

- Provide input to planning scheme scoping investigations to determine linkages between WQIP components and proposed studies to inform the development of the new planning scheme with emphasis on the following study areas, Overlays and associated Codes;
    - o Housing density
    - o Growth spatial studies
    - o Waterways and Wetlands Overlay and Code
    - o Biodiversity Overlay and Code
    - o Bushfire Overlay and Code
    - o Acid Sulphate Overlay and Code
    - o Agricultural Overlay and Code
    - o Steep Lands Overlay and Code
    - o Cultural Heritage Overlay
- Where possible integrate WQIP condition assessment studies with planning scheme studies and/or assist with design and coordination of planning scheme studies to achieve mutual outcomes.

14 Strategic landscape mapping and habitat prioritisation

- Coordinate ecological and environmental studies and mapping across Council departments and with external partners to produce a comprehensive data set for the Townsville landscape;
- Develop criteria to enable prioritisation of landscape elements critical to water quality, habitat and biodiversity values protection and produce GIS products/maps of the same;
- Integrate relevant protection layers with regional planning processes and the development of the new Townsville City Planning Scheme.

15 Population growth and climate change considerations

- Update and refine population growth and urban expansion projections and mapping for inclusion in catchment and receiving waters modelling and the Bayesian Belief Network management practice decision support system;
- Adapt management actions as appropriate to compensate for any issues identified by the refined modelling associated with population growth not previously identified;
- Literature review of linkages between climate change and water quality;
- Based on literature review findings, develop a model, or utilise an existing model, to determine likely scenarios and timeframes for potential deterioration or improvement in water quality associated with climate change in the Black Ross (Townsville) WQIP area;
- Develop long term, intermediate and short-term objectives and actions to address any projected adverse impacts of climate change on water quality in the Black Ross (Townsville) WQIP area.

Condition assessment and mapping (Ecosystem health improvement)

MANAGEMENT OUTCOME 6:
On-ground actions are prioritised for improving water quality and ecosystem health
Management actions to achieve: MAT 6.1 and MAT 6.2
Action area and tasks (enabling and cross catchment)
16 Condition assessment and prioritisation ▪ Scope requirements for collating and gathering condition assessment data and information associated with; o Catchment condition assessment, o Aquatic ecosystem health assessment, o Riparian condition assessment, o Wetland condition, o Report card format verification, o Acid sulphate soils. ▪ Liaise with TCC Planning and Development, and other TCC departments, to identify natural resource condition studies being undertaken by Council departments and possibilities for integration and value adding; ▪ Carry out condition assessments and develop a prioritisation process to rank areas for rehabilitation on the basis of water quality improvement potential; ▪ Scope the requirements to prepare a greenspace management system for all properties owned or maintained by TCC containing greenspace i.e. parkland and natural areas, and prepare the management system; ▪ Through a staged process of consultation with Traditional Owners determine Indigenous cultural and spiritual environmental values of waterways and waterbodies in the Black Ross (Townsville) WQIP area, including protocols for use of the information and management options to protect the identified environmental values.

On ground actions (Ecosystem health improvement)

MANAGEMENT OUTCOME 6:
On-ground actions are prioritised and effective in improving water quality and ecosystem health
Management actions to achieve: MAT 6.3
Action area and tasks (enabling and cross catchment)
21 Riparian rehabilitation ▪ Identification and prioritisation of areas for maximum water quality benefit from protection mechanisms and on-ground action; ▪ Develop action plans (may be included in Waterway Management Plans etc); ▪ Implement actions and protection measures.
22 Wetland restoration and construction ▪ Identification and prioritisation of areas for maximum water quality benefit from protection mechanisms and on-ground action; ▪ Develop action plans; ▪ Implement actions and protection measures.
23 Aquatic ecosystem health improvement ▪ Define priority areas for action based on condition assessment and prioritisation task (16); ▪ Develop waterway improvement plans for high priority urban streams; ▪ Implement priority management actions potentially including; o Freshwater fish - removal or modification of instream movement barriers, o Aquatic vegetation - control of exotic species, o Channel and floodplain features - maintain ‘natural’ flow regimes and processes, o Riparian vegetation - grazing management e.g. fencing and off-stream watering points.

Socio-economic and behavioural actions (Community involvement and capacity)

MANAGEMENT OUTCOME 7:

All sectors of the Townsville community have access to the information and training required to contribute to implementation of relevant water quality improvement actions in the Black Ross WQIP area

Management actions to achieve: MAT 7.1, MAT 7.2, MAT 7.3 and MAT 7.4

Action area and tasks (enabling and cross catchment)

17 Community Based Education and Involvement (CBEI)

- Supporting community and raising capacity through existing programs:
  - Creekwatch,
  - Catchment tours (eco-certified),
  - Dry Tropics Watersmart,
  - Rowes Bay Sustainability Education Centre, Learnscapes and Transect,
  - Citisolar,
  - Catchment management/natural resource management via Landcare and Coastcare.
- Incorporate behaviour change strategies in CBEI activities.

18 Reef Guardian Councils implementation of BMP

TCC and GBRMPA are working together to identify and/or develop actions to protect the water quality of the Great Barrier Reef Marine Park including by:

- Producing information with key Great Barrier Reef messages for events such as Ecofiesta and River Festival;
- Developing best management practice approaches and guidelines for Council staff;
- Developing behaviour change strategies for uptake of BMP;
- Wastewater reuse investigations (as part of Dry Tropics Watersmart).

19 Social learning and behaviour change studies

- Undertake behaviour change studies as required for urban and peri-urban landscapes using methods developed by the leading proponents of Community Based Social Marketing (CBSM) (Dr Doug Mackenzie-Mohr), Thematic Interpretation (Prof. Sam Ham) and Collective Social Learning (Prof. Valerie Brown);
- Promote community and community group leaders involvement in behaviour change training programs and studies.

20 Market based instruments investigation

- Investigate the potential for application of market based instruments (MBIs) as incentive measures for the uptake of water quality improvement management actions in all land uses of the Black Ross (Townsville) WQIP area, and in particular as part of the toolkit for behaviour change.

Water quality monitoring and modelling (Monitoring, evaluation and reporting)

MANAGEMENT OUTCOME 8:

To ensure water quality improvement actions are effective in improving water quality and results are communicated appropriately to the Townsville community

Management actions to achieve: MAT 8.1

Action area and tasks (enabling and cross catchment)

24 Integrated water quality monitoring and modelling (IWQM and M)

- Implement the Integrated Water Quality Monitoring and Modelling Strategy including detailed program design for:
    - Critical sub catchment and river sites (to inform and validate modelling),
    - Ecosystem health and ambient water quality monitoring (see Figure 7.1),
    - Community based education and involvement monitoring (see Figure 7.1),
    - Developing a set of local water quality guidelines for the wet and dry catchments of the Black Ross (Townsville) WQIP area in conjunction with DERM/EPA (see Figure 7.1),
    - Socio-economic monitoring and management practice uptake,
    - Modelling, and in particular relating management actions to resource condition.
- Implement water quality monitoring programs as designed;
- Update the Creek to Coral water quality monitoring activity report prepared in 2004;
- Develop protocols and management systems for coordinating water quality monitoring initiatives and analysing and sharing data and results i.e. through quality assurance;
- Extract monitoring data from the database relevant to stormwater treatment measures and land uses for further analysis and to assist with development of mitigation measures including for the new USQMP, and other water quality improvement initiatives;
- Build on the water quality monitoring database developed by Creek to Coral for the Black Ross (Townsville) WQIP to encompass additional data including from commercial/private sources;
- Incorporate monitoring data from large scale developments and developing areas e.g. Rocky Springs, Northshore;
- Develop strategies for enabling inclusion of water quality monitoring data generated from commercial enterprises e.g. development projects and Environmental Impact Assessments;
- Refine catchment scale models (WaterCAST and updates) by incorporating on-going monitoring results (see Figure 7.2);
- Improve knowledge on the connection between terrestrial runoff and receiving water health through improved linkage of catchment models and receiving waters models (see Figure 7.2);
- Investigate linkages between previous socio-economic modelling (Greiner et al 2005) and the Bayesian Belief Network (BBN) model being developed for the Black Ross (Townsville) WQIP area (Lynam et al 2008);
- Further develop the BBN decision support model to add to the tools available to identify the most appropriate management actions for water quality improvement measures in the Black Ross (Townsville) WQIP area;
- Finalisation of Marine and Tropical Sciences Research Facility (MTSRF) Project 4.9.7. [Understanding and enhancing social resilience: science and management integration] (Gooch et al 2008) Townsville component through monitoring community response to a water quality management intervention designed after conducting a community based social marketing study,
- Integrate with Burdekin WQIP paddock to reef monitoring, modelling and reporting.

Communication plus (Monitoring, evaluation and reporting)

MANAGEMENT OUTCOME 8:
To ensure water quality improvement actions are effective in improving water quality and results are communicated appropriately to the Townsville community
Management actions to achieve: MAT 8.2, MAT 8.3, MAT 8.4 and MAT 8.5
Action area and tasks (enabling and cross catchment)
25 Integration, communication, monitoring, evaluation and adaptive management ▪ Facilitate WQIP integration with other Council and external processes; ▪ Develop and implement the Black Ross (Townsville) WQIP communication strategy incorporating reporting processes to communicate results of water quality monitoring and modelling and other relevant processes; ▪ Foster partnerships and relationships for water quality improvement including participation in and leadership of cross regional groups; ▪ Refine and implement the WQIP monitoring and evaluation framework; ▪ Refine and extend the ABCD Management Practice Framework for urban and peri-urban areas; ▪ Progress and test the Bayesian Belief Networks decision support system, ▪ Develop and implement a detailed adaptive management strategy to underpin implementation of the Black Ross (Townsville) WQIP.

TOWNSVILLE CITY COUNCIL

PO BOX 1268
TOWNSVILLE QLD 4810

TELEPHONE » 1300 878 001
FACSIMILE » 07 4727 9056

enquiries@townsville.qld.gov.au
www.townsville.qld.gov.au

www.creektocoral.org