# Water Quality Improvement Plan

Mackay | Whitsunday | Isaac

# 2014 - 2021


REEF CATCHMENTS

Australian Government

# Draft Report

## Mackay Whitsunday Water Quality Improvement Plan 2014-2021

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# Executive Summary

The 2014-2021 Mackay Whitsunday Water Quality Improvement Plan (WQIP) aims to ensure water quality is suitable for human uses and aquatic ecosystem protection. This plan builds upon the 2008 WQIP and describes management interventions for rehabilitation of priority habitats and reduction of pollutant loads from diffuse and point sources. If resourced and implemented, this plan will improve the water quality and ecological health of the waterways, estuaries, wetlands, and the Great Barrier Reef within the Mackay Whitsunday region.

**The region**

The Mackay Whitsunday region in central Queensland extends from south of Bowen to north of Clairview. The region encompasses parts of the Great Barrier Reef, including the internationally renowned Whitsunday Islands. The WQIP divides the region into 33 catchment management areas and eight receiving waters. High Ecological Value (HEV) areas are identified as well as risks to the marine environment from land-based pollutants.

**Key pollutants and sources**

Key water quality pollutants of concern in the region are dissolved and particulate forms of nitrogen and phosphorus, suspended sediment, and the residual herbicides ametryn, atrazine, diuron, hexazinone, and tebuthiuron. The majority of the nutrient and herbicide pollutants are from agricultural diffuse sources (sugarcane farming followed by grazing).

Sugarcane farming is the dominant intensive agricultural land use (18% of land area in the region) and produces about 32% of the regional load of particulate nitrogen, approximately 65% of the regional dissolved inorganic nitrogen load, 40% of the filterable reactive phosphorus load, and 26% of the regional suspended sediment load. Sugarcane farming produces the majority of filterable reactive phosphorus, ametryn, atrazine, diuron, and hexazinone.

Grazing and forestry is the dominant extensive land use in the region (54% of land area) and produces about 27% of the total regional particulate nitrogen and dissolved inorganic nitrogen loads, 41% of particulate phosphorus and filterable reactive phosphorus loads, and 53% of the regional sediment load. Although conservation areas (which account for approximately 18% of the land in the region) were estimated to contribute to the suspended sediment load, this is considered natural and reflects the steep nature and high runoff volumes of these natural bushland catchments.

Horticulture (less than 1% of the land area) is a minor contributor to all regional loads. Urban and other intensive uses account for just over 10% of the total regional particulate nutrient load, and 4% of the regional dissolved inorganic nitrogen load. Point sources (e.g., sewage treatment plants from major urban centres) may be significant to local management areas.

**Environmental values**

This water quality improvement plan has been developed to address requirements established under the Australian Government’s Reef water quality programme and requirements for healthy waters management plans (HWMPs) specified in section 24 of the Environmental Protection Policy (Water). Where WQIPs adequately address matters specified under the EPP Water for HWMPs, they may be accredited as HWMPs.

The 2008 WQIP established Environmental Values (EVs) for the protection of aquatic ecosystems and human uses. Environmental Values are those qualities of the waterway that make it suitable to support particular aquatic ecosystems and human uses. Freshwater and estuarine HEV areas were also identified for the region.

Environmental values (EVs) and water quality objectives (WQOs) for Mackay-Whitsunday region waters were scheduled in 2013 by the Queensland Government under the Environmental Protection Policy (Water). These include mapping of waters identified for high ecological value level of protection in fresh, estuarine, and coastal/marine waters. Scheduled EVs and WQOs are based on the earlier WQIP, with local updates based on additional information, stakeholder inputs, etc..

Subsequently, the 2014-2021 WQIP has reviewed the 2008 WQIP EVs and HEV areas, the scheduled EPP water EVs and WQOs within the Mackay Whitsunday region and updated the Water Quality Objectives (WQOs) and Ecosystem Health Objectives (EHOs) required to protect the EVs and HEV areas.

**Water Quality Objectives and targets**
The WQIP presents an overview of waterway values and uses, WQOs and targets to protect waterways, and load reductions required to achieve the 2021 targets and progress toward 2050 WQOs. The reviewed and updated WQOs, current condition, and targets (expressed as concentrations) for freshwater and marine environments under ambient and event conditions are presented within.

Pollutant load reduction targets for the year 2021 (and the corresponding WQOs) are presented for each catchment management area. Load reduction targets were developed from a combination of modelling and water quality data, and the likely reductions that could be expected from widespread adoption of land management practices. Load reduction targets are based on WQOs to protect EVs, management practices required to meet WQOs, and reasonable adoption of improved management practices. In some catchment management areas, targets are limited by the level of adoption of management practices; in these areas, water quality targets are less stringent than WQOs. Reaching these targets by 2021 would be seen as a major achievement toward meeting Water Quality Objectives by 2050 and the targets outlined in the Reef Water Quality Protection Plan ("Reef Plan") and Reef 2050 Long-term Sustainability Plan.

Provided sufficient resources are allocated to the region, estimated load reductions by 2021 from improved nutrient management will be 15% for dissolved inorganic nitrogen, and 14% for filterable reactive phosphorus. Improved sugarcane and horticulture practices are expected to reduce herbicide loads by 16%. Adoption of improved soil management is expected to reduce particulate parameters by a minimum of 32%. The voluntary adoption of targets for management practices are considered achievable, with financial and extension support.

**Ecosystem Health Objectives and targets**
This WQIP has updated and refined the Ecosystem Health Objectives and targets developed in the 2008 WQIP. Ecosystem health indicators presented in this WQIP include riparian vegetation, fish community health, barriers to fish migration, and flow. A summary of ecotoxicity research conducted as part of this WQIP update is included, as well as new ecotoxicity targets for individual herbicides as well as mixtures of herbicides. The overall ecological condition for freshwater management areas and receiving waters was assessed using these ecosystem health indicators and the results are presented.

**Implementation, adoption, and review**
Implementation of the WQIP involves a range of management interventions, modelling, and monitoring. The implementation period for this WQIP is from 2014 to 2021. Implementation is adapted through annual reviews and a major mid-term review in 2021 which will result in the development of a new WQIP to cover the next planning period.

**Management interventions**
Considerable gains in water quality improvement are likely to be achieved across the region through accelerated voluntary adoption of management practices in rural and urban communities. The range of management practices, existing and emerging technologies available require industry involvement and commitment, with consultancy agencies required for extension needed to achieve on-ground actions to meet the water quality targets in the WQIP.

The estimated total on-farm cost of improved soil, nutrient and herbicide management practices for sugarcane/horticulture and grazing in the region is $36M by 2021. The estimated cost for sugarcane/horticulture and grazing consultation and extension support for the adoption of improved management practices is $10M. The estimated cost of improved urban management practices is $28M.

Considerable gains in ecosystem health are likely to be achieved through the targeted implementation of a range of activities, including installation of 25 fishways, rehabilitation of in-stream habitat and improved management of riparian vegetation areas. The estimated on-ground cost is $20M.

**Monitoring and Management**
A monitoring and management plan has also been developed. Many of the monitoring activities should also be implemented at a cross-regional reef-wide scale. Monitoring data will be used to test the validity of existing models and to assist further development. Modelling approaches should also be used in conjunction with appropriately targeted water quality monitoring at paddock, subcatchment, and catchment scale, and includes aquatic ecosystem response monitoring and modelling.

Monitoring of management practices will be conducted in conjunction with the sugarcane, horticulture, and grazing industries. Management practice validation to assess environmental and financial outcomes is recommended. Further research on the biological effects of pollutants on ecosystems is needed to ensure that targets developed in the WQIP are appropriate.

The estimated cost to implement the monitoring, modelling, and management practice validation strategy is approximately $12M. Costs to implement all activities in the WQIP are presented below, with further details available in this report.

**Prioritisation and intervention summary**
This plan identifies the major issues impacting water quality, the major pollutants of concern, and the geographical hotspots for pollutant generation. The plan also identifies waterways with the highest ecological value in the region, and establishes priority areas for improving the condition and function of these ecosystems.

The implementation framework and prioritisation methods within this plan have been developed using the best available knowledge. It identifies the priority locations and the interventions that will provide the greatest value for money to ensure targets set within the plan are realised.

In order for this plan to be successful in reaching its targets, a number of fundamental commitments will be required to accelerate improvements in water quality within the region, including:

- Sufficient resources for extension and incentives to accelerate adoption of management practices, and research including monitoring, modelling and practice validation;
- Continued and enhanced collaboration between industry leaders, government agencies, science providers and regional bodies; and
- Urban and industry sectors to take lead roles in achieving targets and a desire for continual improvement.

| Implementation Activities to 2021 | Cost |
|---|---|
| Sugarcane / horticulture and grazing on farm improved soil, nutrient and herbicide management activities | $36M |
| Sugarcane / horticulture and grazing consultancy and extension support for adoption of improved management practices | $10M |
| Urban on-ground cost of improved new development and infill development management activities | $28M |
| Ecosystem health and system repair activities | $20M |
| Monitoring, modelling and management practice validation | $12M |

| Total | $106M |
|---|---|

# SECTION A | Introduction

This section sets the scene for this Water Quality Improvement Plan (WQIP). The section outlines the background to this WQIP, including regional information, the needs and drivers for the WQIP, and the resulting objectives and purposes. This section also presents information on the legislative framework the WQIP was developed within and must be implemented within. A discussion on climate change and how predictions have been incorporated into the WQIP is also provided in this section.

# 1. Background

## 1.1. Regional overview

The character of the Mackay Whitsunday region is strongly influenced by its proximity to the adjacent Great Barrier Reef (GBR). Areas of the GBR World Heritage Area (WHA), the world's largest WHA, fall within the Mackay Whitsunday region. The GBRWHA contains the largest single collection of coral reefs in the world, supporting many diverse ecosystems of immense conservation value (Drewry et al. 2008).

The Mackay Whitsunday region covers a land area greater than 900,000 ha extending from Eden Lassie Creek catchment south of Bowen (in the north) to Flaggy Rock Creek catchment in the south (see Figure 1). The region is bounded by the Connors-Clarke ranges to the west and the Coral Sea and internationally renowned GBRWHA and the Whitsunday Islands to the east. These islands include the Cumberland, Lindeman, and Northumberland group of islands, and the internationally renowned resort islands such as Hamilton Island, Lindeman Island, Keswick Island, and Hayman Island.

The region includes many aquatic and associated environments worthy of protection. It is one of the most bio-diverse regions in the GBR catchment. This diversity of habitats and species has supported the development of a significant tourism industry. Tourism in this region is dominated by Australian residents and it is the second largest tourism region in the GBR with the most extensive system of islands close to the coast (GBRMPA 2014). The inshore and Whitsunday Island fringing coral reef areas vary from reefs with low diversity close to the Proserpine River discharge area, to diverse soft coral communities in inlets (Ball 2008; Drewry et al. 2008). The area is also known for its iconic sites including Eungella National Park, Whitsunday Islands National Park, Cape Palmerston National Park, and Goorganga Plains, Sand and St Helens Bay, and Sarina Inlet wetlands. Additionally, the region encompasses areas of good riparian vegetation, extensive mangrove forest, seagrass and fish habitat, forested mountain ranges, and areas of recreational fishing and camping (Drewry et al. 2008). Significant National Parks, conservation land and waters identified for high ecological value level of protection also exist within the Mackay Whitsunday region.

Driven by a distinctive wet tropical climate, the productive landscapes of the region are the focus for agriculture and provide great diversity for the tourism sector. Agricultural production (sugarcane, grazing, and horticulture) is significant in the region. The Mackay Whitsunday region is the largest area of sugarcane production in Australia, producing approximately one third of Australia's sugar.

The region also supports industries from adjacent regions' coalfields. The resources sector provides jobs and investment through mining services, transport, and port facilities.

The region's population of 175,700 is concentrated in the coastal zone and the major urban centres of Mackay, Airlie Beach and Cannonvale. Smaller regional centres include Proserpine, Calen, Mirani, Sarina, and Carmila, which service rural industry and provide for a variety of lifestyles. For Indigenous people who identify with this coastal country, including the Gia, Ngaro, Yuwi-bara and Koinjmal groups, the land and sea is rich with cultural heritage, identity, and traditional practices.

## 1.2. Water quality issues in the region and GBR

Catchments draining to the GBR receiving waters stretch from Cape York Peninsula in the far north to the Burnett-Mary catchment in southern Queensland. The Mackay Whitsunday region occupies only about 2% of the total area of all GBR catchment regions. However, the coastal length of the region (including the Whitsunday Islands) accounts for approximately 20% of the total coastline length of all GBR catchment (Drewry et al. 2008).

It is widely acknowledged that the quality of water entering the GBR lagoon from adjacent lands

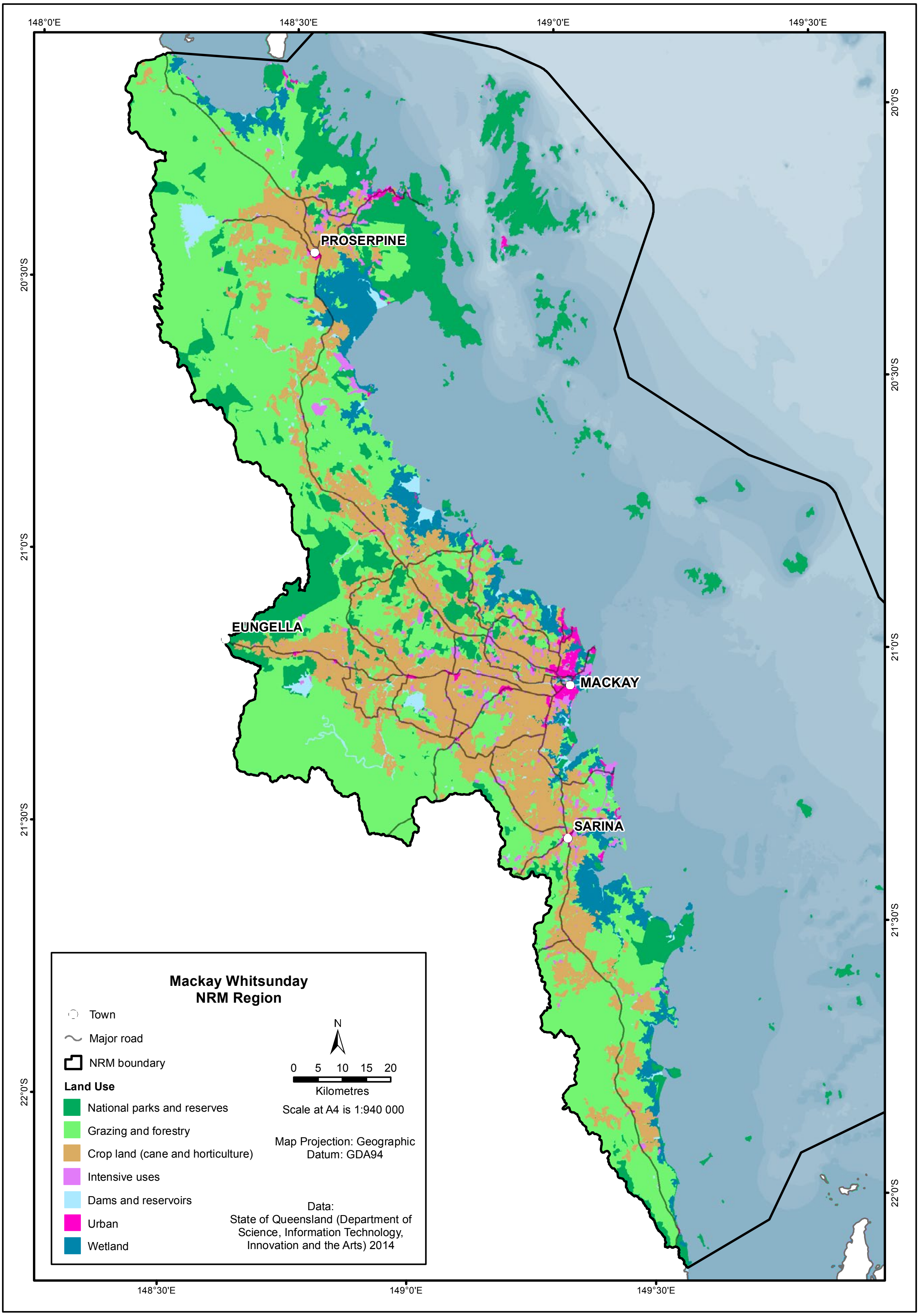


**Figure 1 Regional map of the Mackay Whitsunday area.**

has deteriorated dramatically over the past 100-150 years, and continues to detrimentally impact the marine ecosystem (State of Queensland 2013; Brodie et al. 2013). Grazing, sugarcane, horticulture and urban development in the region have resulted in increased inputs of sediment, nutrients and herbicides. Freshwater ecosystems within intensively developed catchments commonly show impacts of poor water quality, such as fish kills, blue green algae blooms, increasing exotic weeds and changes in fish populations (Brodie 2004; Moore et al. 2007; Drewry et al. 2008). Although the majority of the 2900 reefs in the GBR are in good condition, in 2003 it was estimated that 450 inshore reefs were showing impacts consistent with a decline in water quality (The State of Queensland and Commonwealth of Australia 2003).

Nutrient, sediment and herbicide inputs to the GBR have increased with development in the GBR catchments (Haynes et al. 2005; McKergow et al. 2005; Brodie et al. 2007). A study of 86 marine sites across the GBR region showed the Mackay Whitsunday and the Wet Tropics inshore waters to be enriched in chlorophyll-*a*, compared to inshore waters of Cape York. These differences were attributed to nutrient delivery from agricultural land use (Brodie et al. 2007). Considerable evidence exists indicating sediment and nutrients from land-based sources are impacting on the inner reefs and seagrass areas (The State of Queensland and Commonwealth of Australia 2003; Brodie et al. 2013; Reef Catchments *unpubl*.). Additionally, McCulloch et al. (2003) showed that the inner GBR is highly influenced by flood plumes from the Burdekin River; there was a greater frequency of flood plumes and a five to tenfold increase in the sediment delivery.

Coral reefs that are exposed to discharge from developed catchments are in poorer condition than those in the far northern region of the GBR (Brodie et al. 2007). Lough (2007) used coral records to determine that while there does not appear to be any overall trends toward wetter or drier conditions, the variability of rainfall and river flow had increased during the twentieth century, with no indication that the amount of freshwater to the GBR has changed since European settlement (Lough 2007). In a study evaluating inshore coral cores, Jupiter et al. (2007) reported strong evidence that terrestrially-derived nitrogen reaches the reefs of the inshore Keswick Island during flood events.

Inshore marine monitoring of the Whitsunday Islands showed that sites were influenced by the O'Connell and Pioneer Rivers. Of the regions monitored during the wet season, nitrogen and phosphorus at the Whitsunday marine monitoring sites were among the highest levels recorded (Prange et al. 2007). The majority of the pollutants (including herbicides) in the more developed catchments are sourced from agriculture (Drewry et al. 2008). Based on an assessment of photosystem II inhibiting (PSII) herbicides (i.e. ametryn, atrazine, diuron, hexazinone, and tebuthiuron), seagrass in the Mackay Whitsunday region was considered to be at high risk, with 40% of seagrass existing in the highest relative risk class, compared to 10% for other regions (Brodie et al. 2013; Reef Catchments *unpubl*.). Subsequently, the Mackay Whitsunday region was identified as a priority area for managing the use of PSII herbicides (Brodie et al. 2013; Reef Catchments *unpubl*.).

A cooperative approach under the Reef Water Quality Protection Plan (The State of Queensland and Commonwealth of Australia 2003), known as 'Reef Plan', has been undertaken to address many of these issues with stakeholders. The Reef Plan was updated in 2009 and again in 2013. Paddock to Reef, a monitoring and evaluation program, was established to assess the success of Reef Plan implementation. Report cards communicating the progress have been published since 2009. The report cards indicate that management changes and water quality improvements are on a positive trajectory and are progressing toward Reef Plan targets, however, the improvements are not occurring at the rate needed to achieve the targets set in Reef Plan (Reef Catchments *unpubl*.). The latest report card assessed the 2012-2013 improvements and found that adoption rates were improving overall, however still not to the degree required. In the Mackay Whitsunday region, the adoption rates achieved for sugarcane land was 55% (compared to the Reef Plan 2013 target of 80%), grazing land was 11% (compared to a target of 50%), and horticultural land adoption rates were 66% (compared to a target of 80%) (Reef Catchments *unpubl.*).

A conceptual diagram of nutrient generation, transport and impacts is shown in Figure 2. Key water quality pollutants of concern in the WQIP include dissolved and particulate forms of nitrogen and phosphorus, suspended sediment and the residual herbicides ametryn, atrazine, diuron, hexazinone, and tebuthiuron.

Further general information on water quality in the Mackay Whitsunday region is available in Faithful (2003); Brodie (2004); Brodie et al. (2007); Rohde et al. (2006; 2008); Mackay Whitsunday Healthy Waterways (2007); Galea et al. (2008a, 2008b); Drewry et al. (2008); Brodie et al. (2013); Reef Catchments (*unpubl.*); and State of Queensland (2013).

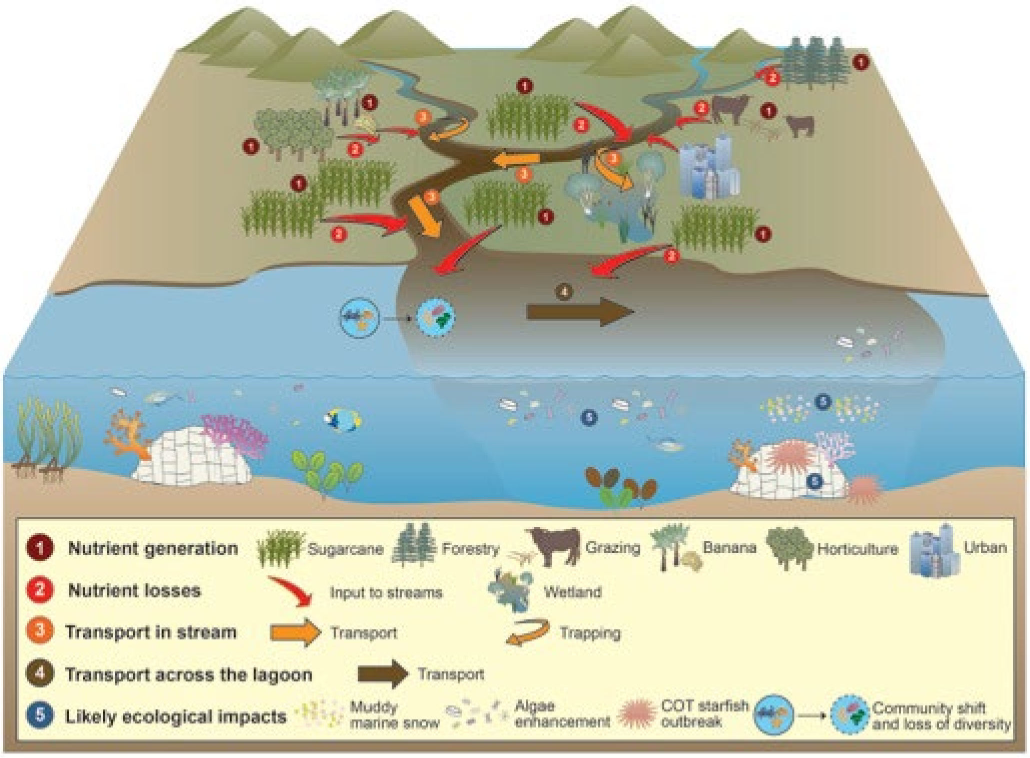


**Figure 2 Conceptual diagram of nutrient pollution generation, transport, and the effects on the marine environment of the Mackay Whitsunday region of the Great Barrier Reef lagoon (adapted by T. Marshall from original by J. Prange, GBRMPA).**

## 1.3. Water quality policy environment

The water quality policy environment operating in the Mackay Whitsunday region is multi-jurisdictional and complex. This is partly a reflection of the level of importance placed upon maintaining the GBR by the Queensland and Australian Governments and the international community. This presents challenges to efficient delivery of water quality outcomes for the GBR, despite the establishment of the *Great Barrier Reef Marine Park Act 1975* and its supporting Great Barrier Reef Marine Park Regulations 1983 (the Regulations) to provide a framework for coordinating the activities of stakeholders across all jurisdictions.

An example of challenges faced is the changing approaches to regulation at the state government level which can then unbalance approaches that are reliant on a whole policy approach across jurisdictions and involve an appropriate mix of regulation, education, motivation and incentives to deliver water quality improvement to the GBR. The current revision of Water Resource Plans has the potential to impact on other planning instruments such as Water Quality Improvement Plans (WQIPs) and the priorities and targets they include.

This water quality improvement plan has been developed to address requirements established under the Australian Government's Reef water quality programme and requirements for healthy waters management plans (HWMPs) specified in section 24 of the Environmental Protection Policy (Water). Where WQIPs adequately address matters specified under the EPP Water for HWMPs, they may be accredited as HWMPs. The HWMP guidelines are available from the department's website at http://www.ehp.qld.gov.au/water/policy/water_quality_improvement_plans.html.

Environmental values (EVs) and water quality objectives (WQOs) for Mackay-Whitsunday region waters were scheduled in 2013 by the Queensland Government under the Environmental Protection Policy (Water). These include mapping of waters identified for high ecological value level of protection in fresh, estuarine and coastal/marine waters. Scheduled EVs and WQOs are based on the earlier WQIP, with local updates based on additional information, stakeholder inputs, etc.

Documents and plans are available from the Department of Environment and Heritage Protection (EHP) website at
http://www.ehp.qld.gov.au/water/policy/schedule1/mackay-whitsunday-scheduled-evs-wqos.html

As planning and reporting initiatives such as next generation WQIPs and comprehensive regional Reef Report Cards evolve to become more integrated and all encompassing, the supporting policy environment must evolve similarly. Policies and programs, and the way in which they are administered and delivered, must continue to strive for a coordinated collaborative and integrated approach if they are to effectively support the delivery of water quality outcomes necessary to protect the GBR.

The extensive range of current policy instruments and how they influence the GBR are listed in Chapter 2.

### 1.4. The Water Quality Improvement Plan

Considerable efforts are being undertaken to protect the GBR region from risks of pollution and eutrophication from adjacent catchments. Generally, WQIPs are targeted toward high risk catchments identified in the Reef Plan, and their outputs are integrated with Natural Resource Management (NRM) Plans. Environmental Values and water quality objectives (WQOs) can be incorporated into Schedule 1 of the Environmental Protection (Water) Policy 2009 (EPP Water), thus giving them a statutory status – the EVs and long-term (2050) WQOs for the Mackay Whitsunday region identified in the 2008 WQIP were updated and scheduled under the EPP Water in 2013. Additionally, while the NRM Plan operates at a more strategic level for the region as a coordinated mechanism, the WQIP is the document focused on operations and onground implementation.

In 1997, the Mackay Whitsunday NRM Group (MWNRM) was formed with a purpose to improve the linkages between government, industry and the community for managing natural resources. The group was a non-statutory, not-for-profit organisation, representing people with an interest in the use and management of natural resources. In 2008, the MWNRM Group produced the Mackay Whitsunday WQIP referred to as Drewry et al. (2008). The 2008 WQIP divided the Mackay Whitsunday region into 33 catchment management areas, and developed relevant WQOs and ecosystem health objectives, and quantified current condition and targets for each area. It provided a strategy for maintaining and improving water quality and aquatic ecosystem health across the region. Aquatic ecosystem and human use EVs for each management area waterway in the region were used to help determine WQOs (as discussed in detail in Drewry et al. 2008).

The 2008 WQIP included an implementation phase until 2014, involving recommended management interventions, monitoring and modelling, planning and legislation, and was adapted through annual and mid-term reviews.

The 2014 WQIP builds upon information in the 2008 WQIP, EVs/WQOs scheduled in 2013, and reviews of the implementation success of the 2008 WQIP implementation period. The updated WQIP further revises and further refines targets and management interventions proposed for the 2014-2021 period. Details on the revised WQOs, targets, and management interventions can be found in Chapters 8 to 15. A conceptual diagram of the process driving the WQIP and purpose of the associated objectives and targets is shown in Figure 3.

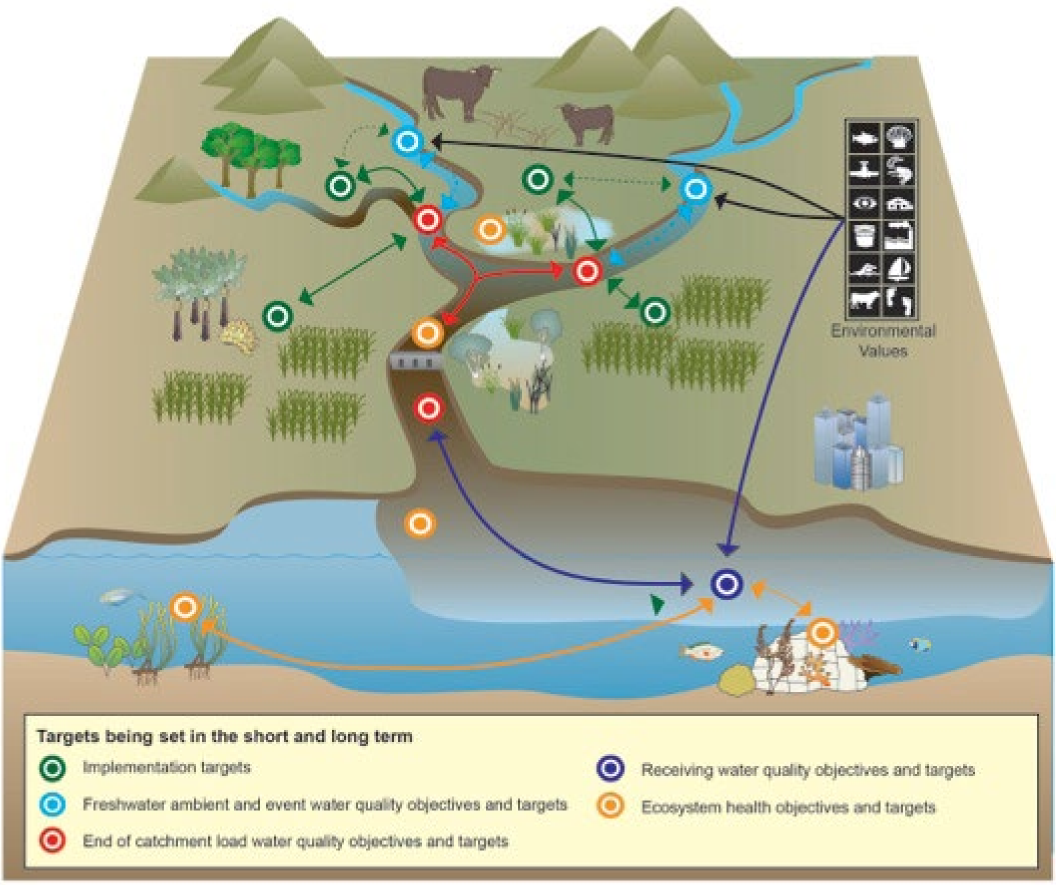


**Figure 3 Conceptual diagram of the process of establishing freshwater ambient and event, and marine water quality objectives, ecological health objectives, and targets to maintain or improve water quality and ecological condition in the Mackay Whitsunday region of the Great Barrier Reef lagoon (adapted by T. Marshall from original by J. Prange, GBRMPA).**

## 1.5. Report objectives and strategic direction

### 1.5.1. Report objectives

The overall objectives of this report are to determine the main water quality issues in the region, and to identify and prioritise land management activities that can assist to improve water quality and ecosystem health. The prioritisation of the management activities should be used by funders to guide investment in the region.

The specific objectives of this updated WQIP for the 2014-2021 period include:

- Presenting an overview of the process and strategies utilised in updating the WQIP since the 2008 report;
- Revising and refining information presented in the 2008 WQIP for EVs, WQOs, and targets for water quality and ecosystem health;
- Review of the EVs/WQOs and HEVs/SD waters scheduled under EPP Water;
- Assessing changes in land management practices and their corresponding changes in water quality and ecosystem health since the 2008 WQIP;
- Describing the current water quality and ecosystem health in the WQIP area;

- Presenting an overview of the process and strategies developed to rehabilitate priority aquatic habitats and reduce pollutant loads from diffuse and point sources in the region;
- Presenting information developed during the WQIP update process that is not presented in other reports; and
- Presenting an updated implementation plan for water quality and ecosystem health improvement in the Mackay Whitsunday region for the 2014-2021 period.

This 2014-2021 WQIP will be reviewed and updated in 2021. The review will assess the implementation and how the current waterways and marine environment condition within the region is tracking toward the 2050 WQOs.

### 1.5.2. Strategic direction of the 2014-2021 WQIP

This updated WQIP fits into the overarching strategic direction for the Mackay Whitsunday region, and more generally, the GBR catchments. The key aims of the WQIP align with the Reef Plan, NWQMS, EPP (Water), and the Mackay Whitsunday NRM Plan. The WQIP aims to continually provide feasible solutions and intervention options, and guide the use of investment for the best possible outcomes.

One key purpose of the WQIP implementation is relationship building with industry and stakeholders. These relationships aim for the continual improvement of practices, with the aim to improve water quality. The relationships encourage voluntary adoption of land practice change, as well as consultation surrounding relevant policies and legislation.

The process undertaken and described in the update of the WQIP highlights the dynamic process of the WQIP implementation, which is constantly evolving, refining and improving. As new information comes to light, on water quality condition or issues in the region, or regarding new practices for land management, it is incorporated into the WQIP and associated implementation activities.

Land managers across the Mackay Whitsunday region are changing practices to improve water quality to the catchment, including the Great Barrier Reef Lagoon. Pictured is Warren Watts, a cane farmer and grazier near Proserpine who is involved on-the-ground in the Australian Government Reef Programme (formerly Reef Rescue).

### 1.6. Structure of this report

This structure of the report is presented in Table 1.

**Table 1 Structure of the 2014-2021 WQIP.**

| | |
|---|---|
| **Section A: Introduction** | |
| Chapter 1 | Background |
| Chapter 2 | Legislation and Planning |
| Chapter 3 | Climate Change |
| **Section B: Updating the Water Quality Improvement Plan** | |
| Chapter 4 | General Update |
| Chapter 5 | Community Consultation |
| Chapter 6 | Defining the Region |
| Chapter 7 | Environmental Values |
| **Section C: Targets and Objectives** | |
| Chapter 8 | Pollutant Sources |
| Chapter 9 | Water Quality Objectives and Targets |
| Chapter 10 | Water Quality Improvement |
| Chapter 11 | Ecosystem Health Targets |
| **Section D: Regional Intervention and Investment Priorities** | |
| Chapter 12 | Management Interventions to Improve Water Quality |
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| Chapter 14 | Prioritisation of Management Interventions |
| Chapter 15 | Adoption Targets and Costs |
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| Chapter 16 | Monitoring Plan |
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| Chapter 18 | References |
| **Catchment Management Area Reports** | |
| **Receiving Water Modules** | |
| **ABCD Management Frameworks** | |
| **Appendices** | |

# 2. Legislation and Planning

The intention of the WQIP is to maintain and improve water quality to protect ecological and human uses of waterways. To achieve this goal, accelerated adoption of improved land management practices is required. Legislation often provides a platform to enable minimum standards to be set and can be an important tool to minimise resource damage. However, the 2008 and 2014-2021 WQIPs recommend a range of voluntary adoption mechanisms, such as incentives and extension efforts, in partnership with legislation to achieve required outcomes.

This chapter contains information on institutional or commercial support arrangements, legislation, and planning relevant to the WQIP.

## 2.1. Institutional or commercial support arrangements

### 2.1.1. Reef Plan

In 2003 the Queensland and Australian Governments signed the Reef Water Quality Protection Plan (The State of Queensland and Commonwealth of Australia 2003), known as 'Reef Plan'. The 'Reef Water Quality Partnership' was also established to facilitate coordination and collaboration among Reef Plan stakeholders, including NRM groups, the Australian Government, and the Queensland Government.

The main aim of the Reef Plan is to "halt and reverse the decline of water quality on the Great Barrier Reef". Reef Plan represents a coordinated and cooperative approach to improve the water quality in the GBR from agricultural activities, through focusing on achieving clear goals and specific targets for pollutant levels, groundcover, wetland extent and adoption of better management practices. The Reef Plan sets out a range of strategies and activities to meet the key objectives, from self-management of rural and diffuse sources of pollutants through to monitoring and evaluation.

The Reef Plan was reviewed and updated in 2009 and 2013.

The development of the 2014-2021 WQIP contributes to the Reef Plan goals. The targets and actions within the WQIP aim to work toward meeting the requirements and goals of the Reef Plan (refer to Chapter 10.2) and contribute towards protecting scheduled EVs/WQOs under EPP Water. Paddock to Reef is the monitoring and evaluation program that assesses the success of the Reef Plan actions, with yearly report cards issued. Further information on the report cards and associated results is contained in Chapter 1.

Implementation of Reef Plan in the Mackay Whitsunday region is enabled by Reef Catchments through the management of Reef Programme (formerly Reef Rescue) water quality grants and contributing to promoting improved land management practices. In addition, since 2009 Reef Catchments has contributed directly to the Paddock to Reef program by managing key monitoring sites and collecting data on practice adoption. Since 2008, Reef Catchments has facilitated the investment of $27.5 million in the Mackay Whitsunday region into improved agricultural practices. This investment has implemented 918 projects across three industries; $29.5 million co-investment by farmers; 93,000 ha of improved soil management; 59,000 ha of improved nutrient management; and 95,000 ha of improved pesticide management.

### 2.1.2. Reef 2050 Long-term Sustainability Plan

In 2015, the Australian Government released the Reef 2050 Long-Term Sustainability Plan with the purpose to set "out what Australians, as custodians for the international community, want the future of the Great Barrier Reef World Heritage Area to be and how this will be achieved" (Commonwealth of Australia 2015). The Plan was developed in response to requests from the World Heritage Committee and is the governments' commitment to working in partnership with industry and the community to protect the Reef 's Outstanding Universal Value and its natural integrity and cultural values.

### 2.1.3. Healthy Waterways Alliance

The Healthy Waterways Alliance Mackay Whitsunday Isaac (Healthy Waterways Alliance) was established by Reef Catchments in 2010. The Healthy Waterways Alliance engaged key stakeholders to establish strategic partnerships to progress water quality and ecosystem improvement goals for regional terrestrial, freshwater, estuarine, coastal, and marine environments. The Healthy Waterways Alliance also has the purpose to ensure strong governance arrangements are in place to underpin, guide and drive the implementation recommendations within the WQIPs.

## 2.2. Legislation

As the Mackay Whitsunday region includes areas of the GBR and GBRMP, including a WHA, international agreements and legislation specific to the GBRMP are also relevant to the WQIP. A list of the most relevant international agreements, and Australian and Queensland Governments legislation is provided below. Refer to Appendix A for further detail on the purpose of each different Act.

**International agreements**

- Convention concerning the Protection of the World Cultural and Natural Heritage 1972;
- Convention on Biological Diversity 1992;
- Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973;
- Convention on the Conservation of Migratory Species of Wild Animals 1979;
- Convention on Wetlands of International Importance Especially as Waterfowl Habitats 1971;
- China–Australia Migratory Bird Agreement 1986;
- International Convention for the Prevention of Pollution from Ships 1973;
- Japan–Australia Migratory Bird Agreement 1974;
- Republic of Korea–Australia Migratory Bird Agreement 2007;
- United Nations Convention on the Law of the Sea 1982; and
- United Nations Framework Convention on Climate Change 1992.

**Australian Government legislation:**

- *Great Barrier Reef Marine Park Act 1975* and associated documents;
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- *Water Act 2007*;
- *Environment Protection (Sea Dumping) Act 1981*;
- *Historic Shipwrecks Act 1976*;
- *Native Title Act 1993*;
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*; and
- *Sea Installations Act 1987*.

**Queensland legislation:**

- *Water Act 2000* - the Mackay Whitsunday EVs and WQOs (presented in Drewry et al. 2008) were scheduled in EPP (Water) 2000 in 2013;
- *Vegetation Management Act 1999*;
- *Environmental Protection Act 1994* and associated Environmental Protection (Water) Policy 2009;
- *Fisheries Act 1994*;
- *Local Government Act 1993*;
- *Coastal Protection and Management Act 1995*;
- *Nature Conservation Act 1992*;
- *Marine Parks Act 2004*;
- *River Improvement Trust Act 1940*;
- *Sustainable Planning Act 2009*;
- *State Planning Policy* (SPP) (updated 2014), incorporating state interest - water quality;
- *Aboriginal Cultural Heritage Act 2003*;
- *State Development and Public Works Organisation Act 1971*;
- *Land Act 1994*;
- *Environmental Offsets Act 2014*;
- *Agricultural and Veterinary Chemicals Code Act 1994*;
- *Biosecurity Act 2014*;
- *Regional Planning Interests Act 2014*; and
- Regional Plans and Local Planning Schemes.

Additionally, the following also have relevance:

- *Native Title (Queensland) Act 1993*;
- *Transport Operations (Marine Pollution) Act 1995*;
- *Transport Operations (Marine Safety) Act 1994*;
- *Transport Infrastructure Act 1994*; and
- *Workplace Health and Safety Act 1995*.

The Environmental Defenders Office (EDO) conducted a review of changes in Queensland's environmental law framework as a result of the 2012 change in government, with a focus on changes that affect NRM groups and their objectives. Key findings from the review (EDO 2014) showed that the changes within the following legislation are most relevant to Reef Catchments and the WQIP:

- *Vegetation Management Act 1999*;
- *Water Act 2000*;
- *Agricultural and Veterinary Chemicals Code Act 1994*;
- *Sustainable Planning Act 2009*;
- *Land Act 1994*;
- *Nature Conservation Act 1992*;
- *Fisheries Act 1994*;
- *State Development and Public Works Organisation Act 1971*; and
- *Coastal Protection and Management Act 1995.*

Further detail on these changes in legislation and their impacts to NRM groups and the WQIPs can be found in Appendix A.

In May 2014, the Queensland and Australian Governments released a draft statutory approval bilateral agreement regarding the transfer of Australian Government powers to approve actions under the EBPC Act to the Queensland Government. This transfer of power may result in Matters of National Environmental Significance (MNES) being at risk to impacts caused by development, mining and extractive activities (EDO 2014). Additionally, the proposed change to remove the referral stage will result in fewer opportunities for public submissions on whether the action is a controlled action (EDO 2014).

## 2.3. Policy and planning

This section outlines selected relevant policies and plans.

### 2.3.1. National Water Quality Management Strategy

Through the Natural Resource Management Ministerial Council (NRMMC), the National Water Quality Management Strategy (NWQMS) was developed by the Australian Government in cooperation with state and territory governments. The NWQMS is part of the Council of Australian Governments (COAG) Water Reform Framework and is acknowledged in the National Water Initiative (NWQMS 2008).

### 2.3.2. National Water Initiative

The National Water Initiative (NWI) is a collaboration between the Australian Government and state and territory governments, with the aim to drive water reform in Australia. The initiative builds upon the effort of the shared commitment to water reform in recognition of the Council of Australian Governments. The NWI acknowledges (National Water Commission 2008):

- "The continuing national imperative to increase the productivity and efficiency of Australia's water use;
- The need to service rural and urban communities; and
- Ensuring the health of river and groundwater systems, including establishing clear pathways to return all systems to environmentally sustainable levels of extraction".

Development of performance indicators and implementation of the NWI is the responsibility of the Natural Resource Management Ministerial Council (NRMMC; National Water Commission 2008). The reporting responsibility resides with the Productivity Commission.

### 2.3.3. Coastal Catchments Initiative

The Coastal Catchments Initiative (CCI) announced in 2002 is aimed at achieving targeted reductions in pollution discharges to coastal water quality "hot spots". Hot spots are broadly defined as coastal waters of high conservation value threatened by pollution, and where there is a strong jurisdictional commitment to improve water quality. The CCI supports the development and implementation of WQIPs in accordance with the Australian Government Framework for Marine and Estuarine Water Quality Protection (DEWHA 2002). The framework is based on the NWQMS and the National Principles for the Provision of Water for Ecosystems.

### 2.3.4. Caring for Our Country

Caring for Our Country commenced in 2008 and replaced the previous Natural Heritage Trust. The goal of Caring for Our Country is to have an environment that is healthy, better-protected, well-managed, resilient, and provides essential ecosystem services in a changed climate. The program focuses on six national priority areas:

- A national reserve system;
- Biodiversity and natural icons;
- Coastal environments and critical aquatic habitats;
- Sustainable farm practices;
- Natural resource management in remote and northern Australia; and
- Community skills, knowledge and engagement.

### 2.3.5. Mackay Whitsunday Regional NRM Plan

The aim of Mackay Whitsunday NRM Plan is to “develop actions, mechanisms and partnerships to manage natural resources and their associated cultural values sustainably”. The Mackay Whitsunday Natural Resource Management Plan (2014-2024) has been developed by the Mackay, Whitsunday and Isaac community and key stakeholders to guide regional strategic investment and activity in natural resource management.

The purpose of the NRM Plan is to capture the aspirations and vision of the community and stakeholders, which translates to goals, outcomes and management actions at a strategic scale. The 2014-2021 WQIP will act as an implementation plan for the updated NRM Plan, with operational, onground actions for the Mackay Whitsunday region. The implementation goals of the WQIP will be incorporated into the Regional Investment Strategy of the NRM Plan.

### 2.3.6. Australian Government Reef Programme (formerly Reef Rescue Plan)

During the 2007 election campaign, the Australian Labor party announced the Reef Rescue Plan, with the commitment to invest $200 million over five years to tackle climate change and improve water quality to the GBR. The aim of the plan was to “work with farmers, Indigenous communities, conservation groups, tourism operators and the fishing industry to dramatically improve water quality and keep the Reef healthy in the face of climate change”. Reef Rescue Plan ran from 2008-2013.

Reef Programme follows on from the Reef Rescue Plan, as the second stage (from 2013-2018). The Reef Programme focuses on six integrated components within the GBR catchments, as follows:

**Water Quality Grants and Partnerships**:

- Increase the voluntary uptake of improved land management practices by landholders that will reduce the discharge of sediments, nutrients and pesticides into the Great Barrier Reef; and
- $64 million has been committed to Water Quality Grants for 2013/14 to 2015/16, and $3 million (GST excl.) allocated to Water Quality Partnerships over five years (2013/14 to 2017/18).

**Systems Repair and Urban Grants:**

- Funding will support the programme to increase the GBR’s resilience to climate change; and
- Funding will be available for wetland, riparian and mangrove protection, and restoration projects and provided to support planning and on-ground projects to improve the quality of water entering the Great Barrier Reef from highly developed areas of the reef catchment.

**Water Quality Monitoring and Reporting and Research and Development (R&D):**

- Aims to track the progress of investment against the broader program objectives, while monitoring the health of the GBR; and
- The R&D will continue to improve the understanding of the link between agricultural and industrial impacts and health of the Great Barrier Reef.

**Crown of Thorns Starfish (COTS) Control:**

- Aims to decrease the impact of COTS by supporting tourism operators to continue to defend high value tourism sites, and will also fund research on new control methods;
- Over two years, the Association of Marine Park Tourism Operators will be provided with $4

million to undertake activities to control COTS; and
- $1 million available for the continuation of research into starfish management.

**Land and Sea Country Partnerships:**
- Continue to strengthen communications between local communities, GBR managers and stakeholders, and build a better understanding of Traditional Owner use of the GBRMP.

**Great Barrier Reef Marine Park Authority (GBRMPA):**
- Operational support for the GBRMPA which will allow GBRMPA to enhance the conservation of the GBR, and maintain and develop reef management systems and resilience programs.

This WQIP contains clear direction on the activities and investment that will help to achieve the goals of the Reef Programme. The WQIP and Reef Programme are complementary and investment indicated by the Reef Programme will enable effective implementation of the Mackay Whitsunday WQIP.

### 2.3.7. State Planning Policy – State Interests

The State Planning Policy State interest - water quality seeks to ensure that development is planned, designed, constructed, and operated to protect the environmental values of Queensland waters (available from http://www.statedevelopment.qld.gov.au/about-planning/state-planning-policy.html).

The State Planning Policy state interest - water quality requires consideration of the development and operational phases for activities assessed under the Sustainable Planning Act 2009, for areas generally greater than 2500 m². The SPP code - water quality requires reductions in the loads known to be generated as a result of urbanisation, by percentages specified for the relevant climatic region across Queensland ('Central Queensland North' for the Mackay Whitsunday region) for key pollutants of total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), and gross pollutants. This is generally undertaken though implementation of water sensitive urban design (WSUD) and treatments that may include bio-filtration basins, grassed swale, constructed wetlands and proprietary devices such as cartridge filters.

Activities including building and construction on lots smaller than the 2500 m² threshold must minimise impact under the general environmental duty provisions of the *Environmental Protection Act 1994.*

The provisions of the SPP state interest - water quality allow for local governments to adopt alternative, locally appropriate, solutions to stormwater management in their planning schemes.

### 2.3.8. Other plans and policies

Other plans and policies relevant to this WQIP include:

- Coastal Management Plan 2014;
- Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004;
- Whitsunday Hinterland and Mackay Regional Organisation of Councils 2015;
- Local government stormwater management plans;
- Queensland Wetland Protection Policy;
- Commonwealth Wetlands Policy 1997;
- Queensland Water Plan 2005-2010;
- Rural Water Use Efficiency Initiative 2;
- 1999 Strategy for the conservation and management of Queensland wetlands;
- Carbon Farming Initiative (2011);
- NRW Land and Water Management Plans;
- 'OnePlan' (NRW); and
- Leasehold land strategy.

# 3. Climate Change

Predicted changes in climate will have a significant impact on land managers and the community in the Mackay Whitsunday area, which is heavily reliant on natural resources for local industries (including tourism, agriculture and mining) as well as lifestyle.

## 3.1. Introduction

Climate refers to the average weather pattern over years or decades. Climate system components occur on different timescales (shown in Figure 4). Climate change refers to a change in the average weather pattern and occurs as a natural process over geological timescales (Figure 4); with glacial (ice ages) and interglacial cycles (warm periods). Weather reflects the state of the atmosphere at a particular time and place, and occurs on shorter timescales from hours to months. Weather terms include rain, sunshine, and temperature, and is influenced by the time of year and atmospheric conditions.

The increase of atmospheric concentration of $CO_2$ since 1750 has led to an uptake of energy by the climate system resulting in increased global average temperatures, changes in the water cycle, ocean warming and sea level rise already evident (IPCC 2014; IPCC 2007). It is extremely likely that human influence has been a dominant cause of the observed warming since the mid-20$^{th}$ century (IPCC 2014).

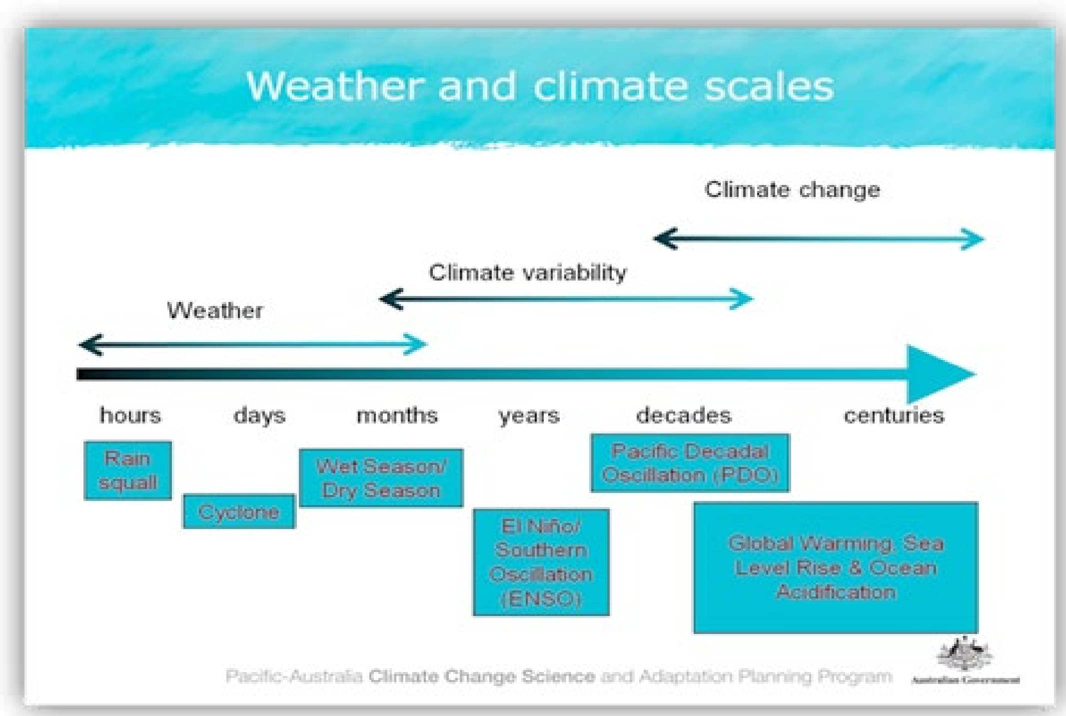



**Figure 4 Climate system component timescales (Source: [http://www.pacificclimatefutures.net/en/help/climate-projections/understanding-climate-variability-and-change/](http://www.pacificclimatefutures.net/en/help/climate-projections/understanding-climate-variability-and-change/)).**

Climate variability is an expression of interactions between the ocean and atmosphere, and occurs over months to decades (Figure 4). Atmospheric and oceanic phenomena operating on varying time scales that influence climatic patterns in the Mackay Whitsunday region include the Southern Annular Mode (SAM), El Nino Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), the Madden Julian Oscillation (MJO) and the Indian Ocean Dipole (IOD).

Climate change occurs over decades to centuries (Figure 4). Factors that contribute to climate change include:

- Changes in the Earth's orbit around the sun;
- Changes in the sun that can affect the amount of solar radiation produced;
- Large volcanic eruptions that can produce large amounts of ash that stay in the atmosphere for long periods, reflecting solar radiation back into space; and
- Changes in greenhouse gas concentrations in the atmosphere.

Any changes to the climate will impact on natural systems, agricultural systems and built environments. Therefore understanding the impacts and risks associated with these changes is critical for long term sustainability.

## 3.2. Climate change impacts for the Mackay Whitsunday region

Trends and impacts from climate change are predicted through global models, with over 40 world global models used by the Intergovernmental Panel for Climate Change (IPCC) to present projected future global and regional impacts.

Climate change trends already evident are projected to increase on a national to regional basis. The trends that may impact on water quality relevant to the Mackay Whitsunday region and the 2014-2021 WQIP include:

- Increased atmospheric $CO_2$;
- Increases in average air temperatures, more hot days and fewer cold days. On a national basis, Australia's climate has warmed by 0.9°C, with more extreme heat and fewer cool extremes (Bureau of Meteorology and CSIRO 2014). Projections for the Mackay Whitsunday region show that average maximum temperatures may increase by 1°C by 2030 and 2°C by

2070 (RPS 2014);
- Annual rainfall is not expected to change, however the intensity of extreme events are expected to increase (Hilbert et al. 2014). Projections for the Mackay Whitsunday region indicate baseline (1995) 1 in 100 year rainfall events may occur every 70 years by 2030 and every 60 years by 2050 (RPS 2014);
- The intensity (not frequency) of tropical cyclones is expected to increase (Hilbert et al. 2014);
- Evapotranspiration is expected to increase in all seasons (Hilbert et al. 2014);
- Wind speeds are expected to increase across eastern Australia (Hilbert et al. 2014); and
- Sea levels will continue to rise, and the frequency and height of storm surges are expected to increase (Hilbert et al. 2014).

As these trends are predicted to increase in the future, the 2014-2021 WQIP needs to recognise and understand what these changes mean, and account for them in the implementation and intervention activities.

## 3.3. Implications of climate change on water quality in the Mackay Whitsunday region

The implications on water quality in the Mackay Whitsunday region (and relevant to the 2014-2021 WQIP) of the predicted climate change impacts mentioned above are shown in Table 2.

**Table 2 The implications of the climate change predictions to water quality in the Mackay Whitsunday region.**

| Climate change predictions | Implications to Mackay Whitsunday region |
|---|---|
| Increased intensity of extreme events (rainfall and cyclones) | Increased erosion from land and stream banks with inadequate cover/riparian vegetation |
| Increased atmospheric $CO_2$ | Increased demand from water resources (surface/ground) |
| Greater wind speeds | Increased demand from water resources (surface/ground) |
| Increased evapotranspiration | Increased demand from water resources (surface/ground) |
| Altered streamflow regimes | Decline in aquatic ecosystem health |
| Altered streamflow regimes | Previously permanent streams may become perennial, impact on fish migration and other aquatic ecosystem parameters |
| Altered streamflow regimes | Longer dry seasons may lead to the increased incidence of blue-green algae outbreaks |
| Ongoing sea level rise | Land uses and natural areas in the coastal zone will be impacted adversely |
| Increased frequency and height of storm surges | Increased erosion, which will have an additional negative impact on water quality |

The text below provides further detail on the impacts of climate change in the region and on different land uses. Potential adaptation responses that could be adopted for differing land uses are also discussed. Refer to the later sections in this report for more information on land management activities –Chapter 12 discusses the ABCD Management Frameworks which are presented at the end of the report.

### 3.3.1. Agricultural land practices

Of the climate change impacts discussed above, agricultural land practices (specifically sugarcane) may be impacted in the following ways:

- Potential opportunities for the sugarcane industry with increased respiration from higher atmospheric $CO_2$, however this may also increase water use demand;
- Reduced availability of groundwater for irrigation in coastal aquifer systems impacted by sea water intrusion due to sea level rise;
- Increased erosion from land and stream banks as a result of increased intensity of extreme events; and
- Increased losses of sugarcane growing in low-lying areas due to increased flooding and increased greenhouse gas emissions with nitrification from soils in low lying areas.

Refer to Figure 5 and Figure 6 for more detail on where these impacts may occur.

In response to the identification of these potential impacts to agricultural land and agricultural activities, the following adaptation responses are suggested and incorporated in the 2014-2021 WQIP implementation plan:

- All B and A Class soil, nutrient, chemical and water management practices identified in the Sugarcane ABCD Management Framework incorporate responses to climate change impacts; and
- Use of seasonal forecasting tools for making management decisions (e.g. cultivation, fertiliser, herbicide application, timing of block harvesting) will be more important with increased climate variability. Longer-term climate forecasting for longer-term decision-making is necessary (changing farm layout, crop diversification, new infrastructure).

### 3.3.2. Grazing land practices

Of the climate change impacts mentioned above, grazing land may be impacted in the following ways:

- New (and possibly more) pests, weeds and diseases (Hilbert et al. 2014), resulting in increased use of chemicals and pesticides that have the potential to impact adversely on water quality;
- Higher temperatures, more $CO_2$, and less infiltration from higher intensity rainfall may mean that pastures could be less nutritious (Hilbert et al. 2014). Attempts at pasture renovation may impact adversely on water quality with increased areas of bare ground exposed for longer periods; and
- Increased sheet, rill, and gully erosion on the land, and increased stream bank erosion as a result of rainfall events generating higher energy rainfall runoff events and peak discharged in streams and rivers.

Refer to Figure 5 and Figure 6 for more detail on where these impacts may occur.

The following adaptation responses are suggested and have been incorporated in the 2014-2021 WQIP implementation plan in response to the identification of potential impacts to grazing land and associated activities:

- A and B Class grazing pasture nutrient and chemical management are responses to climate change impacts. A Class pasture spelling, riparian and gully management will provide an improved response to climate change impacts; and
- Use of seasonal forecasting tools for making management decisions (pasture renovation, fertiliser, and herbicide application) will be more important with increased climate variability. Longer-term climate forecasting for longer-term decision-making will be necessary (crop diversification, new infrastructure).

### 3.3.3. Urban land use

Of the climate change impacts mentioned above, it is expected that urban land use in the Mackay Whitsunday region may be impacted in the following ways:

- Increases in average air temperatures are likely to increase water consumption for domestic

and industrial uses, putting greater pressure on existing water resources;
- Increased intensity of extreme weather events may lead to increased erosion on development sites, damage to stormwater mitigation devices, and failure and overflow of sewage treatment plants; and
- Sea level rise and increased frequency and height of storm surges will lead to increased erosion and damage to industrial, tourism, urban and natural ecosystems in the Mackay Whitsunday coastal zone where the majority of development is located. In particular, loss of natural ecosystems in the coastal zone that assist in absorbing land-based pollutants (e.g., mangroves) will have adverse consequences for water quality draining to the GBR lagoon.

Refer to Figure 5 and Figure 6 for more detail on where these impacts may occur on urban land.

In response to the identification of these potential climate change impacts on urban land the 2014-2021 WQIP implementation plan and Urban ABCD Management Framework incorporates A Class management practices that are all adaptation responses to climate change.

Additionally, other adaptation responses that could be implemented to reduce climate change impacts on urban areas are listed below, however the implementation of these responses is outside the scope of this WQIP:

- Use of seasonal forecasting tools for short-term management decisions. Longer term climate projections are utilised for assessing development applications and the design and location of infrastructure (roads, sewage treatment plants, urban/ industrial development, landfill sites, etc.);
- New developments located away from risk areas such as floodplains, coastal areas (due to sea level rise (SLR) and storm surge), wetlands and endangered species habitats, Good Quality Agricultural Land (GQAL), subsidence areas, landslides, and ecological networks/ corridors;
- The preparation of hazard risk area overlay maps by regional councils (identifying areas of SLR, storm surge, wildfire, flooding, landslip) and planning schemes and development controls reflecting the outcome (adjustments to building codes, sub-division regulations, infrastructure standards);
- Development and implementation of food waste strategy (waste management), such as the development of rationalised composting facilities (resulting in a volume reduction to landfills) and compost production;
- Council infrastructure projects incorporating porous paving (reduced hard surfaces, reduced runoff) in parking areas and using pale asphalt (reduce heat) in road construction (Palazzo & Steiner 2011);
- Transport infrastructure designed and developed using risk hazard categories, dependent on the position in the landscape (thereby decreasing damage from flood/storm/salinity/high temperatures);
- Designs for development incorporating natural elements of the landscape so natural drainage and hydrology patterns are not impacted (Palazzo & Steiner 2011); and
- The use, location and frequency of open space areas designed to improve rainfall infiltration & reduce runoff. Low lying open space could incorporate artificial wetlands (carbon sequestration, bird habitat, reduced runoff).

A and B Class grazing pasture nutrient and chemical management are responses to climate change impacts.

Sea level rise and increased frequency and height of storm surges will lead to increased erosion and damage to industrial, tourism, urban and natural ecosystems in the Mackay Whitsunday coastal zone where the majority of development is located.

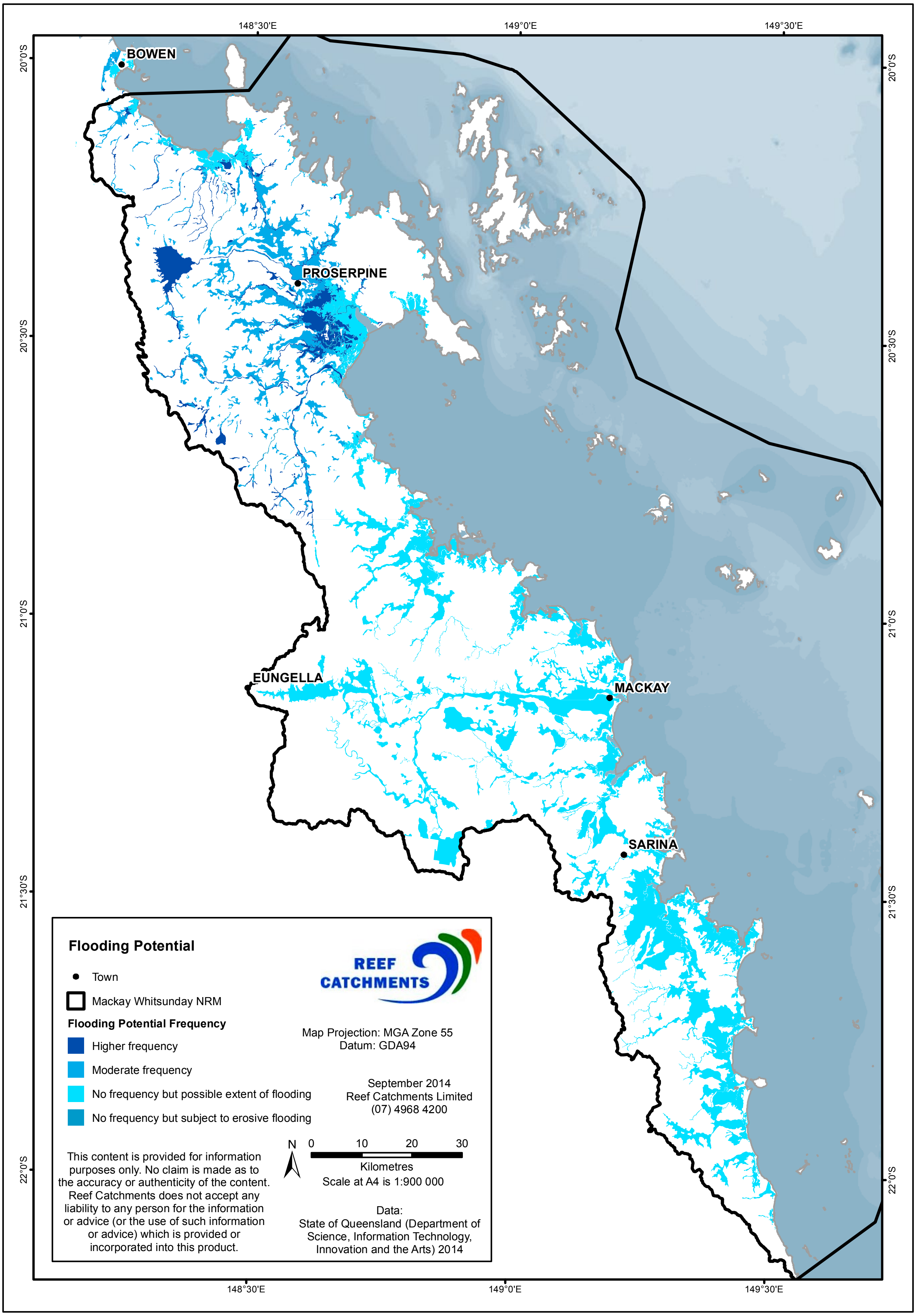



Figure 5: Potential areas of increased flooding.

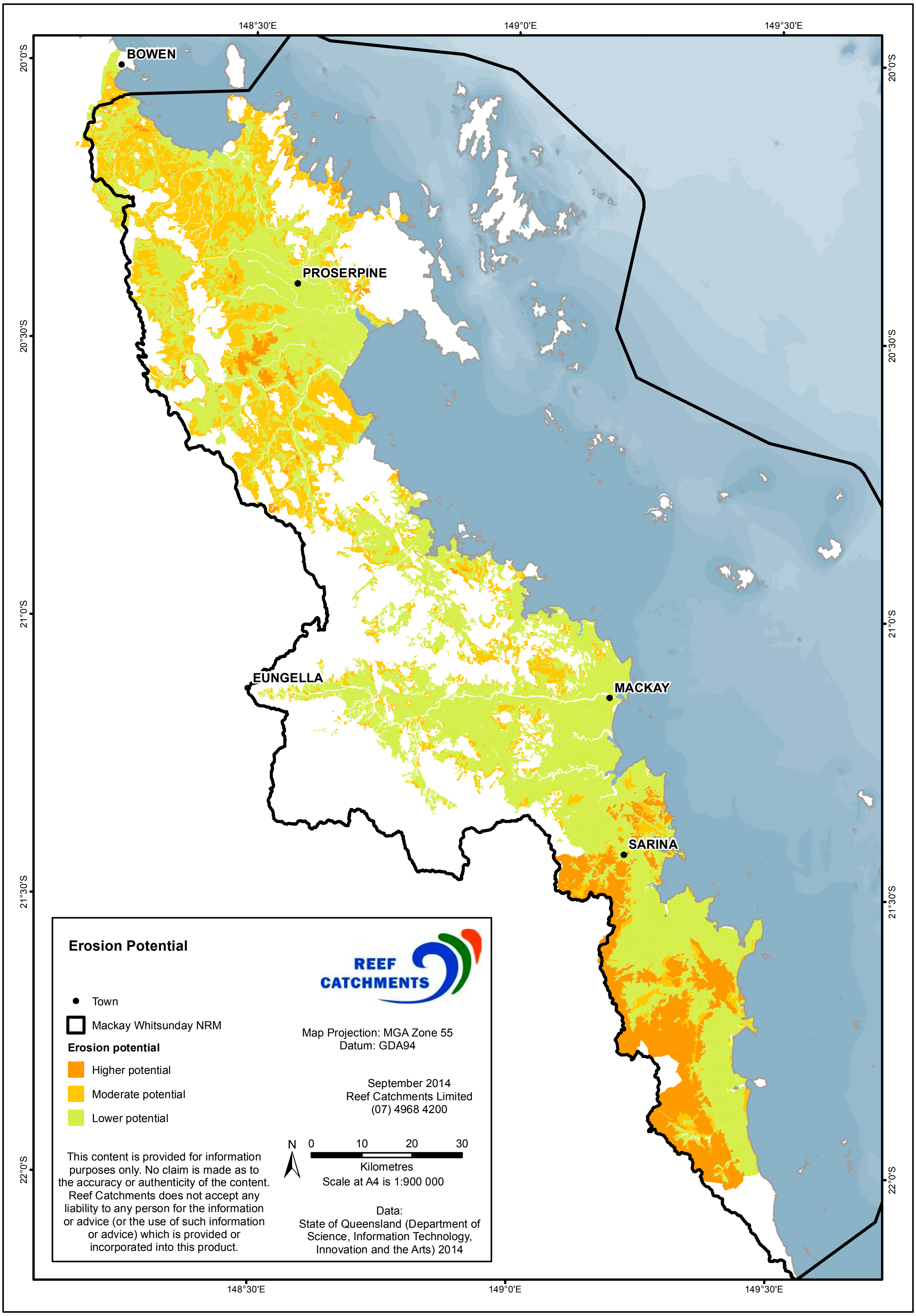



**Figure 6: Potential areas of increased erosion.**

# SECTION B

## Updating the Water Quality Improvement Plan

This section provides the outline of the process undertaken to update the WQIP from the 2008 version. The science and community consultation activities that were undertaken in the update are outlined, including details on outcomes of the consultation and the incorporation of the results into this WQIP. The definition of the region has also been updated in this version of the WQIP to include eight receiving waters in the marine environment and any land use changes. Additionally, this section provides some information on the current condition of the marine environment as this was a gap in the 2008 WQIP. Lastly, this section also presents the development and identification of Environmental Values and High Ecological Value areas and how these differ from those presented in the 2008 WQIP.

# 4. General Update

The process undertaken to develop and produce the 2014-2021 WQIP is shown in Figure 7.

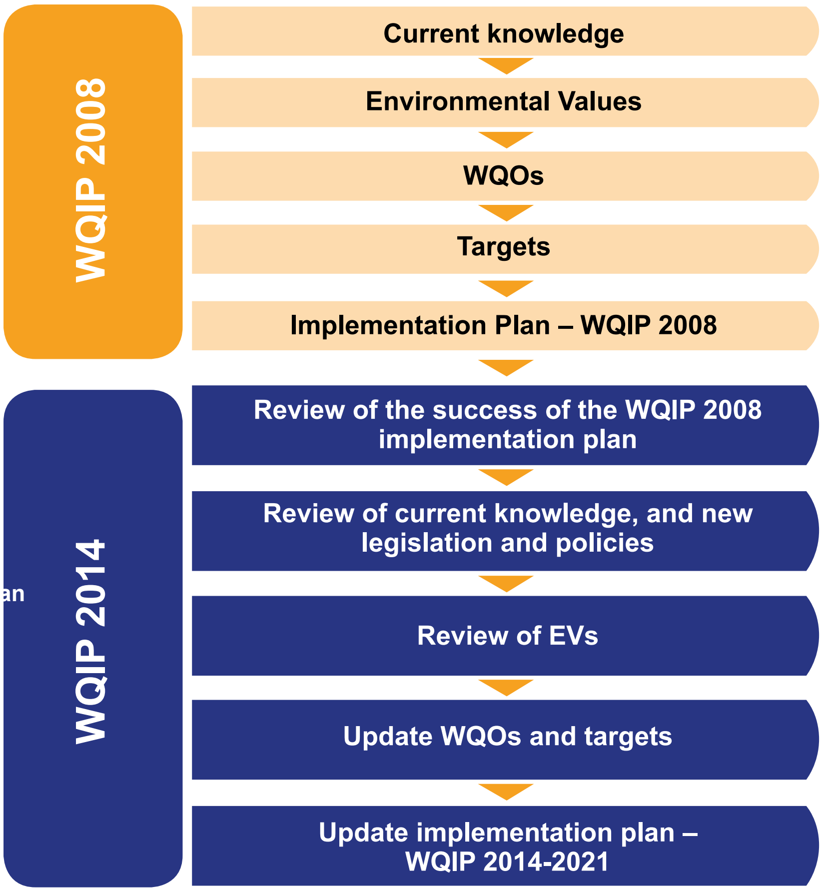



**Figure 7 Process undertaken in the development and revision of the WQIP.**

A summary of activities undertaken during the development of the 2014-2021 WQIP includes:

- Extensive community, industry and science-based consultation;
- Review of Environmental Values and High Ecological Value areas, identified in the 2008 WQIP;
- Review of EVs/WQOs and HEV/SD waters scheduled under EPP Water;
- Review of water quality monitoring data (ambient freshwater, event-based freshwater, and marine event plumes);
- Assessment of 2008 WQIP ambient freshwater WQOs and targets in 33 management areas, and marine WQOs based on Mackay Whitsunday region water quality data, community consultation and state or national water quality guidelines;
- Differentiation of the marine environment into eight receiving waters suitable for marine management areas;
- Assessment of the current condition of a range of indicators in the receiving waters;
- Evaluation of current condition of waterways and development of targets for improvement in water quality where required;
- Development of end-of-catchment WQOs and targets for 33 freshwater management areas using modelled data, and monitoring data, and management practice adoption;
- Development of aquatic health indicators;
- Identification, classification, and refinement of management practices in to an 'ABCD' framework;
- Regional load reduction modelling from management practice adoption;
- Economic analyses of the cost of implementing management practices on-farm at a catchment and region scale;
- Social and economic analysis of management practices;
- Review of pollutant exports to waterways of selected nutrient and herbicide management

practices for sugarcane based on plot- and paddock-scale field experiments and rainfall simulation by DNRM staff; and
- Development of an integrated monitoring program for this region and the GBR.

The following text provides detail on the community consultation that occurred during the update of the WQIP, how the region is defined (both freshwater catchments and marine areas), and the review of the region's EVs.

# 5. Community Consultation

This chapter details the science and community consultation processes that were developed to:
1. Support, facilitate and track the implementation of the WQIP between 2008 and 2014;
2. Review the rate of implementation of recommendations in the 2008 WQIP; and
3. Update the WQIP recommendations for the 2014-2021 implementation period.

Community and stakeholder engagement is a critical part of achieving collaborative outcomes for water quality across the region.

## 5.1. Supporting, facilitating and tracking the implementation of the 2008 WQIP

At the time of publication in 2008, the WQIP represented a major shift in our understanding of the sources of pollutants and the resulting management interventions required to improve water quality in the Mackay Whitsunday region.

The 2008 WQIP broke new ground for the region in delivering:
- Robust water quality datasets generated through an intensive two year water quality monitoring program at 13 sites across the 33 catchment management areas;
- Defined regional EVs and WQOs;
- Defined management practice change targets required to improve water quality in the region;
- Benchmarked management practice adoption targets and water quality targets to be achieved by 2014 and 2050;
- Current condition report on 33 catchment management areas; and
- Five year implementation plan to achieve regional water quality improvement targets.

Reef Catchments was well-equipped to facilitate improvements to regional water quality with knowledge, goals and a plan to reach the identified targets.

At the same time, it was recognised that a high level of effort was required to engage with key strategic stakeholders whose involvement was critical to implement the WQIP recommendations.

As mentioned in Chapter 2.1.2, Reef Catchments formed the Healthy Waterways Alliance in 2010 to engage key stakeholders to establish strategic partnerships to progress water quality and ecosystem improvement goals. The Alliance also had the purpose of ensuring strong governance arrangements to underpin, guide and drive the implementation of the recommendations in the WQIP. The scope of the Alliance membership enabled synergies between organisations involved in aquatic resource management to be maximised, helping to ensure the future health of the Mackay Whitsunday waterways, and to meet the key performance indicators of the WQIP.

The objectives of the Healthy Waterways Alliance were to:

- Create a coordinated partnership amongst key strategic stakeholders to improve end of catchment water quality;
- Make strategic decisions that improve implementation program performance;
- Identify key Reef protection programs and strategic linkages to regional water quality improvement initiatives;
- Link Mackay Whitsunday regional programs with other Reef protection programs; and
- Track overall program and implementation performance.

The Healthy Waterways Alliance structure contains four organisational units:

1. **The Panel** or overarching steering committee, representing senior decision makers from Queensland, Australian, and Local Government, and natural resource management, tourism and industry groups. The Panel has the capacity to negotiate regional work plan arrangements, provide high-level advice, links to government, and coordination with other agencies and programs. The Panel considers Position Papers developed by the three other organisational units – the:

2. **Ecosystem WQ Think Tank**

3. **Urban Think Tank**

4. **Agriculture Think Tank**

The Think Tanks provide expert scientific and technical advice for planning, monitoring and evaluation of water quality and ecosystem management and industry activities (Table 3).

In August 2010 the Healthy Waterways Alliance consolidated the Alliance's *Vision for the Region.* To achieve the Vision, the Alliance proposed a series of management and research recommendations that emphasised the importance of focusing on solutions and practical applications that individuals, organisations, corporations, and government could implement. Equally important was the creation of opportunities to celebrate achievements, best practice, innovation, and excellence that empowers and rewards achievement in various sectors.

Monitoring recommendations included a science-based focus on tracking ecosystem health improvements and management practice change effectiveness. A social-based focus was also recommended to track community understanding and behaviour change related to ecosystem health improvements.
By 2012 there had been considerable effort and resources invested across the region directed toward implementing the WQIP recommendations and management practice changes for improving water quality. In June 2012 the Healthy Waterways Alliance presented the Healthy

Waterways Symposium, bringing together key stakeholders, industry and community to track achievements, celebrate success and help visualise the next phase of WQIP implementation and monitoring in the Mackay Whitsunday region. At the same time, the inaugural Healthy Waterways Alliance Awards championed individuals and organisations that had demonstrated innovation and excellence for regional water quality and ecosystem health benefits.

### 5.2. Reviewing the rate of implementation success of the recommendations of the 2008 WQIP

During 2013, the Healthy Waterways Alliance was heavily involved in reviewing the implementation success of the 2008 WQIP. This review included two key questions to determine if the recommendations, investment levels, and the efforts by the community had achieved the water quality improvement targeted.

> **Question 1.** Has the Mackay Whitsunday region achieved the management practice adoption targets of the 2008 WQIP to improve water quality?
>
> **Question 2.** Has the change in water quality seen in data for the period since 2008 progressed us on the path to the water quality improvement targets set for 2014?

The first task in the process was to determine which implementation activities recommended in the 2008 WQIP had been accomplished, where they were accomplished, and how successful and appropriate these activities may have been in contributing toward an improvement in regional freshwater quality.

After community and industry consultation (Table 3), the results were summarised in Implementation Success Review Statements for sugarcane, grazing, horticulture, ecosystem health and urban management and also presented in 33 catchment condition reports. Results were reviewed against the implementation recommendations and targets in the 2008 WQIP, as well as against the level of investment received across particular industries or landscapes.

During this time Reef Catchments also undertook a community consultation process to review the content, structure, functionality, and communication effectiveness of the 2008 WQIP document.

> The process to review the 2008 WQIP was an important opportunity for the whole of the community to look back at what had been achieved, reflect on the lessons learnt, and plan the next steps on the path to continued water quality improvements for the Mackay Whitsunday region.

### 5.3. Updating the Mackay Whitsunday WQIP for 2014-2021

A lot of changes occurred between 2008 and 2014 in water quality governance specific to the GBR and NRM regions that may influence targets and goal setting in the updated WQIP for 2014-2021. Such changes include:

**2009** Implementation of the Australian Government Reef Rescue program;
**2009** Update of the Reef Water Quality Protection Plan;
**2009** Launch of Project Catalyst supporting cutting edge innovation in sugarcane production;
**2010** Introduction of Reef Regulations for specified agricultural activities in high priority catchments (Great Barrier Reef Protection Amendment Act 2009);
**2010** Establishment of the Healthy Waterways Alliance Mackay Whitsunday Isaac;

**2011** Introduction of the Carbon Farming Initiative;
**2013** Mackay Whitsunday EVs and WQOs scheduled in EPP (Water) 2009;
**2013** Review of Reef Water Quality Protection Plan;
**2014** Update of the State Planning Policy (SPP) incorporating state interests;
**2014** Update of Mackay Whitsunday NRM Plan; and
**2014** Update of State of the Region Report.

Reef Catchments has also been closely involved in the delivery of the 2014 NRM Plan and the State of the Region Report. This involvement has offered an excellent opportunity for improved integration in management planning for key regional issues including urban and coastal development, biodiversity management, carbon and climate change. Additionally, it has provided an opportunity to set achievable actions and targets to address these issues in the period post-2014.

### 5.3.1. The 2014-2021 WQIP update process

The process to update the WQIP began in December 2012 with the drafting of the Water Quality Improvement Plan Update Design Process with key senior managers from Queensland Government and Great Barrier Reef Marine Park Authority. This Design Process statement was referred to The Panel in April 2013 for endorsement. Subsequently, information on investment, programs, actions, and outputs to help define new targets for EVs and WQOs for the 2014-2021 WQIP was collated and developed. This process included:

- Updating regional water quality and ecosystem health information across 33 Mackay Whitsunday freshwater catchments;
- Determining eight receiving waters as marine management areas;
- Defining linkages between regional terrestrial and marine receiving water zones across the region;
- Reviewing WQIP and EPP Water environmental values, water quality and flow objectives, and defining a new suite of environmental indicators to reference ecosystem health;
- Compiling and reviewing additional information such as regional growth, industry forecasts and climate change scenarios;
- Updating key pollutants of concern and setting revised water quality and ecosystem health targets;
- Developing a response plan around land use management practice changes and implementation costs benchmarked to ABCD Management Frameworks;
- Developing a response plan for ecosystem health improvement with prioritised system repair actions to help achieve water quality and ecosystem health targets;
- Integrating monitoring and adaptive management strategies to respond to new information and changes in the landscape; and
- Building effective linkages with other relevant plans and strategies.

### 5.3.2. Crafting future scenarios

The new targets for the 2014-2021 period for the Mackay Whitsunday region need to clearly link management actions to the water quality and ecosystem health indicators that are defined in the WQIP.

Key to the success of the 2008 WQIP was the implementation strategies designed around ABCD Management Frameworks for sugarcane, grazing, and horticulture industry groups. These frameworks enabled the measurement of change across landscapes, plus measurement of the shifts in the population in terms of willingness and commitment to adopting change for ecosystem health and water quality benefits. They also provided a way of classifying different suites of practices based on their water quality benefits. The design of the frameworks enabled information around a diverse range of activities that generate multiple responses in the landscape to be readily communicated to a broad audience.

For these reasons the ABCD Management Framework model has now become an invaluable tool in communicating to policy makers, investors, industry, and producers. Furthermore, this approach to benchmarking activities and tracking management practice adoption has since been adapted and implemented across all GBR NRM regions.

The frameworks for sugarcane, grazing and horticulture were updated during the 2008 WQIP implementation period. A newly developed urban framework is launched in the 2014-2021 WQIP, together with the development of new forestry and fisheries ABCD Management Frameworks. These frameworks are fundamental to describing the required improvement in actions and industry practice required to meet our regional targets for ecosystem health and water quality improvement outcomes.

The 2021 targets for water quality and management practice change adoption set in the 2008 WQIP have been reviewed for the updated WQIP (refer to Chapters 9, 10, 12, and 15). The updated targets take into consideration shifts in use of resources, for example changes in irrigation licensing in a subcatchment. The updates also reflect changes in our understanding of ecosystems, changes in recreational demands and shifts in community values. Through the review process, targets did not necessarily change in all catchments.

As Mackay Whitsunday is the first GBR NRM region to move into the WQIP update phase, Reef Catchments is committed to ensuring that we retain our innovative edge in managing improvement in water quality for the region.

ABCD Management Frameworks developed for sugarcane, grazing, and horticulture help to measure change across landscapes, plus measurement of the shifts in the population in terms of willingness and commitment to adopting change for ecosystem health and water quality benefits.

**Table 3 Summary of consultation activities undertaken in the update of the WQIP.**

| PHASE | PARTICIPATING STAKEHOLDERS | ACTIVITY | DATE |
|---|---|---|---|
| **Launch WQIP 2008** | **Community, industry, research institutions and government** | Official launch - WQIP 2008 | Apr-09 |
| **Updating current knowledge** | **Cane Regional Working Group** | Update Sugarcane ABCD Management Framework | Jul-10 |
| **Understanding current regional conditions** | **The Panel** | Terms of Reference established<br>Structure of HWA<br>Identification of Healthy Waterways Alliance (HWA) foundational program<br>Identify partnership gaps<br>Identify political and resource allocation<br>Identify key actions and program for Think Tanks<br>Value adding to Paddock to Reef Monitoring and Modelling Program<br>Synthesising GBR wide monitoring and modelling for WQIP (2008) update | Aug-10 |
| **Understanding current regional conditions** | **Ecosystem WQ Think Tank** | Establish Terms of Reference for Think Tank<br>Review of regional programs and monitoring<br>Identify potential projects, partnerships, knowledge gaps<br>Development of leadership capacity of HWA | Oct-10 |
| **Understanding current regional conditions** | **Urban Think Tank** | Development Urban Think Tank membership and priorities<br>Identify program, policy and compliance gaps<br>Potential partnerships<br>Terms of Reference | Oct-10 |
| **Understanding current regional conditions** | **Urban Think Tank** | Review WQIP (2008) Urban chapter | Nov-10 |
| **Establishing linkages** | **The Panel** | Review HWA structure and Terms of Reference for The Panel<br>Identify linkages to Whitsunday Hinterland and Mackay (WHAM) and Mackay Whitsunday NRM Plan<br>Consultation mechanisms | Nov-10 |
| **Catchment prioritisation** | **Ecosystem WQ Think Tank** | Identify new water quality and aquatic ecosystem health issues<br>Assessment and catchment prioritisation<br>Draft updated regional water quality monitoring program | Jan-11 |
| **Understanding current regional conditions** | **Ag industry Think Tank** | Ag Industry Think Tank capacity<br>Review regional activities<br>Terms of Reference | Mar-11 |
| **Embedded consultation** | **Ecosystem WQ Think Tank** | Development of HWA launch program and engagement potential<br>Review of educational field trips opportunities for Launch program | Mar-11 |
| **Education, knowledge sharing and consultation** | **Healthy Waterways Alliance Launch** | Review of regional activities and new initiatives<br>Vision setting for the HWA<br>Regional field trip program: 80 attendees over 2 days of presentations, professional development workshops and field trips | Apr-11 |
| **Review Indicators Review implementation** | **Urban Think Tank** | Draft 22 management areas/themes for updated Urban ABCD Management Framework | May-11 |
| **Understanding current regional conditions** | **Ag industry Think Tank** | Identification of industry gaps (interpretative report cards for industry with links to high levels, annual ABCD Management Framework reviews, review of Reef Rescue priorities, improvement in industry communications)<br>ROLE OF THE AG INDUSTRY THINK TANK TRANSFERRED TO REGIONAL WORKING GROUPS FROM 2012 | Jun-11 |
| **Catchment prioritisation Review indicators** | **Ecosystem WQ Think Tank** | Assessment and catchment prioritisation (cont.)<br>Gap analysis of environmental drivers<br>Design catchment scale on-ground program<br>Discussion of WQIP update process to include groundwater, climate change<br>Review potential funding opportunities for WQIP update | Jun-11 |

**Table 3 (continued).**

| PHASE | PARTICIPATING STAKEHOLDERS | ACTIVITY | DATE |
|---|---|---|---|
| **WQIP update** | **Cane Regional Working Group** | Update Sugarcane ABCD Management Framework | Jul-11 |
| **WQIP update** | **Grazing Regional Working Group** | Update Grazing ABCD Management Framework | Jul-11 |
| **Review Indicators Review implementation** | **Urban Think Tank** | Review new suite management areas/themes for updated Urban ABCD management framework<br>Refine management class actions and activities to 13 key management areas/themes | Jul-11 |
| **Review Indicators Review implementation** | **Ecosystem WQ Think Tank** | Review draft updated regional water quality monitoring program<br>Discussion first GBR Report Card<br>Discussion need to include hydrological connections to Reef in updated WQIP<br>Development new suite of ecosystem health indicators (to include groundwater and wetlands)<br>Formation of Groundwater/Wetlands sub-group to progress detailed discussion | Aug-11 |
| **Review Indicators Review implementation** | **Urban Think Tank** | Review and develop testing for new Urban ABCD Management Framework<br>Assess potential implementation costs | Sep-11 |
| **New knowledge** | **Groundwater/ Wetlands (Ecosystem WQ) Think Tank sub-group** | Development groundwater monitoring program metrics | Sep-11 |
| **Review Indicators Review implementation** | **Urban Think Tank** | Adjustments to framework after initial testing in two Local Government areas<br>Opportunities for local government to lead regional water quality monitoring | Oct-11 |
| **Review Indicators Review implementation** | **Urban Think Tank** | Results of testing new Urban ABCD Management Framework across three Local Government areas | Nov-11 |
| **New knowledge** | **Groundwater/ Wetlands (Ecosystem WQ) Think Tank sub-group** | Development groundwater monitoring program metrics | Nov-11 |
| **New knowledge** | **Ecosystem WQ Think Tank** | Development of business paper for The Panel around new marine and terrestrial ecosystem health and water quality indicators plus budget estimates | Nov-11 |
| **Review implementation** | **Ecosystem WQ Think Tank** | Discussion of feedback from The Panel on new marine and terrestrial ecosystem health and water quality indicators plus budget estimates<br>Review regional implementation sites<br>Development of WQIP update process and timeline | Feb-12 |
| **Review Endorsement** | **Urban Think Tank** | Present new Urban ABCD Management Framework to The Panel for initial endorsement<br>Future opportunities for Urban Think Tank.<br>International River Symposium, Healthy Waterways Alliance Symposium, Healthy Waterways Awards<br>EPA/DERM/Local Government ESC partnership opportunities | Feb-12 |
| **Review Endorsement** | **Urban Think Tank** | Finalise Symposium presentation<br>MRC WQMP<br>WQIP update actions and priorities for Urban Think Tank | Apr-12 |
| **Funding** | **The Panel** | Resourcing WQIP (2008) updating<br>Review new Urban ABCD Management Framework developed by Urban Think Tank | Apr-12 |
| **WQIP update** | **Urban Think Tank** | Review Healthy Waterways Awards nominees<br>Identify gaps in WQIP (2008) and actions for update | May-12 |

**Table 3 (continued).**

| PHASE | PARTICIPATING STAKEHOLDERS | ACTIVITY | DATE |
|---|---|---|---|
| **Update implementation Embedded consultation** | **Ecosystem WQ Think Tank** | Development of WQIP implementation review process and WQIP update<br>Development of Healthy Waterways Alliance Symposium program and Healthy Waterways Awards | May-12 |
| **WQIP update** | **The Panel** | Endorse WQIP (2008) process, framework, timeline, consultation<br>Alignments with Statutory Plan and NRM Plan<br>Urban coastal and port development brief | Aug-12 |
| **Review implementation Review new knowledge** | **Ecosystem WQ Think Tank** | Analysis of efficacy and appropriateness of implementation activities<br>Prioritisation of Mackay Regional Council Natural Environment Levy works program<br>Review Mackay and Townsville (Black-Ross) draft Environmental Values - EPP Water<br>Development of Mackay Whitsunday Citizen Scientist Network<br>Wetlands ABCD Management Framework opportunities | Aug-12 |
| **Embedded consultation** | **Healthy Waterways Alliance Awards** | Acknowledging the achievement of community, industry and government | Oct-12 |
| **Education, knowledge sharing and consultation** | **Healthy Waterways Symposium** | Community and industry event to update on regional and state initiatives with linkages to Mackay Whitsunday water quality management: 200+ attendees over 3 days of presentations, professional development workshops and field trips | Oct-12 |
| **WQIP update** | **The Panel** | Endorse Implementation Review Success Statements and WQIP (2008) update process to date<br>Brief on Communication and consultation strategy<br>Linkages to GBR Strategic Assessment and Outlook Report<br>Urban coastal and port development brief (cont.) | Dec-12 |
| **WQIP update** | **Ecosystem WQ Think Tank** | Discussion WQIP update  review process | Mar-13 |
| **WQIP update** | **The Panel** | Ongoing interrogation urban coastal development and port development issues and WQIP update | Mar-13 |
| **WQIP Review Consultation** | **Stakeholders and Industry** | Consultation and on-line feedback on WQIP (2008) Implementation Success Review Statements | Mar-13 |
| **Current Understanding** | **DNRM, GBRMPA and Reef Catchments** | Groundwater Dependent Ecosystem mapping workshop for Mackay Whitsunday region, associated with development of online Australia Atlas | May-13 |
| **Review Endorsement** | **Grazing Regional Working Group** | Review of Implementation Success Statements | Jul-13 |
| **Review endorsement** | **Cane Regional Working group** | Review of Implementation Success Statements | Jul-13 |
| **WQIP Review Consultation** | **Whole of community** | WQIP (2008) Implementation Success Review Statements live to Reef Catchments website | Aug-13 |
| **WQIP update** | **Ecosystem WQ Think Tank** | System repair prioritisation<br>Draft update of WQIP update to date - new ecological health indicators, water quality monitoring program, updated pollutant load targets, water quality objectives, flow objectives, environmental values, updated analysis of threats to water quality and flow, review of implementation success report cards for 33 catchments | Dec-13 |
| **WQIP update** | **Cane Regional Working Group** | Update Sugarcane ABCD Management Framework | Dec-13 |
| **WQIP update** | **Ecosystem WQ Think Tank** | Review of WQIP update to date - new ecological health indicators, water quality monitoring program, updated pollutant load targets, water quality objectives, flow objectives, environmental values, updated analysis of threats to water quality and flow, review of implementation success report cards for 33 catchments | Feb-14 |
| **WQIP update** | **Urban Think Tank** | Review and validate new Urban ABCD Management Framework<br>Storm Water Quality Offset opportunities | Feb-14 |

| PHASE | PARTICIPATING STAKEHOLDERS | ACTIVITY | DATE |
|---|---|---|---|
| **WQIP update** | **The Panel** | Review new suite of Ecosystem Health Indicator for WQIP update<br>Endorse 33 catchment condition reports for WQIP update<br>Urban coastal and port development brief (cont.)<br>Integration of HEVs and marine receiving waters to WQIP update<br>Endorse WQIP update design | Mar-14 |
| **WQIP update** | **Urban Think Tank - Mackay Regional Council** | Draft Recommended Mackay Regional Council Implementation Actions for updated WQIP (2014 - 2021) | Mar-14 |
| **WQIP update** | **Urban Think Tank - Whitsunday Regional Council** | Draft Recommended Whitsunday Regional Council Implementation Actions for updated WQIP (2014 - 2021) | Mar-14 |
| **WQIP update** | **Urban Think Tank - Isaac Regional Council** | Draft Recommended Isaac Regional Council Implementation Actions for updated WQIP (2014 - 2021) | Mar-14 |
| **WQIP update** | **Ecosystem WQ Think Tank** | Review of all WQIP update components prior to first round public consultation | May-14 |
| **WQIP update** | **Urban Think Tank** | Review of new ecosystem health indicators and targets prior to public consultation | Aug-14 |
| **WQIP update** | **Ecosystem WQ Think Tank** | Review of new ecosystem health indicators and targets prior to public consultation | Sep-14 |
| **WQIP update** | **Ecosystem WQ Think Tank** | Review of new ecosystem health indicators and targets prior to public consultation | Sep-14 |
| **Embedded consultation** | **Healthy Waterways Alliance eNewsletters** | Quarterly updates to 212 subscribers (industry and stakeholders) on all HWA and regionally important water quality related activities | Apr-12 ongoing |
| **Embedded consultation** | **River Restoration eNewletters** | Quarterly updates on system repair activities  to 137 community members living in local catchments | Jan-13 ongoing |

Trials being hosted by innovative landholders in the Mackay Whitsunday region help set the bar for the uptake of A class or aspirational land management practices. Opposite, Simon Mattsson, a cane grower from Marian stands in his multi-species cropping trial which aims to test the benefits of plant diversity on soil health, including carbon.

# 6. Defining the Region

The 2008 WQIP divided the Mackay Whitsunday region into catchment management areas, based on catchment hydrological boundaries and adjacent biophysical catchments with similar land use and management. The 2014-2021 WQIP retains the same 33 freshwater catchment management areas defined in Drewry et al. (2008). The 2008 WQIP separated the marine environment into one inshore management area and one offshore management area. This WQIP has revised these management areas and differentiated the marine environment into eight receiving waters (see Chapter 6.2).

Detailed description and mapping of the freshwater management areas are presented in the Catchment Management Area Reports, with some information also incorporated in the Receiving Waters Modules. The determination of catchment management area and receiving waters is useful for management, implementation, communication and reporting purposes.

Landuse in the Mackay Whitsunday region is diverse, with a heavy focus on agriculture, as well as conserved land and wetlands, urban and intensive landuse.

## 6.1. Freshwater catchments

It is estimated that in 2014 approximately 54% of the land in the Mackay Whitsunday region was under grazing and forestry, 19% under sugarcane farming and horticulture, 18% conserved land (National Parks and reserves), 6% wetlands, and 3% under urban and intensive land uses. The 2008 WQIP grouped management areas into catchment classes based on their percentage of land under sugarcane farming. The catchment classes remain largely unchanged in the current WQIP (Table 4). Management areas with changes to flow regimes, point source pollutants and urban centres were also identified.

**Table 4 Catchment class using percentage of area in sugarcane land use as a guide for management areas.**

| Percentage sugarcane | Catchment class |
|---|---|
| < 2 | Bushland |
| 2-4 | Grazing |
| 5-19 | Grazing + Sugarcane |
| 20-39 | Sugarcane/Grazing |
| 40+ | Sugarcane |

Information on the freshwater catchment management areas, including percentage of land under sugarcane, catchment class, as well as drainage basins and the receiving waters was reviewed in the WQIP update and is presented in Table 5. Since 2008, a number of catchment management areas have changed slightly in terms of the percentage of land under sugarcane farming. These changes ranged from 1-4% (both increases and decreases) with the majority of changes not affecting the classification of the catchment. Only Carmila Creek and Lethebrook catchment classifications changed as a result of a change in the percentage of land under sugarcane farming, both went from Grazing+Sugarcane to Sugarcane/Grazing.

**Table 5 The percentage of land under sugarcane, catchment class, drainage basin, and the receiving water for each catchment management area.**

| Catchment Management Area | Percentage Sugarcane 2008 | Percentage Sugarcane 2014 | Catchment Class | Drainage Basin | Receiving Waters |
|---|---|---|---|---|---|
| Repulse Creek | 0 | 0 | Bushland | Proserpine | Whitsunday Coast |
| Upper Proserpine River | 0 | 0 | Bushland | Proserpine | Repulse Bay |
| Eden Lassie Creek | 1 | 0 | Bushland | Proserpine | Edgecumbe Bay |
| Cape Creek | 1 | 0 | Bushland | Plane | Ince Bay |
| Whitsunday Coast | 1 | 1 | Bushland | Proserpine | Whitsunday Coast |
| Blacks Creek | 1 | 1 | Bushland | Pioneer | Sandringham Bay |
| Waterhole Creek | 3 | 2 | Grazing | O'Connell | Repulse Bay |
| Andromache River | 3 | 3 | Grazing | O'Connell | Repulse Bay |
| Gillinbin Creek | 3 | 4 | Grazing | Plane | Carmila Coast |
| Flaggy Rock Creek | 5 | 5 | Grazing+Sugarcane | Plane | Carmila Coast |
| Sarina Beaches | 6 | 6 | Grazing+Sugarcane | Plane | Sarina Inlet |
| Gregory River | 9 | 10 | Grazing+Sugarcane | Proserpine | Edgecumbe Bay |
| Thompson Creek | 10 | 10 | Grazing+Sugarcane | Proserpine | Repulse Bay |
| O'Connell River | 11 | 11 | Grazing+Sugarcane | O'Connell | Repulse Bay |
| West Hill Creek | 12 | 13 | Grazing+Sugarcane | Plane | Carmila Coast |
| Upper Cattle Creek | 14 | 13 | Grazing+Sugarcane | Pioneer | Sandringham Bay |
| Marion Creek | 13 | 15 | Grazing+Sugarcane | Plane | Carmila Coast |
| St Helens Creek | 16 | 15 | Grazing+Sugarcane | O'Connell | Seaforth Coast |
| Constant Creek | 19 | 18 | Grazing+Sugarcane | O'Connell | Seaforth Coast |
| Lethebrook | 18 | 20 | Sugarcane/Grazing | Proserpine | Repulse Bay |
| Carmila Creek | 19 | 20 | Sugarcane/Grazing | Plane | Carmila Coast |
| Plane Creek | 21 | 21 | Sugarcane/Grazing | Plane | Sarina Inlet |
| Rocky Dam Creek | 24 | 23 | Sugarcane/Grazing | Plane | Ince Bay |
| Murray Creek | 25 | 23 | Sugarcane/Grazing | O'Connell | Seaforth Coast |
| Blackrock Creek | 30 | 29 | Sugarcane/Grazing | O'Connell | Seaforth Coast |
| Myrtle Creek | 32 | 32 | Sugarcane/Grazing | Proserpine | Repulse Bay |
| Proserpine River Main Channel | 34 | 32 | Sugarcane/Grazing | Proserpine | Repulse Bay |
| Mackay City | 37 | 33 | Sugarcane/Grazing | Pioneer | Sandringham Bay |
| Reliance Creek | 38 | 34 | Sugarcane/Grazing | O'Connell | Seaforth Coast |
| Pioneer River Main Channel | 50 | 49 | Sugarcane | Pioneer | Sandringham Bay |
| Sandy Creek | 51 | 51 | Sugarcane | Plane | Sandringham Bay |
| Alligator Creek | 54 | 53 | Sugarcane | Plane | Sandringham Bay |
| Bakers Creek | 61 | 57 | Sugarcane | Plane | Sandringham Bay |

## 6.2. Marine environment

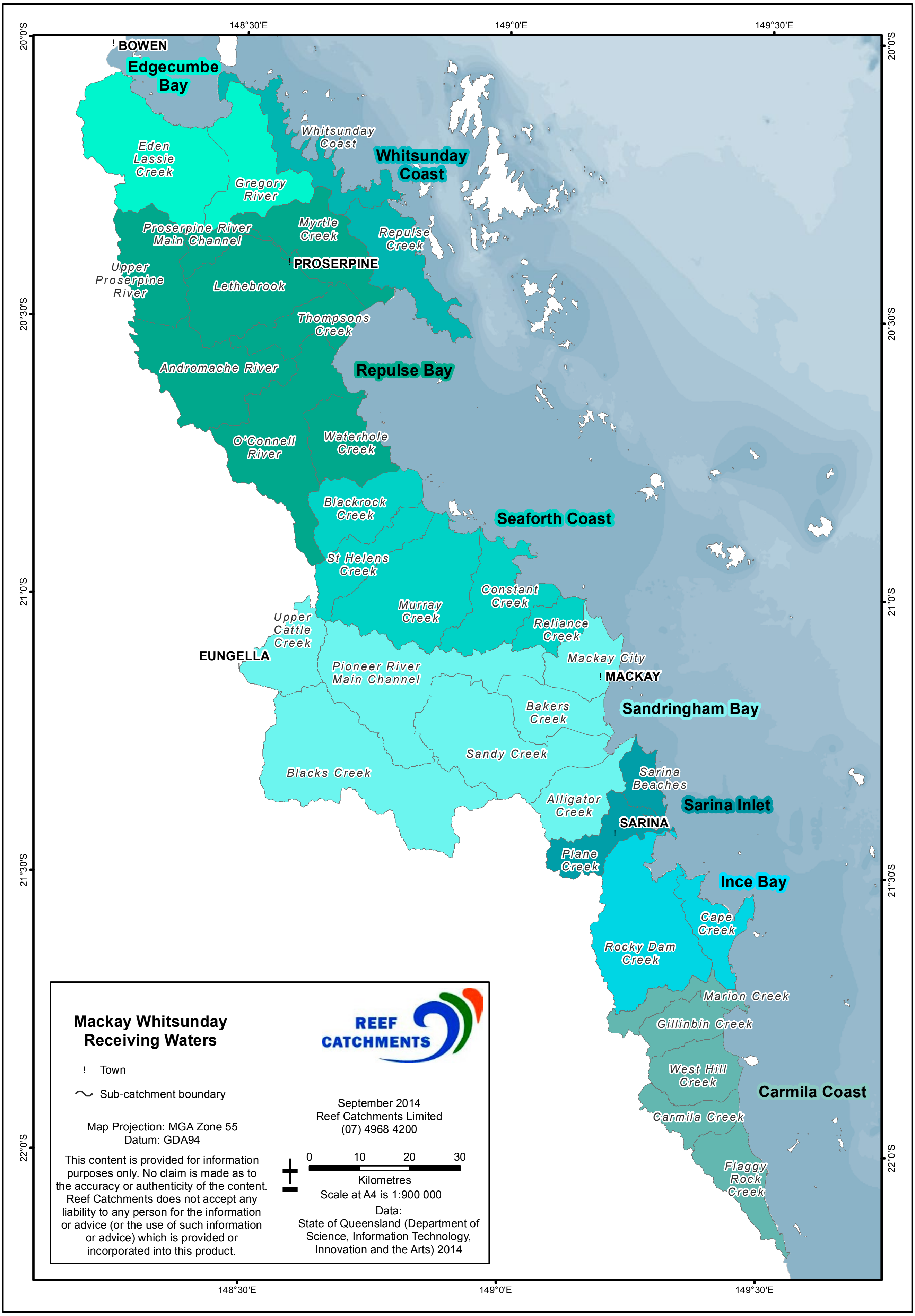
As discussed in Chapter 1, the GBR is under threat from increased sediments, nutrients, and herbicides draining from the adjacent catchments into the GBR lagoon. The importance of assessing and monitoring the marine environment remains high. Additionally, monitoring the marine environment can assess the results of on-ground activities implemented within the catchments.

The differentiation of the Mackay Whitsunday marine environment into eight discrete receiving waters allowed assessment of those receiving waters, and to utilise the marine risk index to provide a risk rating of the marine environment. The receiving waters were determined based on adjacent lands draining into a discreet or semi-discreet area and provide marine management areas. The catchment management areas which drain into each receiving water are shown in Table 6 below and in Figure 8.

Assessments of the marine environment were conducted separately for each receiving water to determine the current condition of marine indicators, including marine condition, seagrass, coral, and also the risk index, as outlined in the following sections.

**Table 6 Receiving waters and their corresponding catchment management areas.**

| Receiving Waters | Catchment Management Areas |
|---|---|
| Edgecumbe Bay | Eden Lassie Creek<br>Gregory River |
| Whitsunday Coast | Whitsunday Coast<br>Repulse Creek |
| Repulse Bay | Myrtle Creek<br>Proserpine River Main Channel<br>Upper Proserpine River<br>Thompson Creek<br>Lethebrook<br>Andromache River<br>O'Connell River<br>Waterhole Creek |
| Seaforth Coast | Blackrock Creek<br>St Helens Creek<br>Murray Creek<br>Constant Creek<br>Reliance Creek |
| Sandringham Bay | Mackay City<br>Pioneer River Main Channel<br>Upper Cattle Creek<br>Blacks Creek<br>Bakers Creek<br>Sandy Creek<br>Alligator Creek |
| Sarina Inlet | Sarina Beaches<br>Plane Creek |
| Ince Bay | Rocky Dam Creek<br>Cape Creek |
| Carmila Coast | Marion Creek<br>Gillinbin Creek<br>West Hill Creek<br>Carmila Creek<br>Flaggy Rock Creek |




**[ Figure 8 Mackay Whitsunday receiving waters.**

### 6.2.1. Condition

The condition of the marine environment was assessed by analysing the pollutant loads entering each receiving water. The loads analysed included particulate nitrogen (PN), dissolved inorganic nitrogen (DIN), particulate phosphorus (PP), filterable reactive phosphorus (FRP), total suspended solids (TSS), and ametryn, atrazine, diuron, and hexazinone. The load of each pollutant from each catchment management area was compared to the relevant 2050 WQO (documented in Drewry et al. 2008 and scheduled under EPP Water) and represented as a rate of exceedance of the WQOs.

The following rules were used to determine the condition category:

- **Very good:** At least 1 indicator < 2050 WQO, all other indicators equal to 2050 WQOs
- **Good**: All indicators equal to 2050 WQOs
- **Moderate**: All indicators < 2 times the 2050 WQOs
- **Poor**: One indicator > 2 times the 2050 WQO
- **Very poor**: Two or more indicators > 2 times the 2050 WQO

The WQOs are based on the individual catchment management area characteristics, such as land use and the 2007 condition of the parameters, and the likely adoption rates of land practice change (refer to Chapter 9 for full detail), therefore the WQOs are specific to each catchment management area. As a result, the exceedances reported are also specific to each catchment management area.

The overall condition includes all parameters (PN, DIN, PP, FRP, TSS, ametryn, atrazine, diuron, and hexazinone). The overall results and the results for only TSS/nutrients for each catchment management area are presented in Table 7. The catchment management area results were then combined into their respective receiving waters, to provide the overall and TSS/nutrients results for each receiving water.

For both overall condition and TSS/nutrients condition, based on exceedances of the WQOs, the majority of the catchment management areas were shown to be in very poor to moderate condition (Table 7). Only two catchment management areas (Whitsunday Coast and Repulse Creek) received an overall score of good or better, with Repulse Creek scoring very good. Three catchments (Whitsunday Coast, Gillinbin and Cape Creeks) received a good score for TSS/ nutrients, and Repulse Creek received a very good.

The condition of the marine environment was assessed by analysing the pollutant loads entering each receiving water.

**Table 7 Overall condition and the TSS/nutrients condition for each catchment management area based on annual loads and exceedances of WQOs. The breakdown of catchment management areas into receiving waters is also shown.**

| Receiving waters | Catchment management area | TSS/nutrients | Overall |
|---|---|---|---|
| Edgecumbe Bay | Eden Lassie Creek | Moderate | Moderate |
| | Gregory River | Moderate | Moderate |
| Whitsunday Coast | Whitsunday Coast | Good | Good |
| | Repulse Creek | Very good | Very good |
| Repulse Bay | Myrtle Creek | Poor | Very poor |
| | Proserpine River Main Channel | Poor | Very poor |
| | Upper Proserpine River | Moderate | Moderate |
| | Thompson Creek | Moderate | Moderate |
| | Lethebrook | Moderate | Poor |
| | Andromache River | Poor | Poor |
| | O'Connell River | Moderate | Poor |
| | Waterhole Creek | Moderate | Moderate |
| Seaforth Coast | Blackrock Creek | Poor | Very poor |
| | St Helens Creek | Moderate | Poor |
| | Murray Creek | Moderate | Poor |
| | Constant Creek | Moderate | Poor |
| | Reliance Creek | Poor | Very poor |
| Sandringham Bay | Mackay City | Poor | Very poor |
| | Pioneer River Main Channel | Poor | Very poor |
| | Upper Cattle Creek | Moderate | Moderate |
| | Blacks Creek | Poor | Poor |
| | Bakers Creek | Poor | Very poor |
| | Sandy Creek | Poor | Very poor |
| | Alligator Creek | Very poor | Very poor |
| Sarina Inlet | Sarina Beaches | Poor | Poor |
| | Plane Creek | Poor | Poor |
| Ince Bay | Rocky Dam Creek | Moderate | Very poor |
| | Cape Creek | Good | Moderate |
| Carmila Coast | Marion Creek | Poor | Very poor |
| | Gillinbin Creek | Good | Moderate |
| | West Hill Creek | Very poor | Very poor |
| | Carmila Creek | Moderate | Poor |
| | Flaggy Rock Creek | Very poor | Very poor |

Results for the overall condition varied across the receiving waters, with 71% of results in Sandringham Bay being very poor, to 50% of the results from Whitsunday Coast receiving waters being within the very good category (Table 8). The results showed the majority of receiving waters to be in very poor, poor, or moderate condition.

When analysing only TSS and nutrients, Whitsunday Coast receiving waters also recorded

100% in the good and very good categories. Ince Bay and Carmila Coast receiving waters both recorded results in the good category (50% and 20%, respectively). One out of the eight receiving waters recorded very poor TSS and nutrients results (Table 9), compared to two out of eight for the overall condition.

**Table 8 Percentage of results occurring in each condition category for overall condition, broken down by receiving waters.**

| Condition Category | Edgecumbe Bay | Whitsunday Coast | Repulse Bay | Seaforth Coast | Sandringham Bay | Sarina Inlet | Ince Bay | Carmila Coast |
|---|---|---|---|---|---|---|---|---|
| Very Poor | 0% | 0% | 25% | 60% | 71% | 0% | 50% | 60% |
| Poor | 0% | 0% | 25% | 40% | 14% | 100% | 0% | 20% |
| Moderate | 100% | 0% | 50% | 0% | 14% | 0% | 50% | 20% |
| Good | 0% | 50% | 0% | 0% | 0% | 0% | 0% | 0% |
| Very Good | 0% | 50% | 0% | 0% | 0% | 0% | 0% | 0% |
| Overall condition | Moderate | Good | Poor | Very Poor | Very Poor | Poor | Poor | Poor |

**Table 9 Percentage of results occurring in each condition category for TSS and nutrients condition, broken down by receiving waters.**

| Condition Category | Edgecumbe Bay | Whitsunday Coast | Repulse Bay | Seaforth Coast | Sandringham Bay | Sarina Inlet | Ince Bay | Carmila Coast |
|---|---|---|---|---|---|---|---|---|
| Very Poor | 0% | 0% | 0% | 0% | 14% | 0% | 0% | 40% |
| Poor | 0% | 0% | 38% | 40% | 71% | 100% | 0% | 20% |
| Moderate | 100% | 0% | 62% | 60% | 14% | 0% | 50% | 20% |
| Good | 0% | 50% | 0% | 0% | 0% | 0% | 50% | 20% |
| Very Good | 0% | 50% | 0% | 0% | 0% | 0% | 0% | 0% |
| Overall condition | Moderate | Good | Poor | Poor | Very Poor | Poor | Moderate | Poor |

### 6.2.2. Seagrass

The amount of seagrass occurring within each risk category (ranging from very low risk through to very high risk) was defined for each receiving water. The mapped seagrass was overlaid with the regional risk index mapping (developed through the work conducted by Brodie et al. 2013). This provided the amount of mapped seagrass (as a percentage of the total area of seagrass estimated within the receiving water) occurring within each risk category.

The risk posed to seagrass within the Mackay Whitsunday region varied between the receiving waters (Table 10). Sarina Inlet was identified as the receiving water with the highest risk to seagrass; all seagrass occurred within the very high or high risk categories. The Whitsunday Coast receiving waters had no seagrass occurring within the very high risk category, and only 9% in the high risk category.

**Table 10 Amount of seagrass within each risk category as a percentage of the total amount of seagrass existing within that receiving water.**

| Percent of mapped seagrass occurring within each risk category (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Risk Category | Edgecumbe Bay | Whitsunday Coast | Repulse Bay | Seaforth Coast | Sandringham Bay | Sarina Inlet | Ince Bay | Carmila Coast |
| Very High | 12 | 0 | 5 | 20 | 11 | 17 | 12 | 0 |
| High | 18 | 9 | 60 | 53 | 69 | 83 | 57 | 68 |
| Moderate | 25 | 47 | 27 | 19 | 20 | 0 | 26 | 28 |
| Low | 35 | 31 | 7 | 6 | 0 | 0 | 3 | 3 |
| Very Low | 11 | 13 | 1 | 2 | 0 | 0 | 2 | 2 |

### 6.2.3. Coral

Similarly to the seagrass methodology, the amount of coral occurring within each risk category (from very low risk through to very high risk) was defined for each receiving water. The mapped coral was overlaid with the regional risk index mapping (developed through the work conducted by Brodie et al. (2013)) to determine the amount of mapped coral (as a percentage of the total area of coral estimated within the receiving water) occurring within each risk category.

The risk posed to coral within the Mackay Whitsunday region varied between the receiving waters (Table 11). Sandringham Bay and Seaforth Coast both had reasonable amounts of coral falling within the very high and high risk categories, however, Carmila Coast receiving waters had 73% of the coral within the high risk category. Edgecumbe Bay had only 3% of coral within the high risk category, and 37% within the very low risk category.

**Table 11 Amount of coral within each risk category as a percentage (%) of the total amount of coral existing within that receiving water.**

| Percent of mapped coral occurring within each risk category (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Risk category | Edgecumbe Bay | Whitsunday Coast | Repulse Bay | Seaforth Coast | Sandringham Bay | Sarina Inlet | Ince Bay | Carmila Coast |
| Very High | 0 | 0 | 2 | 13 | 14 | 0 | 0 | 0 |
| High | 3 | 12 | 21 | 18 | 23 | 14 | 7 | 73 |
| Moderate | 41 | 38 | 57 | 41 | 29 | 35 | 82 | 17 |
| Low | 18 | 31 | 18 | 22 | 29 | 45 | 8 | 10 |
| Very Low | 37 | 19 | 2 | 6 | 5 | 7 | 4 | 0 |

## 6.3. Marine Risk Index

A method for conducting a marine risk assessment, specifically for areas within the GBR, was developed by Brodie et al. (2013). The purpose of the risk assessment was to “provide robust and scientifically defensible information for policy makers and catchment managers on the key land-based pollutants of greatest risk to the health of the two main GBR ecosystems (coral reefs and seagrass beds)” (Brodie et al. 2013), and subsequently assist and inform management prioritisation for Reef Rescue and Reef Plan. As coastal habitats nearest to river mouths are most impacted by marine water quality, the method takes into account the variation of catchment-associated risk, regarding the distance from the river mouth (Brodie et al. 2013).

The risk assessment methodology is explained in detail in Brodie et al. (2013), but in general uses pollutant loads and an estimated risk of degraded water quality to coral reefs and seagrass communities to provide a relative risk for the marine environment of the NRM regions of the GBR. The following indices were generated and data from the Mackay Whitsunday region was assessed to gain a result for each index:

- Loads Index;
- Coral Reef Marine Risk Index;
- Seagrass Marine Risk Index; and
- Relative Risk Index (combines Coral Reef and Seagrass Marine Risk Indices).

The results of the risk assessment for the Mackay Whitsunday area are presented in Table 12 and shown in Figure 9. The Mackay Whitsunday region was given an overall "moderate" ranking of relative risk (Brodie et al. 2013).

**Table 12 Results from the risk assessment for the Mackay Whitsunday region (source: Brodie et al. 2013).**

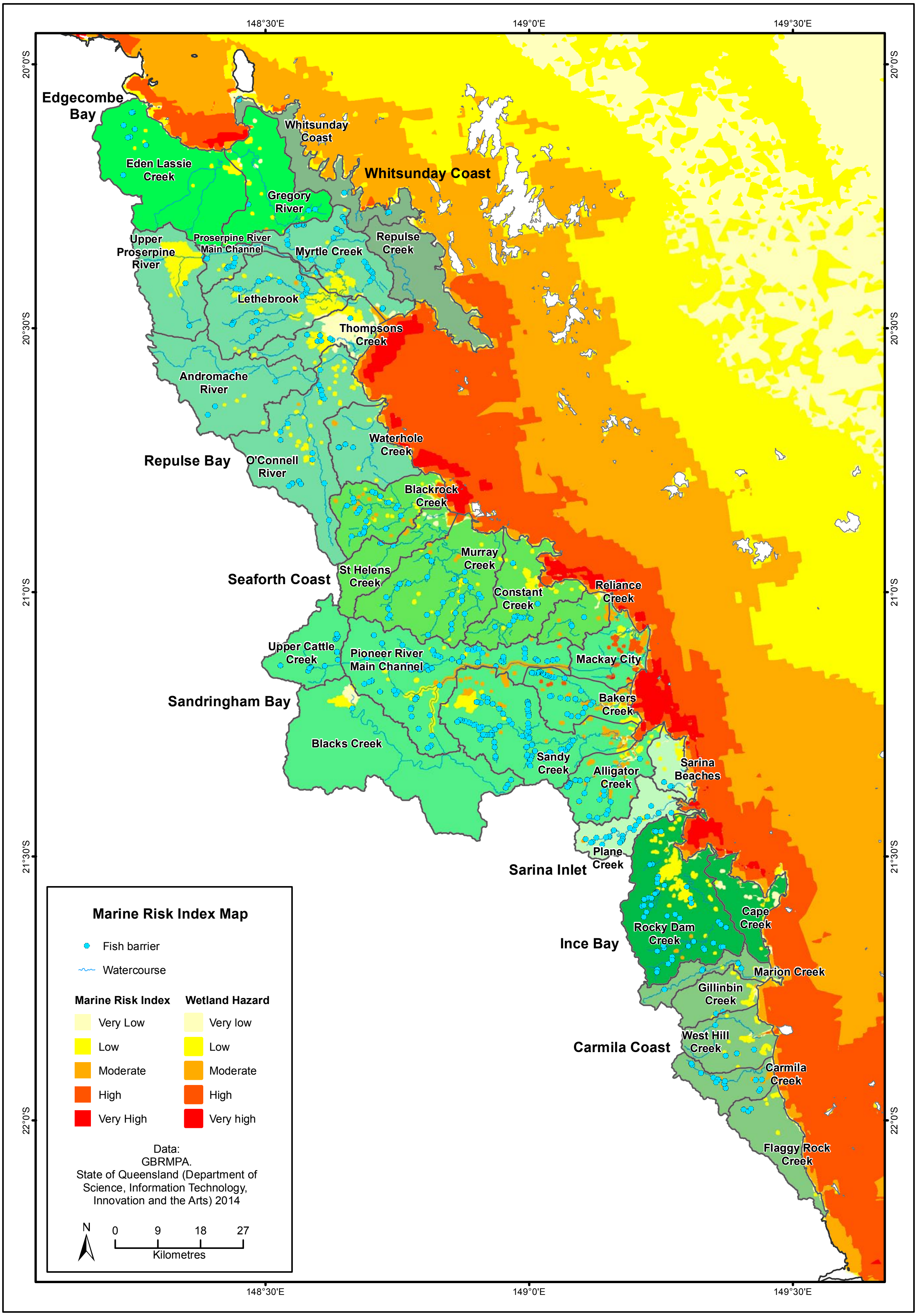
| Index type | Index result (0-100) | Risk class |
|---|---|---|
| Loads Index | 25 | Low |
| Coral Reef Marine Risk Index | 54 | Medium |
| Seagrass Marine Risk Index | 37 | Low |
| Relative Risk Index | 50 | Medium |

The results of the risk assessment highlighted the Mackay Whitsunday region as presenting the highest ecological risk from pesticides (of all NRM regions), with 'high' and 'medium' PSII herbicide risks from the Pioneer and O'Connell Rivers, and Sandy Creek.

From an assessment of all the GBR NRM areas, the priority actions for the Mackay Whitsunday region were identified to be:

- Pesticide reduction in all catchments; and
- Fertiliser nitrogen reduction (Brodie et al. 2013).

The Mackay Whitsunday region is renowned for its association with the iconic Great Barrier Reef lagoon and surrounding marine environment, which attracts visitors annually from all corners of the globe.




[ **Figure 9 Marine Risk Index map for the Mackay Whitsunday region (source: Brodie et al. 2013).**

# 7. Environmental Values

Environmental Values (EVs) are those qualities of the waterway that make it suitable to support particular aquatic ecosystems and human uses (EPA 2005). HEV waters are typically undeveloped natural areas where the management intent is to protect and maintain current condition. In areas that are not HEV waters, the management intent is to prevent decline and, where possible, improve water quality and ecosystem health (Drewry et al. 2008). The ANZECC and ARMCANZ 2000 Guidelines provide a framework for developing water quality guideline values based on the condition of aquatic ecosystems and the levels of protection provided to those ecosystems (EHP 2009).

In the 2008 WQIP, EVs were developed to protect aquatic ecosystems and the capacity of waterways to support human use. The corresponding water quality objectives (WQOs) and targets were designed to protect these EVs and HEV waters. The EVs and HEV areas described in the 2008 WQIP were scheduled under EPP Water in 2013. These scheduled WQOs were based on the 2050 long term WQOs in the 2008 WQIP with amendments based on additional information, inclusion of estuarine WQOs and updated coastal/marine WQOs etc. The HEV waters are those waters that have been identified for HEV level of protection.

For the 2014-2021 WQIP, these WQOs and targets have been further reviewed and improved (Chapter 9). The overarching intent of the 2014 -2021 WQIP remains to be the protection of aquatic ecosystems and the capacity of waterways to support human uses.

Community consultation was a key part in the development process as WQOs are based on the communities' choices for EVs and HEV areas, and the water quality guidelines to protect them (EPA 2005). Feedback from community consultation (including Catchment Reference Panels) was incorporated into the final WQIPs.

## 7.1. Policy and legislation changes

The State Planning Policy (SPP) was introduced in December 2013, and updated in July 2014 with the overarching aim to express "all state interests in land use planning and development in a single place, [and provide] efficiency, consistency and certainty in Queensland's land use planning and development system" (DSDIP 2014).

The SPP aims to ensure matters of environmental significance are valued and protected, and the health and resilience of biodiversity is maintained or enhanced to support ecological integrity (EHP 2014). Within the SPP, Matters of State Environmental Significance (MSES) are defined to be:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992*;
- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004*;
- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;
- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;
- Regulated vegetation under the *Vegetation Management Act 1999* that is:
    - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
    - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
    - Category R areas on the regulated vegetation management map;
    - Areas of essential habitat on the essential habitat map for wildlife prescribed as 'endangered wildlife' or 'vulnerable wildlife' under the *Nature Conservation Act 1992;*
    - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse map; and
    - Regional ecosystems that intersect with wetlands identified on the vegetation

management wetlands map.

- Wetlands in a wetland protection area or wetlands of high ecological significance shown on the Map of Referable Wetlands under the Environmental Protection Regulation 2008;
- Wetlands and watercourses in High Ecological Value waters as defined in the Environmental Protection (Water) Policy 2009, Schedule 1; and
- Legally secured offset areas.

Under the State interest category of water quality, the SPP identifies that environmental values and quality of Queensland waters are to be protected and enhanced (DSDIP 2014). The SPP also states that planning, design, construction and operation of development should be undertaken in a manner that protects environmental values and maintains or enhances water quality, through the making or amending of planning schemes, and designating land for community infrastructure, so as to integrate the state interest (in this case, water quality) (DSDIP 2014).

The SPP is divided into themes (previously were individual state planning policies). The "Environment and Heritage" theme includes the state interests of biodiversity, coastal environment, and water quality (which includes the management of acid sulfate soils previously dealt with under SPP 2/02, and broader water supply protection provisions previously covered by the Declared catchment provisions under the Water Act 2000). The "Planning for safety and resilience to hazards" theme includes matter to be included in planning schemes dealing with natural hazards, risk and resilience from natural hazards including, bushfire, landslide, flooding, and coastal hazards such erosion prone areas with coastal management districts.

The SPP includes a self-assessable code for wetland protection areas in Great Barrier Reef catchments (Part F) which is to be addressed by proponents when undertaking development within the GBR catchments.

Many of the state interests have interim development provisions (including Codes) which development proponents and assessing local governments must specifically consider when assessing development application's until such time as the Local Planning scheme adequately reflects the requirements of the SPP in a locally appropriate manner.

Of particular relevance to the WQIP, are the mechanisms put forth for receiving waters, including:

1) Facilitating the protection of environmental values and the achievement of water quality objectives for Queensland waters;
2) Identifying land for urban or future urban purposes in areas which avoid or minimise the disturbance to natural drainage and acid sulfate soils, erosion risk, impact on groundwater and landscape features;
3) Requirements that development for an urban purpose is located, designed, constructed and/or managed to avoid or minimise:
    a. Impacts arising from:
        i. altered stormwater quality or flow, and
        ii. waste water (other than contaminated stormwater and sewage)
        iii. the creation or expansion of non-tidal artificial waterways, such as urban lakes
    b. The release and mobilisation of nutrients that increase the risk of algal blooms;
4) Adopting the applicable stormwater management design objectives relevant to the climatic region, or demonstrate current best practice environmental management for development that is for an urban purpose;
5) Facilitating innovative and locally appropriate solutions for urban stormwater management that achieve the relevant urban stormwater management design objectives;
6) Planning for safe, secure and efficient water supply; and
7) Requirements that development in water resource catchments is undertaken in a

manner which contributes to the maintenance and enhancement (where possible) of water quality to protect the drinking water and aquatic ecosystem environmental values in those catchments.

The EPP HEV mapping, in conjunction with the SPP state interest requirements for local planning schemes means there is now a state planning mechanism which restricts activities that can occur in such areas (for example, disposal of waste waters to waterways), thereby adding another layer of protection for these waterways within the Mackay Whitsunday region.

## 7.2. Review of the Environmental Values and High Ecological Value areas

The following text provides the results from the review of the EVs and HEV areas presented in the 2008 WQIP, combined with a review of the HEV areas identified in the SPP (DSDIP 2014) for the Mackay Whitsunday region. The 2014-2021 WQIP will incorporate all previously described WQIP HEV areas, as well as any additional SPP HEV areas.

The HEV areas identified in the SPP (available through the SPP interactive mapping system) were compared to the WQIP 2008 HEV areas. Overall, the vast majority of the HEV areas align, with some minor differences. The amount of terrestrial HEV areas is similar between the 2008 WQIP and the SPP HEV mapping (246,161 ha and 234,928 ha, respectively). The area mapped as marine HEV differs substantially (589,699 ha for 2008 WQIP and 983,839 ha under SPP mapping) due to the inclusion of a large area of water in the central part of the region as HEV area under the SPP. The result is that the majority of the marine environment within the Mackay Whitsunday region is mapped as HEV.

Further information is included below.

### 7.2.1. Environmental Values

Environmental Values are based on the qualities of waterways and the results of a community consultation process. The 2014-2021 WQIP EVs (scheduled under EPP Water) remain largely unchanged from those developed and described in Drewry et al. (2008).

The cultural and spiritual values for the individual catchment management areas had not been fully assessed at the time of the 2008 WQIP production. Since 2008, a Traditional Owner Reference Group has been established and the cultural and spiritual values for each management area are currently being assessed. These results will be taken into account in the implementation phase of the 2014-2021 WQIP.

The EVs are presented in the following tables, with symbols and interpretation (adapted from EPA 2005) of the EVs for freshwater systems shown in Table 13, and marine systems in Table 14. Additionally, Table 15 provides the definitions of human use for EVs. Table 16a consolidates the EVs for each CMA for the present and the future expected, and Table 16b presents the EVs for human uses of the estuarine and marine areas.

Right, the Eden Lassie catchment area drains into the Declared Fish Habitat and Dugong Protection Area of Edgecumbe Bay. On-farm management practice improvements and efforts to restore and maintain ecosystem health on Eden Lassie Creek have a direct benefit towards water quality improvements and habitat value in this important region.

**Table 13 Environmental Value symbols and interpretation for freshwater (adapted from EPA 2005).**

| EV | Symbol | Interpretation |
|---|---|---|
| | Aquatic Ecosystems | Water for freshwater aquatic ecosystem protection[A] |
| | Irrigation | Irrigating crops such as cane, legumes, etc |
| | Stock watering | Water for stock consumption |
| | Farm use | Water for farm use such as in fruit packing or milking sheds, etc |
| | Aquaculture | Water for aquaculture farming |
| | Human consumption | Human consumption of wild or stocked fish, crustaceans or shellfish |
| | 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 recreation, 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 |

**Table 14 Environmental Value symbols and interpretation for estuarine and marine water (adapted from EPA 2005).**

| EV symbol | Symbol | Interpretation and notes |
|---|---|---|
| | Aquatic Ecosystems | Water for estuarine and marine aquatic ecosystem protection[A] |
| | Aquaculture | Water for aquaculture and prawn 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 recreation, bushwalking, sight seeing |
| | Drinking | Processed drinking water supplies for human consumption such as desalination plant |
| | Cultural & Spiritual | Cultural and spiritual values including the cultural values of traditional owners |

**Table 15 Definitions of human use for Environmental Values.**

| USE | DEFINITION OF BENEFICIAL USE | | |
|---|---|---|---|
| | High use | Medium use | Low use |
| **Aquatic Ecosystems** | High Ecological Value (HEV) – for definition see Table 9 & 10 | Slightly to moderately disturbed systems (SMD) | Highly disturbed systems (HD) |
| **Human Consumption** | Commercial and recreation activities present | Recreational activities only | Infrequent, seasonal use |
| **Primary Recreation** | Recreational facilities/ infrastructure (e.g., dams, water skiing, toilets, change rooms) | Community use, no formal facilities/ infrastructure but may have impromptu facilities such as rope swings, deepened pools, small rock or earth dams | Infrequent, seasonal use |
| **Secondary Recreation** | Recreational facilities/ infrastructure (e.g., dams, water skiing, boat sheds, boat ramps) | Community use, no formal facilities/ infrastructure but may have impromptu facilities such as non-paved boat ramps, 4WD tracks | Infrequent, seasonal use |
| **Visual Recreation** | Recreational facilities/ infrastructure (e.g., gardens, toilets, signed walking tracks) | Community use, no formal facilities/ infrastructure but may have impromptu facilities such as rough walking track, 4WD tracks | Known to be used by specialist groups only (such as bushwalkers, birdwatchers, researchers) |
| **Cultural and Spiritual Values** | The categories for aquatic ecosystems are currently being used for this category while this is being evaluated | The categories for aquatic ecosystems are currently being used for this category while this is being evaluated | The categories for aquatic ecosystems are currently being used for this category while this is being evaluated |
| **Industrial Use** | Large industry or multiple industry use | Small, single industry use | Occasional, opportunistic use |
| **Aquaculture** | Stand alone operation | Operated in conjunction with other farming activities | Licensed but not currently operational |
| **Drinking Water** | City >5000 people | Town <5000 people | Single household use only |
| **Irrigation** | Irrigation scheme with shared infrastructure, dams, canals, pipelines | Many irrigation licences (riparian and bores) | Few irrigation licences (riparian and bores) |
| **Stock Water** | Grazing >30% of catchment | Grazing 10-30% of catchment | Grazing <10% of catchment |
| **Farm Supply** | Water supply for large packing shed/multi farm operation | Small single farm operation | Occasional, opportunistic use only |
| **Oystering** | Commercial activity | Recreational activity only | Infrequent, seasonal use |

Environmental Values are those qualities of the waterway that make it suitable to support particular aquatic ecosystems and human uses.

**Table 16a Summary of Environmental Values for human uses for freshwater management areas.**
*H – High importance/use; M – moderate importance/use; L – low importance/use; '–' waterway use/value not selected (i.e., no use) '?' - Not currently assessed.*

| Management area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Eden Lassie Creek Now | L | L | H | H | L | - | - | L | L | - | ? |
| Eden Lassie Creek Future | L | L | H | H | L | - | - | L | L | - | ? |
| Gregory River Now | H | M | H | H | L | L | - | L | L | M | ? |
| Gregory River Future | H | M | H | H | L | L | - | L | L | L | ? |
| Whitsunday Coast Now | L | L | L | - | L | L | - | H | L | - | ? |
| Whitsunday Coast Future | L | L | L | - | L | L | - | H | L | - | ? |
| Upper Proserpine River Now | L | L | H | - | M | H | H | H | L | - | ? |
| Upper Proserpine River Future | L | L | H | - | M | H | H | H | L | - | ? |
| Proserpine River Main Channel Now | H | H | L | - | L | M | - | L | H | H | ? |
| Proserpine River Main Channel Future | H | H | L | - | L | M | - | L | H | H | ? |
| Myrtle Creek Now | H | H | M | - | L | H | - | H | M | M | ? |
| Myrtle Creek Future | H | H | M | - | L | H | - | H | M | - | ? |
| Repulse Creek Now | - | - | - | - | L | L | - | H | L | - | ? |
| Repulse Creek Future | - | - | - | - | L | M | - | H | L | - | ? |
| Lethe Brook Now | H | H | H | - | L | L | - | L | L | - | ? |
| Lethe Brook Future | H | H | H | - | L | L | - | L | L | - | ? |
| Thompson Creek Now | M | M | H | - | L | L | - | L | L | - | ? |
| Thompson Creek Future | M | H | H | - | L | L | - | L | L | - | ? |
| Andromache River Now | M | L | H | - | L | M | - | L | L | - | ? |
| Andromache River Future | H | H | H | - | L | M | - | L | L | - | ? |
| O'Connell River Now | H | H | H | H | L | H | - | H | M | - | ? |
| O'Connell River Future | H | H | H | H | L | H | - | H | M | - | ? |
| Waterhole Creek Now | L | L | H | - | L | L | - | L | L | M | ? |
| Waterhole Creek Future | L | M | H | - | L | L | - | L | L | M | ? |
| Blackrock Creek Now | M | M | M | - | L | L | L | - | L | - | ? |
| Blackrock Creek Future | M | M | M | M | L | L | L | - | L | - | ? |
| St Helens Creek Now | M | M | M | M | L | M | L | M | M | - | ? |
| St Helens Creek Future | M | M | M | M | L | M | L | M | M | - | ? |
| Murray Creek Now | M | M | H | M | L | L | L | L | L | - | ? |
| Murray Creek Future | M | M | H | M | L | L | L | L | L | - | ? |
| Constant Creek Now | M | M | H | M | L | M | L | H | L | - | ? |
| Constant Creek Future | M | M | H | M | L | M | L | H | L | - | ? |

**Table 16a (continued).**

| Management area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reliance Creek Now | M | M | M | - | L | M | L | L | L | -- | ? |
| Reliance Creek Future | M | M | M | - | L | M | L | L | L | - | ? |
| Upper Cattle Creek Now | H | H | L | - | L | H | L | H | M | - | ? |
| Upper Cattle Creek Future | H | H | L | - | L | H | L | H | M | - | ? |
| Blacks Creek Now | H | L | H | - | L | H | H | M | H | H | ? |
| Blacks Creek Future | H | L | H | - | L | H | H | M | H | H | ? |
| Pioneer River Main Channel Now | H | H | M | M | L | H | H | H | M | H | ? |
| Pioneer River Main Channel Future | H | H | M | M | L | H | H | H | H | H | ? |
| Mackay City Now | H | H | L | M | L | M | M | H | H | H | ? |
| Mackay City Future | H | H | L | M | L | M | M | H | H | H | ? |
| Bakers Creek Now | H | M | M | - | L | M | L | M | L | - | ? |
| Bakers Creek Future | H | H | L | M | L | M | L | M | L | - | ? |
| Sandy Creek Now | H | H | M | M | M | H | H | L | M | H | ? |
| Sandy Creek Future | H | H | M | M | M | H | H | L | M | H | ? |
| Alligator Creek Now | H | H | L | - | - | L | - | - | H | - | ? |
| Alligator Creek Future | H | H | L | - | - | L | - | - | H | - | ? |
| Sarina Beaches Now | L | M | M | - | - | L | - | M | - | H | ? |
| Sarina Beaches Future | L | M | M | - | - | L | - | H | - | H | ? |
| Plane Creek Now | M | H | H | - | L | H | H | M | H | H | ? |
| Plane Creek Future | M | H | H | - | L | H | H | M | H | H | ? |
| Rocky Dam Creek Now | M | M | M | - | M | M | - | M | M | M | ? |
| Rocky Dam Creek Future | M | M | M | - | M | M | - | M | M | M | ? |
| Cape Creek Now | - | L | L | - | - | - | - | H | L | - | ? |
| Cape Creek Future | L | L | L | - | - | - | - | H | M | - | ? |
| Marion Creek Now | M | M | H | - | - | L | L | M | L | - | ? |
| Marion Creek Future | M | M | H | - | - | L | L | M | L | - | ? |
| Gillinbin Creek Now | L | L | H | - | - | L | - | - | L | - | ? |
| Gillinbin Creek Future | L | L | H | - | - | L | - | - | L | - | ? |
| West Hill Creek Now | L | M | H | - | - | L | - | L | L | - | ? |
| West Hill Creek Future | L | M | H | - | - | L | - | L | L | - | ? |
| Carmila Creek Now | M | H | H | - | - | M | - | - | M | - | ? |
| Carmila Creek Future | M | H | H | - | - | M | - | - | M | - | ? |
| Flaggy Rock Creek Now | M | M | H | - | - | L | - | - | L | - | ? |
| Flaggy Rock Creek Future | M | M | H | - | - | L | - | - | M | - | ? |

**Table 16b Summary of Environmental Values for human uses for estuary and marine areas.**
*H – High importance/use; M – moderate importance/use; L – low importance/use; '–' waterway use/value not selected (i.e., no use) '?' - Not currently assessed.*

| Management area | | | | | | |
|---|---|---|---|---|---|---|
| Gregory/Eden Lassie Estuary (Edgecumbe Bay) | H | H | L | M | H | ? |
| Repulse Bay | - | H | L | H | H | ? |
| Proserpine Estuary | - | H | L | H | H | ? |
| Lethe Brook Estuary | - | H | L | M | M | ? |
| Thompson Estuary | - | H | L | M | M | ? |
| O'Connell Estuary | - | H | L | M | H | ? |
| Waterhole Creek Estuary | - | H | L | L | H | ? |
| Edgecumbe Bay | - | H | L | H | H | ? |
| Whitsunday Coast and Islands | - | H | H | H | H | ? |
| Repulse Bay | - | H | L | H | H | ? |
| St Helens Bay-(Blackrock, St Helens, Murray- Victor Creek Estuary) | - | H | L | H | H | ? |
| Constant Estuary | - | H | L | H | H | ? |
| Reliance Estuary | H | H | L | H | H | ? |
| Basset Bay (Pioneer Estuary Slade Bay) | - | H | L | H | H | ? |
| Bakers Estuary | H | H | L | H | H | ? |
| Sandringham Bay | H | H | L | H | H | ? |
| All Pioneer Coastal and Marine Waters | - | H | H | H | H | ? |
| Alligator/Sandy Estuary (Sandringham Bay) | H | H | L | M | M | ? |
| Plane Estuary (Sarina Inlet) | H | H | L | H | H | ? |
| Rocky Dam Estuary/ Ince Bay | L | H | L | H | H | ? |
| Marion Creek Estuary | H | H | L | M | M | ? |
| Four Mile Beach | - | - | L | L | - | ? |
| West Hill Estuary | - | H | L | M | M | ? |
| Carmila Estuary | - | H | L | H | H | ? |
| Flaggy Rock Estuary | - | H | L | H | H | ? |
| All Sarina Coast and Marine Waters | - | H | H | H | H | ? |

By incorporating knowledge of local stakeholders and experts, HEV waters were identified and endorsed through community consultation.

### 7.2.2. Freshwater and estuarine High Ecological Value areas

The 2008 WQIP assessed a total of 33 subcatchments and 22 estuaries within the Mackay Whitsunday NRM area to identify HEV waters – freshwater and estuarine areas where HEV waters were evident and where water quality in aquatic ecosystems was determined to require a HEV level of protection (refer to Drewry et al. 2008; Platten 2008). Reference catchment locations were also identified. By incorporating knowledge of local stakeholders and experts, HEV waters were identified and endorsed through community consultation (Drewry et al. 2008; Platten 2008). Further detail on the information used to determine HEV waters can be found in Drewry et al. (2008) and Platten (2008).

For the update of the WQIP, the freshwater and estuarine HEV waters identified in the EPP Water (234,938 ha) were assessed and compared to those mapped in the 2008 WQIP (246,161 ha). All identified HEV waters are shown in Table 17 and Figure 10. The SPP has mapped some wetland areas as HEV and some as "Slightly Disturbed". The majority of these wetland areas were mapped as wetlands in the 2008 WQIP, but not as HEV waters. Inland HEV waters are largely the same between the 2008 WQIP mapping and the EPP Water, with one additional area nominated under EPP Water HEV mapping (previously mapped as natural area, but not HEV), just west of Sarina (Figure 10).

**Table 17 Freshwater and estuarine High Ecological Value waters identified and presented in WQIP 2008 and EPP Water (adapted from Drewry et al. 2008).**

| Catchment management area | Description of HEV area |
|---|---|
| **Various** | All National Parks |
| **Various** | All Type A Fish Habitat Areas |
| **Various** | Wetlands within a wetland protection area or wetlands of high ecological significance, or as defined in EPP (Water) 2009 |
| **Eden Lassie Creek** | Mt Challenger, Mt Maria<br>Eden Lassie Creek estuary |
| **Upper Proserpine River** | Upper catchment headwaters - from north of Peter Faust Dam, south to (and including) the state forest |
| **Myrtle Creek** | State forest in eastern and upper reaches |
| **Repulse Creek** | Entire catchment management area |
| **Lethebrook** | State forest in western and upper west |
| **Thompson Creek** | Goorganga wetland complex in lower reaches<br>Thompson Creek estuary |
| **Andromache River** | State forest in western part of catchment |
| **O'Connell River** | State forest in southern and south-western headwaters |
| **St Helens Creek** | State forest small extension to east of national park<br>Big Green Hill east of state forest |
| **Murray Creek** | State forest areas in upper catchment |
| **Constant Creek** | Small area in upper catchment which joins two national parks |

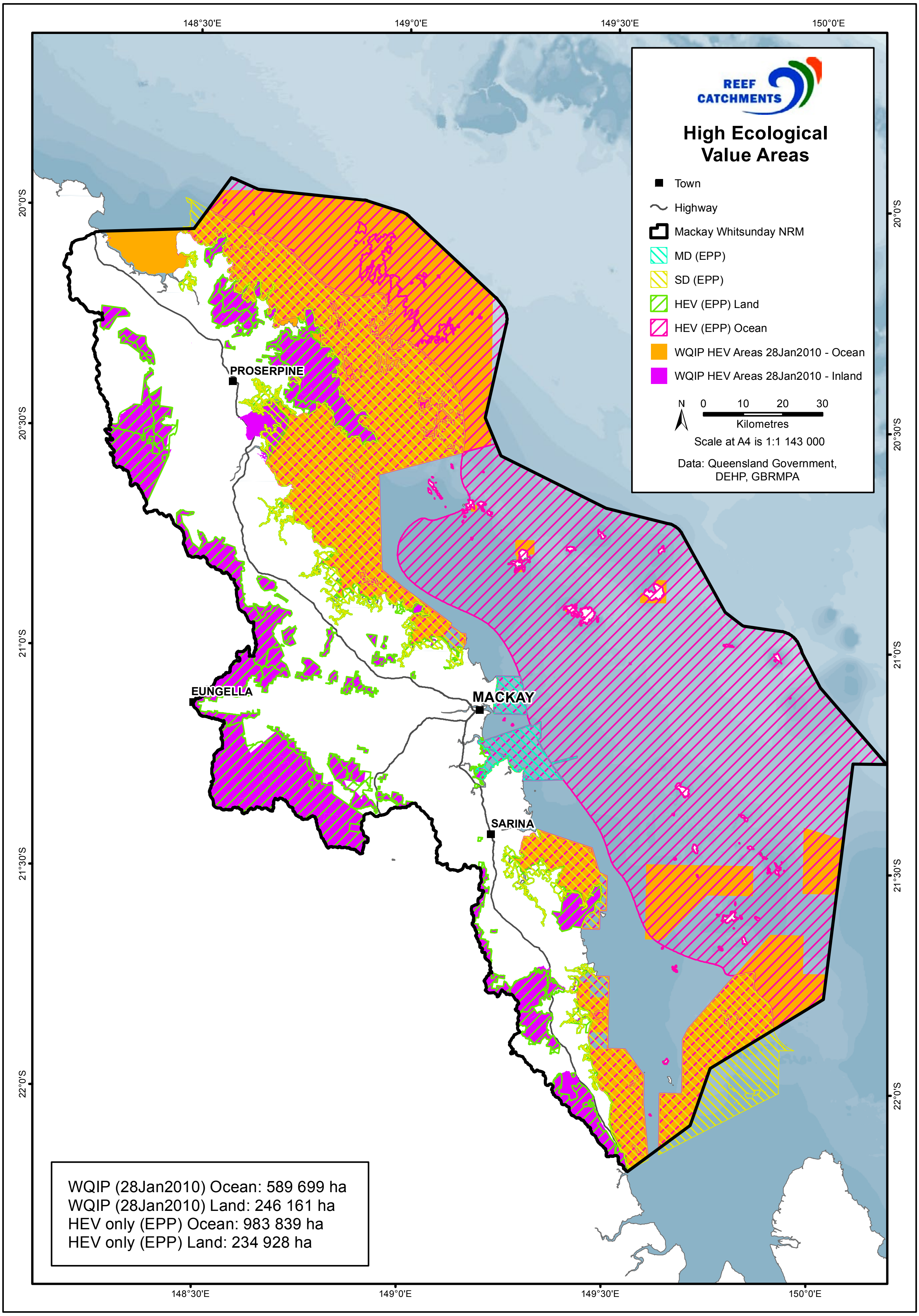



**Figure 10 Comparison of 2008 WQIP mapped HEV waters and EPP HEV waters.**

**Table 17 (continued)**

| | |
|---|---|
| **Pioneer River – Main Channel** | Small areas in the north, south, and southwest |
| **Upper Cattle Creek** | Majority of the catchment, excluding developed lower reaches |
| **Blacks Creek** | Entire catchment management area excluding area around Teemburra Dam, Hogan's Pocket landfill, sugarcane land in lower reaches of Black Waterhole and Stockyard Creeks and improved pasture at Pinnacle Station |
| **Constant Creek** | Constant Creek estuary, Ball Bay, Seaforth Creek, Cape Hillsborough NP to north around headlands |
| **Sandy Creek** | Small areas in the southern and western headwaters |
| **Cape Creek** | Majority of catchment management area except for developed area in the south |
| **Gillinbin Creek** | Majority of catchment management area excluding sugarcane area in southeast<br>Four Mile Creek Estuary |
| **Flaggy Rock Creek** | Majority of catchment management area, excluding lowlands<br>Flaggy Rock Creek estuary, including Dugong Protection Area |
| **Rocky Dam Creek** | Whole area of Rocky Dam Creek estuary and Ince Bay |
| **West Hill Creek** | Headwaters of catchment management area West Hill Creek estuary |

### 7.2.3. Marine High Ecological Value areas

The marine HEV waters (589,699 ha) for the Mackay Whitsunday region were determined by the Catchment Reference Panel and GBRMPA and presented in the 2008 WQIP. When identifying the marine HEV waters, a number of considerations were taken into account, such as influences of river discharge, Marine National Park areas, communities supported, habitat features (such as seagrass, Dugong Protection Areas, and Fish Habitat Areas), use of the area, and environmental impacts (Drewry et al. 2008).

In both the 2008 and 2014-2021 WQIPs, the focus for marine waters of good condition quality/aquatic ecosystems is to protect and maintain their current condition. The focus for marine areas under threat from reduced water quality due to land management practices is water quality improvement. Monitoring programs will continue to provide information on the condition of water quality and aquatic ecosystem health, and on the effectiveness of the management interventions implemented.

This WQIP update has reviewed and included marine HEV waters identified in the EPP Water (983,839 ha). All marine waters requiring a HEV level of protection are shown in Table 18 and Figure 10. The main difference between the marine area mapped as HEV presented in the 2008 WQIP and the new EPP Water relates to the marine area in the middle of the Mackay Whitsunday coast (Figure 10). This area was not nominated as HEV in the 2008 WQIP and accounts for the majority of the difference in area between the two maps. The previous WQIP included only some small sections within this area (i.e. around the Cumberland Group of islands and the Northumberland Islands).

A number of inshore areas were mapped differently in the 2008 WQIP and the EPP Water.

The 2008 WQIP identified the following marine waters as requiring a HEV level of protection, however they were mapped as "Slightly Disturbed Waters" in the EPP:

- Area around Ince Bay and Llewellyn Bay;
- Majority of the marine waters from the north of the Mackay Whitsunday NRM region to St Helens Beach; and
- Inshore areas south of Marion Creek.

Additionally, the 2008 WQIP mapped Edgecumbe Bay as HEV. It is not included as HEV under EPP Water as it is currently being included in the Burdekin/ Don Haughton assessment which is underway (Figure 10).

For the purposes of the 2014-2021 WQIP, all areas included in the 2008 WQIP as HEV will remain identified as HEV areas. Additional HEV waters identified in the EPP Water will also be mapped as HEV for the 2014-2021 WQIP (Figure 10).

**Table 18 Marine High Ecological Value areas identified and presented in WQIP 2008 and EPP (adapted from Drewry et al. 2008).**

| Marine management area | Description of HEV area |
|---|---|
| **Various** | All Marine National Parks and Preservation Areas |
| **Various** | All Type A Fish Habitat Areas |
| **Various** | All Dugong Protection Areas |
| **Repulse Bay** | All of Repulse Bay, including the Repulse Bay Fish Habitat Area and Marine National Park |
| **Repulse Bay Special Management Area** | Includes Marine Park Zone and Fish Habitat Area Includes waters around Whitsunday islands as identified by GBRMPA in 'special management' area |
| **Edgecumbe Bay** | Fish Habitat Area excluding aquaculture impact zone from HEV waters |
| **Whitsundays Special Management Area** | Includes waters around Whitsunday Islands as identified by GBRMPA in 'special management' area Edgecumbe Bay |
| **Coastal/Marine Waters** | Along the entire coastline |
| **Rocky Dam Estuary/Ince Bay/Llewellyn Bay** | Entire area |

### 7.2.4. Summary and the 2014-2021 WQIP

This updated WQIP highlights that the process is dynamic and continually improving, using new knowledge and perspectives, and accounting for changes in land use practices. Any additional areas nominated as requiring a HEV level of protection under the EPP Water are included in the 2014-2021 WQIP. The waterways will continue to be monitored to provide information on EVs and HEV areas, the water quality, and aquatic ecosystem health. This monitoring will also provide valuable feedback on the effectiveness of management practice changes that have been implemented. The following sections of this document provide further information on WQOs and targets (Section C: Targets and Objectives), proposed management interventions (Section D: Regional Intervention and Investment Priorities), and the proposed monitoring (Section E: Monitoring and Management).

SECTION C

# Targets and Objectives

This section provides detail on the development and results of water quality and ecosystem health objectives and targets for the region. The different types of pollutant sources in the Mackay Whitsunday region were identified, with the main pollutant sources being diffuse agricultural, diffuse urban and rural residential sources, followed by urban and industrial point sources. The associated land use contributions to these loads have also been defined and presented.

Water quality objectives (WQOs) are designed to protect the determined Environmental Values of an area. This section provides detail on the development of 2014 current condition, the 2021 targets, and the 2050 WQOs for both freshwater and marine environments, under ambient and event conditions. Following the identification of the current condition, targets, and WQOs the Water Quality Improvement chapter transforms that information into end-of-catchment loads and load reduction targets. It presents a summary of modelled regional loads for current condition and 2021 targets, and load reductions expected through adoption of improved management practices.

Finally, this section also discusses the development of ecosystem health indicators for the region, and how these have been refined and updated since the previous WQIP. For each ecosystem health indicator (riparian vegetation, fish community health, barriers to fish movement, and flow), the current condition and the 2021 target is presented. The targets have been based on feasible ecosystem health improvement activities to be implemented between 2014 and 2021. Additionally, a summary of work undertaken on ecotoxicity in the Mackay Whitsunday region is discussed in this section.

# 8. Pollutant Sources

The pollutant sources relevant to the Mackay Whitsunday region are discussed in this chapter and include:

- Diffuse agricultural sources;
- Diffuse urban and rural residential sources;
- Urban and industrial point sources; and
- Other sources such as atmospheric deposition and shipping.

This WQIP has encompassed a range of pollutant sources and water quality indicators, with particular attention to diffuse sources as they are the major source of nutrients, sediment and pesticides in the region.

## 8.1. Land use contributions to diffuse pollutant loads

Water quality in the region is influenced by the level of agricultural and urban development in the catchments. Pollutants such as sediment and nutrients originate from both diffuse and point sources. Cropping (sugarcane and horticulture), grazing, and urban land uses are the major diffuse sources of nutrients and sediment. Pesticides (including herbicides) are most commonly contributed from diffuse cropping and urban sources.

A conceptual diagram showing the sources of sediment, transportation in waterways and the resulting effects in the GBR lagoon within the Mackay Whitsunday region is provided in Figure 11. The diagram compares the effects of good land management to poor land management, and highlights improvements that can be made.

Pesticide generation, transportation in waterways, and the resulting effects on the marine environment of the GBR lagoon are shown conceptually in Figure 12**.** The diagram shows the likely impacts to the GBR lagoon, including loss of species diversity within the event plumes of pollutants.

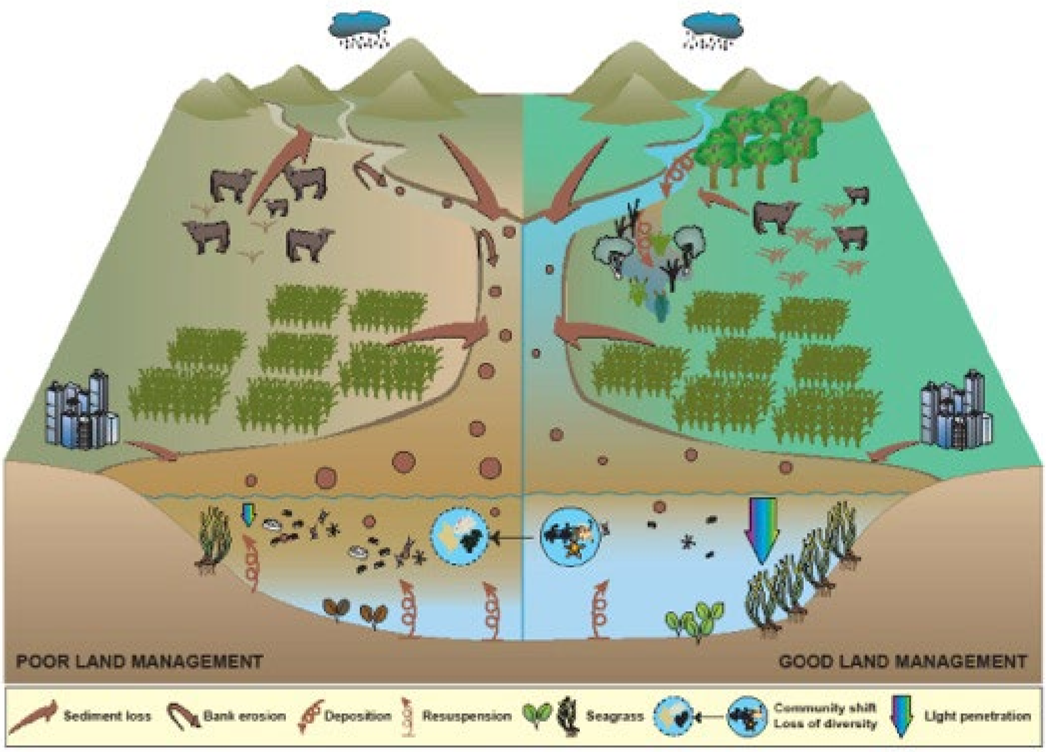



**Figure 11 Conceptual diagram of pollutant generation, transportation, and effects on the marine environment of the Mackay Whitsunday region of the Great Barrier Reef lagoon. (Source: Drewry et al. 2008).**

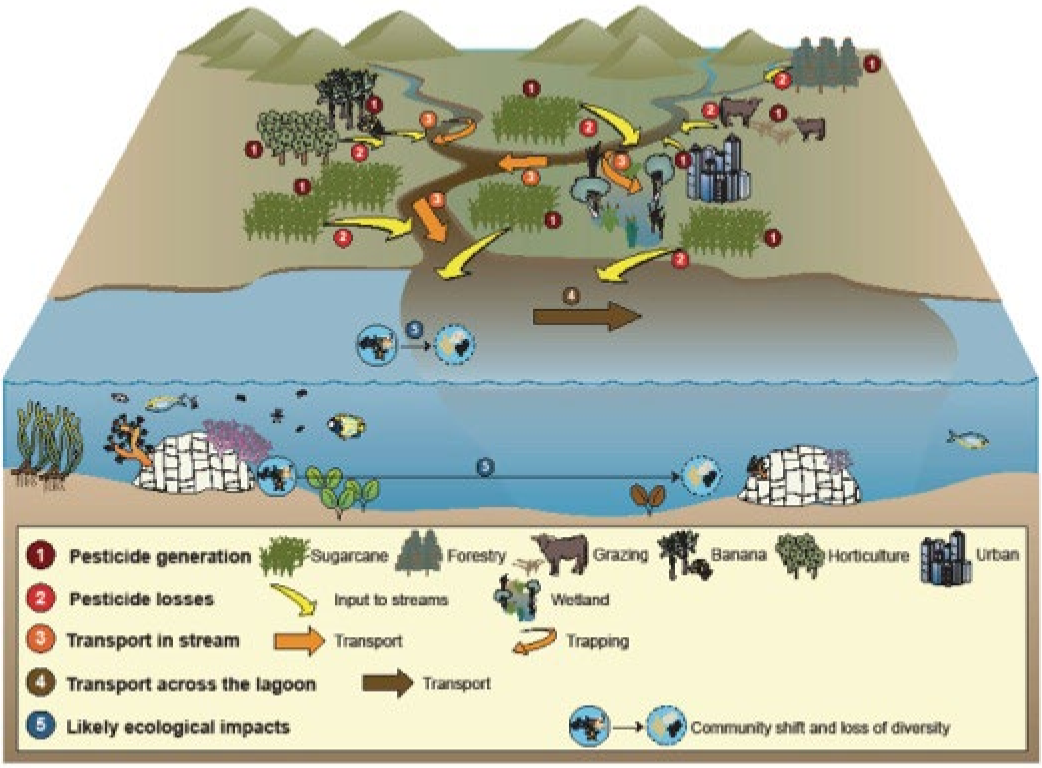



**Figure 12 Conceptual diagram of pesticide pollutant generation, transportation, and effects on the marine environment of the Mackay Whitsunday region of the Great Barrier Reef lagoon. (Source: Drewry et al. 2008)**

Sediment and nutrient contaminants occur naturally, sourced from natural ecosystems (e.g. forest and conservation areas). Erosion-derived pollutants are mainly sourced from surface sources (hillslope) or from subsurface sources, namely gully or streambank sediment. Recent Source Catchments modelling has shown that hillslope erosion is the dominant erosion process (51%) for sediment export to the GBR lagoon across the Mackay Whitsunday region, with streambank contributing 46% and the remaining 3% originating from gully erosion (Packett et al. 2014).

Information on urban diffuse sources is available in various urban stormwater management plans, e.g. Mackay City Council (2006). Urban management comprises two main phases: new development ('Greenfields') and existing urban management ('Infill'). The major diffuse pollutants due to new development are sediments and particulate nutrients. The major diffuse pollutants from existing urban areas are sediments, nutrients, and heavy metals.

In addition to the impact on water quality, urban development can have an ecologically significant impact on in-stream habitat. Urbanisation increases impervious surfaces, which in turn increases the number of runoff events. This increased frequency of runoff events can result in the regular disturbance of in-stream ecosystems and ecosystem degradation. For further information, refer to Section D: Regional Intervention and Investment Priorities.

Pollutant load contributions from each land use in the Mackay Whitsunday region have been estimated using the eWater Limited Source Catchments model (Packett et al. 2014), and are summarised in Table 19. Sugarcane farming is the predominant diffuse source of nutrient and herbicide pollutants, followed by grazing and conservation areas.

Sugarcane is the dominant intensive agricultural land use in the Mackay Whitsunday region (19% of land area in the region) and produces 32% of the regional load of particulate nitrogen (PN). Sugarcane farming produces approximately 65% of the regional dissolved inorganic nitrogen (DIN) load, and 26% of the regional total suspended sediment (TSS) load. It also contributes 40% of the regional filterable reactive phosphorus (FRP) load, and the vast majority of the pesticides ametryn, atrazine, diuron, and hexazinone (Table 19).

Grazing (and forestry) is the dominant extensive land use in the region (54% of land area) and produces approximately 27% of the total region's PN and DIN load, 41% of particulate phosphorus (PP) and FRP, and 53% of the TSS load. The herbicide tebuthiuron is predominantly used on grazing land. Nutrient and sediment generation rates delivered in-stream are lower from grazing lands than from sugarcane (Table 20).

Urban land and other intensive uses (e.g. rural residential, transport corridors) contribute >10% to the regional particulate nutrient load, and 4% of the regional DIN load (Table 19). Horticulture (which accounts for <1% of the land area in the region) has very minor contributions to all regional loads (Table 19).

Nutrient and sediment generation rates modelled by Source Catchments delivered in-stream are greater from sugarcane than from grazing and forestry (Table 20). Horticulture and cropping also generate relatively high rates of pollutants, but only occupy a very minor proportion of the region. Generation rates from national parks and reserves are what could be considered "natural".

**Table 19 Relative contribution of land uses to the regional diffuse source pollutant load (%). Figures have been rounded.**

| Land use | % land use | % DIN | % PN | % FRP | % PP | % TSS | % Ametryn, atrazine, diuron, hexazinone | % Tebuthiuron |
|---|---|---|---|---|---|---|---|---|
| National Parks and Reserves | 18 | 5 | 22 | 8 | 16 | 11 | 0 | 0 |
| Grazing and Forestry | 54 | 26 | 27 | 44 | 41 | 53 | 0 | 100 |
| Sugarcane | 19 | 65 | 32 | 40 | 29 | 26 | 99 | 0 |
| Horticulture and Cropping | <1 | <1 | 1 | <1 | 1 | 1 | <1 | 0 |
| Urban and Intensive Uses | 3 | 4 | 18 | 7 | 13 | 9 | <1 | 0 |
| Wetlands and Water | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 20 Diffuse source sediment and nutrient generation rate coefficients (kg/ha/yr) delivered in-stream estimated from Source Catchments modelling.**

| Land Use | DIN | PN | FRP | PP | TSS |
|---|---|---|---|---|---|
| National Parks and Reserves | 0.34 | 0.80 | 0.07 | 0.23 | 200 |
| Grazing and Forestry | 0.59 | 0.36 | 0.12 | 0.17 | 260 |
| Sugarcane | 4.28 | 1.01 | 0.31 | 0.31 | 430 |
| Horticulture and Cropping | 2.61 | 2.69 | 0.88 | 2.02 | 2300 |
| Urban and Intensive Uses | 1.77 | 4.12 | 0.34 | 1.17 | 520 |
| Wetlands and Water | 0 | 0 | 0 | 0 | 0 |

## 8.2. Point sources

Generally, point sources of pollutants are regulated activities. This means the activity has been assessed, deemed to have met environmental management considerations, and conditioned accordingly (Kroon et al. 2013). The conditions imposed on the activity will include environmental measures that result in the activity causing minimal impact on the environment.

The vast majority of point source discharges to waters in Queensland originate from sewage treatment plants (STPs) (Brodie et al. 2012), followed by sources such as refineries, abattoirs, mining, aquaculture and piggeries/feedlots. Chemical or heavy industries typically produce small amounts of nutrients but higher amounts of other pollutants such as metals, pesticides, acids/bases or organic matter.

Whilst point sources are generally regulated activities, monitoring and permit information is not always available. The lack of information can make it difficult to assess the contribution and impact of pollutants derived from point sources as compared to those derived from diffuse sources (broad-scale land use; see above).

Source Catchments modelling estimates point sources to contribute only a minor proportion (2%) of the total regional DIN load (Packett et al. 2014), however, this was based on limited data as only STPs with a capacity greater than 10,000 equivalent persons were included. Although contributions from point sources are relatively small compared to those derived from diffuse sources, these contributions could be highly significant over short time periods and to local catchment management areas.

Discharge monitoring data from the four major sewage treatment plants in the region for 2013/14 are shown in Table 21.

**Table 21 Discharge monitoring data from the four major point sources in the Mackay Whitsunday region for 2013/14.**

| Point source | Management area | Median TN concentration (mg/L) | Median TP concentration (mg/L) | TN load (kg) | TP load (kg) |
|---|---|---|---|---|---|
| **Cannonvale WWTP[1]** | **Whitsunday Coast** | 1.5 | 0.3 | 1776* | 480* |
| **Proserpine WWTP** | **Proserpine River Main Channel** | 5.2 | 0.4 | 3616** | 232** |
| **Mackay North WRF[2]** | **Reliance Creek** | 5.2 | 0.3 | 7360 | 526 |
| **Mackay Southern WRF** | **Bakers Creek** | 6.6 | 1.3 | 11910 | 3850 |

([1] WWTP – waste water treatment plant; [2] WRF – water recycling facility. * Extrapolated from data from April – June 2014; ** Extrapolated from data from January – June 2014; Cannonvale and Proserpine data provided by Whitsunday Regional Council, and Mackay data is based on or contains data provided by the State of Queensland (Department of Science, Information Technology, Innovation and the Arts) 2014).

## 8.3. Other pollutant sources

In developing the 2008 and 2014-2021 WQIPs, effort has concentrated on agricultural and natural land-based diffuse pollutant sources, and urban sources within the Mackay Whitsunday region (see above). Other minor pollutants associated with urban areas, transport corridors, waste disposal areas and STPs include organic compounds, hydrocarbons and heavy metals (Drewry et al. 2008).

There are likely to be other minor pollutant sources in the region, which have not been assessed due to current modelling constraints, or being outside the scope of this WQIP. However, these sources (or losses) are accounted for in monitored catchment-scale water quality data. Such nitrogen or phosphorus pollutant sources (and losses) to waterways may include the following:

- Atmospheric deposition associated with coastal zones;
- Atmospheric deposition associated with industrial discharges (e.g. from coal fired industries, sugar mills, etc.);
- Rural and peri-urban septic system on-site waste water management systems and septic systems discharge sources; and
- Emissions such as nitrous oxide and ammonia in rainfall.

Aspects of the WQIP using actual water quality monitoring data for WQOs, current condition and targets, or adjustment variations, will include most sources and losses because catchment-scale monitored data was used in part or whole.

Shipping is a potential source of pollution to the GBR lagoon. Shipping pollution is largely via accidents (sinking, breaching hulls, spills, etc.), the discharge of ballast water, or the slow but continual release of components of anti-fouling paints, for example copper (Angel et al. 2012) and diuron (Jones et al. 2003). The expected increase in usage of the GBR shipping lanes, as a result of increased port development, may result in increased risk of pollution from shipping (Kroon et al. 2013).

# 9. Water Quality Objectives and Targets

Water quality objectives (WQOs) are designed to protect the determined Environmental Values (Chapter 7). Load reduction targets are outlined in Chapter 10, while proposed management interventions to improve water quality are described in Chapter 12. Water quality objectives and targets are also linked to the Mackay Whitsunday NRM Plan (Reef Catchments *unpubl.*).

Right, a constructed fishway in the O'Connell River. Aquatic ecosystem condition indicators include aspects such as stream flow, fish community health, and riparian vegetation condition.

### 9.1. Indicators for Water Quality Objectives

Indicators can be used to assess water quality and aquatic ecosystem condition. Water quality can be measured by both abiotic (physico-chemical) and biotic factors. Physico-chemical water quality indicators are detailed in this chapter. Biotic indicators include aspects such as stream flow, fish community health, and riparian vegetation condition. A combination of these can be used to derive an index of relative ecological condition. This is presented in more detail later in Chapter 11.

Water quality indicators are commonly used to define and test changes over time and improvements in condition. It is therefore useful to have estimates of the current condition of waterways, and long-term targets and guidelines. This chapter of the WQIP presents an overview of the development of the physico-chemical WQOs, current condition, and 2021 targets. The WQOs, current condition, and targets are separated into the following:

- Water quality indicators;
- Freshwater ambient (low flow);
- Event-based end-of-catchment (storm flow); and
- Receiving water (marine) event-plume.

The 2008 WQIP (Drewry et al. 2008) identified the key water quality pollutants of concern in the region to be dissolved and particulate forms of nitrogen and phosphorus, suspended sediment and the residual herbicides ametryn, atrazine, diuron, hexazinone, and tebuthiuron.

The WQOs developed and presented in the 2008 WQIP and scheduled under EPP Water are the basis for the WQOs described in the 2014-2021 WQIP. Details including sources of data and the development of WQOs are available in technical reports (Drewry et al. 2008 a,b; Rohde et al. 2006a; Rohde et al. 2008; Galea et al. 2008a; Smith et al. in press), and should be referred to for further information.

All event-based WQOs, current condition, and targets for each catchment management area are shown in the accompanying Catchment Management Area Reports and Receiving Water Modules. The key pollutants identified in Drewry et al. (2008) (PN, DIN, PP, FRP, TSS and herbicides) are the water quality indicators used as WQOs and are presented and justified in Table 22.

**Table 22 Water quality indicators used as WQOs.**

| Indicator | Description | Justification for use |
|---|---|---|
| DIN | Dissolved inorganic N (nitrate + nitrite + total ammonia) | Readily bioavailable |
| PN | Particulate N | Bioavailable in long-term |
| FRP | Filterable reactive P | Readily bioavailable |
| PP | Particulate P | Bioavailable in long-term |
| TSS | Total suspended sediment | Indicator of erosion of sediment |
| Ametryn, atrazine, diuron, hexazinone, tebuthiuron | Agricultural herbicide | Inhibits plant growth |

## 9.2. Ambient freshwater quality

### 9.2.1. Development of ambient freshwater WQOs

The ambient freshwater WQOs developed for the 2008 WQIP (scheduled under EPP Water) have been reviewed and are expected to still be relevant, and therefore, remain unchanged in this WQIP. The indicators for WQOs were selected in consultation with the Scientific Taskforce. Further details including an overview of datasets and other water quality indicators considered are presented in Drewry et al. (2008a).

Full details on how the ambient WQOs were developed can be found in the 2008 WQIP, but in general, data was based on monthly ambient water quality sampling results. This monthly ambient sampling was conducted from July 2006 to June 2007 by the former Queensland Department of Natural Resources and Water (NRW) in conjunction with Healthy Waterways Alliance, and combined with additional data as required (e.g., data collected by the former EPA from 1994-1999).

The HEV and reference freshwater ambient monitoring sites used to develop WQOs were Impulse Creek, Finch Hatton Creek, upper St Helens Creek, Basin Creek and the upper Andromache River. Further details on the sites can be found in Drewry et al. (2008a). The ambient water quality data that was used to generate the WQOs is reported in detail in Galea et al. (2008a).

The WQOs for modified waterways were developed using the 80$^{th}$ percentile of monitored HEV site data or other appropriate reference sites. Additionally, 20$^{th}$, 50$^{th}$ (median) and 80$^{th}$ percentile WQOs of HEV sites were provided. The purpose of the HEV area WQOs was to ensure current water quality is maintained.

Ambient freshwater WQOs were separated into three regional classifications: Mackay Whitsunday Upland, Whitsunday Lowland, and Pioneer Sarina Lowland. These classifications were used to distinguish more pristine conditions (and therefore more stringent WQOs) for upland regions compared to lowland regions. Whitsunday and Pioneer Sarina lowland were differentiated to allow for localised differences, for example, natural phosphorus levels are commonly greater in the catchments of the Whitsunday region compared to catchments in other regions (Faithful 2003).

Ambient herbicide WQOs were generally based on the 80$^{th}$ percentile of locally collected data from lowland catchments. The HEV freshwater areas are recommended to have herbicide concentrations less than the limit of detection (<LOD), which reflects a non-impacted situation.

The ambient WQOs developed for the Mackay Whitsunday region are in some cases more stringent than state or national guidelines. For example, the Mackay Whitsunday WQOs are more stringent than state guidelines (EHP 2009) or national guidelines (ANZECC and ARMCANZ 2000) for DIN and many herbicides because they are based on locally collected water quality data, and are therefore more relevant.

The revised long-term WQO values to protect modified aquatic ecosystems (non-HEV sites) are summarised in Table 23. The WQOs remain largely the same as the previous WQIP. Where the 2007 current condition was better than the long-term “guideline” WQO in the 2008 WQIP, the target and WQO have been revised to equal the 2007 current condition, to ensure that water quality does not degrade from this condition.

**Table 23 Ambient freshwater WQO values to protect modified aquatic ecosystems for the 2014-2021 Mackay Whitsunday WQIP.**

| Indicator | Mackay Whitsunday Upland | Whitsunday Lowland | Pioneer Sarina Lowland |
|---|---|---|---|
| **DIN** | 30 | 30 | 30 |
| **PN** | 80 | 150 | 150 |
| **FRP** | 15 | 25 | 15 |
| **PP** | 15 | 20 | 20 |
| **TSS (mg/L)** | 3 | 5 | 5 |
| **Ametryn** | <LOD | 0.05 | 0.05 |
| **Atrazine** | <LOD | 0.3 | 0.3 |
| **Diuron** | <LOD | 0.5 | 0.5 |
| **Hexazinone** | <LOD | 0.4 | 0.4 |
| **Tebuthiuron** | <LOD | 0.01 | 0.01 |

Note that individual catchment management area WQOs are less than values presented in this table when current condition is an improvement from the WQO. Concentration units are µg/L unless otherwise stated. Concentrations of N and P are reported as µg N/L and µg P/L, respectively. LOD is the limit of detection which is currently 0.01 µg/L for herbicides, but may be lower in the future.

The WQOs for the HEV waters remain unchanged from the 2008 WQIP (and those scheduled under EPP Water), and aim to ensure current water quality is maintained (Table 24). If the concentration of herbicide detected is >0.01 µg/L within HEV waters, management actions should be triggered to remediate the situation.

**Table 24 Ambient freshwater 20th, 50th and 80th percentile WQOs for HEV catchments in the Mackay Whitsunday WQIP.**

| HEV site | Percentile | PN | DIN | PP | FRP | Total Suspended Solids (mg/L) | Ametryn, atrazine, diuron, hexazinone, tebuthiuron |
|---|---|---|---|---|---|---|---|
| Impulse Creek | 20th | 10 | 10 | 4 | 9 | 1 | <LOD |
| | 50th | 16 | 20 | 10 | 10 | 2 | <LOD |
| | 80th | 52 | 31 | 17 | 15 | 3 | <LOD |
| Finch Hatton Creek | 20th | 6 | 5 | 1 | 2 | 0 | <LOD |
| | 50th | 13 | 8 | 3 | 3 | 1 | <LOD |
| | 80th | 26 | 13 | 5 | 6 | 1 | <LOD |
| St Helens Creek | 20th | 21 | 8 | 3 | 4 | 0 | <LOD |
| | 50th | 32 | 11 | 4 | 5 | 1 | <LOD |
| | 80th | 81 | 17 | 5 | 9 | 1 | <LOD |
| Basin Creek | 20th | 39 | 4 | 6 | 1 | 1 | <LOD |
| | 50th | 58 | 9 | 12 | 2 | 2 | <LOD |
| | 80th | 152 | 13 | 22 | 3 | 4 | <LOD |
| Andromache River | 20th | 21 | 9 | 4 | 12 | 0 | <LOD |
| | 50th | 39 | 18 | 9 | 22 | 1 | <LOD |
| | 80th | 62 | 46 | 13 | 28 | 1 | <LOD |

Concentration units are µg/L unless otherwise stated. Concentrations of N and P are reported as µg N/L and µg P/L, respectively. LOD is the limit of detection which is currently 0.01 µg/L for herbicides, but may be lower in the future.

### 9.2.2. Assessment of ambient freshwater current condition

Where available, the 2007 current condition of water quality parameters in the management areas was assessed using the 50th percentile (median) from ambient (low flow) monthly monitoring data. This was conducted for 13 sites, shown in Table 25 (see Drewry et al. 2008a and Galea et al. 2008a for details).

**Table 25 Freshwater ambient monitoring sites.**

| HEV monitoring sites | Developed management area sites |
|---|---|
| Impulse Creek | Carmila Creek |
| Finch Hatton Creek | O'Connell River |
| Upper St Helens Creek | Rocky Dam Creek |
| Basin Creek | Pioneer River |
| Upper Andromache River | Sandy Creek |
| | Myrtle Creek |
| | Plane Creek |
| | Bakers Creek |

For management areas that were not sampled, current condition was extrapolated from monitored management areas that were considered to have similar land use, landform, flow regime, and geology. Management areas were classified into groups including Pioneer-Sarina or Whitsunday regions, upland, lowland, permanent (permanently flowing), and intermittent (not permanently flowing) flow regimes (refer to Drewry et al. 2008a). Some caution should be used where non-sampled management area current condition is assessed.

### 9.2.3. Development of ambient freshwater targets

The water quality targets for reduced pollutant export were determined by evaluating:

- Pollutant reductions that could be expected from widespread adoption of improved sugarcane, grazing, and urban management practices;
- Consideration of the likely reduction in nutrients required to reduce chlorophyll-*a* concentrations in GBR inshore water to acceptable levels (Brodie et al. 2007; see below); and
- Consideration of the reduction in nutrient and sediment required to approximate water quality in HEV/reference catchments.

A detailed evaluation of different land management practices (e.g. for sugarcane, grazing, and urban lands) and the effects likely on water quality are presented in Chapter 12 and Drewry et al. (2008b). Chapter 12 also provides an 'ABCD' framework for management practice evaluation, catchment-scale modelling scenarios, and likely management actions. Chapter 15 presents expected management practice implementation costs for the region.

### 9.2.4. Comparison of ambient freshwater current condition, targets and WQOs

Only limited ambient water quality monitoring (Sandy Creek and Pioneer River only) has been undertaken in the region since the 2008 WQIP, therefore the WQOs, current condition, and 2021 targets remain unchanged for this WQIP. The WQOs, current condition, and 2021 targets for each catchment management area are shown in Table 26 for nutrients and TSS, and Table 27 for herbicides. The information presented indicates that across the region:

- All management areas have ambient TSS and herbicide water quality concentrations similar to the ambient WQO values; and
- Some management areas (including Myrtle, Alligator, Sandy and Bakers Creeks, and Proserpine River main channel) have nutrient concentrations higher than ambient freshwater WQOs.

Pollutant reductions that can be expected from widespread adoption of improved sugarcane, grazing, and urban management practice change are significant.

**Table 26 Ambient WQOs, current condition and targets for nutrients and TSS for each catchment management area. Nutrient concentrations are in µg/L, and TSS is in mg/L.**

| Catchment Management Area | DIN | | | PN | | | FRP | | | PP | | | TSS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| Eden Lassie Creek | 18 | 18 | 18 | 39 | 39 | 39 | 22 | 22 | 22 | 9 | 9 | 9 | 1 | 1 | 1 |
| Gregory River | 30 | 89 | 45 | 43 | 43 | 43 | 6 | 6 | 6 | 6 | 6 | 6 | 2 | 2 | 2 |
| Whitsunday Coast | 20 | 20 | 20 | 16 | 16 | 16 | 10 | 10 | 10 | 10 | 10 | 10 | 2 | 2 | 2 |
| Repulse Creek | 20 | 20 | 20 | 16 | 16 | 16 | 10 | 10 | 10 | 10 | 10 | 10 | 2 | 2 | 2 |
| Myrtle Creek | 30 | 154 | 77 | 112 | 112 | 112 | 25 | 34 | 25 | 20 | 41 | 20 | 5 | 7 | 5 |
| Proserpine River | 30 | 350 | 175 | 150 | 420 | 210 | 25 | 190 | 95 | 20 | 120 | 60 | 5 | 7 | 5 |
| Upper Proserpine River | 18 | 18 | 18 | 39 | 39 | 39 | 22 | 22 | 22 | 9 | 9 | 9 | 1 | 1 | 1 |
| Lethebrook | 8 | 8 | 8 | 101 | 101 | 101 | 8 | 8 | 8 | 18 | 18 | 18 | 3 | 3 | 3 |
| Thompson Creek | 10 | 10 | 10 | 142 | 142 | 142 | 6 | 6 | 6 | 22 | 22 | 22 | 4 | 4 | 4 |
| Andromache River | 18 | 18 | 18 | 39 | 39 | 39 | 22 | 22 | 22 | 9 | 9 | 9 | 1 | 1 | 1 |
| O'Connell River | 30 | 89 | 45 | 43 | 43 | 43 | 6 | 6 | 6 | 6 | 6 | 6 | 2 | 2 | 2 |
| Waterhole Creek | 18 | 18 | 18 | 39 | 39 | 39 | 22 | 22 | 22 | 9 | 9 | 9 | 1 | 1 | 1 |
| Blackrock Creek | 10 | 10 | 10 | 142 | 142 | 142 | 6 | 6 | 6 | 20 | 22 | 20 | 4 | 4 | 4 |
| St Helens Creek | 10 | 10 | 10 | 142 | 142 | 142 | 6 | 6 | 6 | 20 | 22 | 20 | 4 | 4 | 4 |
| Murray Creek | 18 | 18 | 18 | 39 | 39 | 39 | 22 | 22 | 22 | 9 | 9 | 9 | 1 | 1 | 1 |
| Constant Creek | 10 | 10 | 10 | 142 | 142 | 142 | 6 | 6 | 6 | 20 | 22 | 20 | 4 | 4 | 4 |
| Reliance Creek | 30 | 213 | 107 | 110 | 110 | 110 | 15 | 49 | 25 | 20 | 39 | 20 | 5 | 5 | 5 |
| Mackay City | 30 | 213 | 107 | 110 | 110 | 110 | 15 | 49 | 25 | 20 | 39 | 20 | 5 | 5 | 5 |
| Pioneer River | 8 | 8 | 8 | 102 | 102 | 102 | 5 | 5 | 5 | 20 | 20 | 20 | 5 | 5 | 5 |
| Upper Cattle Creek | 8 | 8 | 8 | 78 | 78 | 78 | 5 | 5 | 5 | 10 | 10 | 10 | 3 | 3 | 3 |
| Blacks Creek | 9 | 9 | 9 | 58 | 58 | 58 | 2 | 2 | 2 | 12 | 12 | 12 | 2 | 2 | 2 |
| Bakers Creek | 30 | 912 | 456 | 150 | 245 | 150 | 20 | 55 | 27 | 20 | 57 | 28 | 4 | 4 | 4 |
| Sandy Creek | 30 | 213 | 107 | 110 | 110 | 110 | 15 | 49 | 25 | 20 | 39 | 20 | 5 | 5 | 5 |
| Alligator Creek | 30 | 213 | 107 | 110 | 110 | 110 | 15 | 49 | 25 | 20 | 39 | 20 | 5 | 5 | 5 |
| Sarina Beaches | 9 | 9 | 9 | 58 | 58 | 58 | 2 | 2 | 2 | 12 | 12 | 12 | 2 | 2 | 2 |
| Plane Creek | 8 | 8 | 8 | 101 | 101 | 101 | 8 | 8 | 8 | 18 | 18 | 18 | 3 | 3 | 3 |
| Cape Creek | 9 | 9 | 9 | 58 | 58 | 58 | 2 | 2 | 2 | 12 | 12 | 12 | 2 | 2 | 2 |
| Rocky Dam Creek | 10 | 10 | 10 | 142 | 142 | 142 | 6 | 6 | 6 | 20 | 22 | 20 | 4 | 4 | 4 |
| Marion Creek | 8 | 8 | 8 | 78 | 78 | 78 | 5 | 5 | 5 | 10 | 10 | 10 | 3 | 3 | 3 |
| Gillinbin Creek | 9 | 9 | 9 | 58 | 58 | 58 | 2 | 2 | 2 | 12 | 12 | 12 | 2 | 2 | 2 |
| West Hill Creek | 9 | 9 | 9 | 58 | 58 | 58 | 2 | 2 | 2 | 12 | 12 | 12 | 2 | 2 | 2 |
| Carmila Creek | 8 | 8 | 8 | 78 | 78 | 78 | 5 | 5 | 5 | 10 | 10 | 10 | 3 | 3 | 3 |
| Flaggy Rock Creek | 8 | 8 | 8 | 78 | 78 | 78 | 5 | 5 | 5 | 10 | 10 | 10 | 3 | 3 | 3 |

**Table 27 Ambient WQOs, current condition and targets for herbicides (in µg/L) for each catchment management area.**

| Catchment Management Area | Ametryn | | | Atrazine | | | Diuron | | | Hexazinone | | | Tebuthiuron | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| Eden Lassie Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Gregory River | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Whitsunday Coast | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Repulse Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Myrtle Creek | 0.04 | 0.04 | 0.04 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.08 | 0.08 | 0.08 | <LOD | <LOD | <LOD |
| Proserpine River | 0.04 | 0.04 | 0.04 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.08 | 0.08 | 0.08 | <LOD | <LOD | <LOD |
| Upper Pros-erpine River | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Lethebrook | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.01 | 0.01 | 0.01 | 0.04 | 0.04 | 0.04 | <LOD | <LOD | <LOD |
| Thompson Creek | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD | 0.07 | 0.07 | 0.07 | 0.13 | 0.13 | 0.13 | <LOD | <LOD | <LOD |
| Andromache River | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| O'Connell River | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Waterhole Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Blackrock Creek | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD | 0.07 | 0.07 | 0.07 | 0.13 | 0.13 | 0.13 | <LOD | <LOD | <LOD |
| St Helens Creek | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD | 0.07 | 0.07 | 0.07 | 0.13 | 0.13 | 0.13 | <LOD | <LOD | <LOD |
| Murray Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Constant Creek | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD | 0.07 | 0.07 | 0.07 | 0.13 | 0.13 | 0.13 | <LOD | <LOD | <LOD |
| Reliance Creek | 0.02 | 0.02 | 0.02 | 0.09 | 0.09 | 0.09 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | <LOD | <LOD | <LOD |
| Mackay City | 0.02 | 0.02 | 0.02 | 0.09 | 0.09 | 0.09 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | <LOD | <LOD | <LOD |
| Pioneer River | <LOD | <LOD | <LOD | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD |
| Upper Cattle Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.01 | 0.01 | 0.01 | <LOD | <LOD | <LOD |
| Blacks Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Bakers Creek | 0.01 | 0.01 | 0.01 | 0.17 | 0.17 | 0.17 | 0.11 | 0.11 | 0.11 | 0.14 | 0.14 | 0.14 | <LOD | <LOD | <LOD |
| Sandy Creek | 0.02 | 0.02 | 0.02 | 0.09 | 0.09 | 0.09 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | <LOD | <LOD | <LOD |
| Alligator Creek | 0.02 | 0.02 | 0.02 | 0.09 | 0.09 | 0.09 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | <LOD | <LOD | <LOD |
| Sarina Beaches | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Plane Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.01 | 0.01 | 0.01 | 0.04 | 0.04 | 0.04 | <LOD | <LOD | <LOD |
| Cape Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| Rocky Dam Creek | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD | 0.07 | 0.07 | 0.07 | 0.13 | 0.13 | 0.13 | <LOD | <LOD | <LOD |
| Marion Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.01 | 0.01 | 0.01 | <LOD | <LOD | <LOD |
| Gillinbin Creek | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |

**Table 27 (continued).**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **West Hill Creek** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **Carmila Creek** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.01 | 0.01 | 0.01 | <LOD | <LOD | <LOD |
| **Flaggy Rock Creek** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.01 | 0.01 | 0.01 | <LOD | <LOD | <LOD |

LOD is the limit of detection which is currently 0.01 µg/L for herbicides, but may be lower in the future.

In summary, the percentage of catchment management areas with nutrient and TSS parameters higher than the ambient WQOs was generally low (Table 28). Particulate phosphorus exceeded the WQOs more often than other nutrients.

**Table 28 Percentage of catchment management areas with nutrient and TSS current condition (2007) worse than the ambient freshwater WQOs.**

| Indicator | Current condition exceeding (i.e. worse than) the ambient WQO (% of management areas) |
|---|---|
| DIN | 27 |
| PN | 6 |
| FRP | 21 |
| PP | 36 |
| TSS | 6 |

## 9.3. Event-based freshwater quality

Event-based end-of-catchment WQOs are important because the majority of pollutants are transported during storm events, rather than during ambient conditions. This chapter of the report presents the development of event-based WQOs based on data collected during monitored flood events, and long-term modelling. The water quality indicators used as event-based end-of-catchment WQOs are the same as ambient WQOs (DIN, PN, FRP, PP, TSS, and ametryn, atrazine, diuron, hexazinone, and tebuthiuron).

### 9.3.1. Development of event-based freshwater WQOs

The event-based WQOs and current condition provide an estimate of event mean concentrations (EMCs) during flood events when large amounts of pollutants are transported. The event-based WQOs for nutrients and TSS remain unchanged from the 2008 WQIP and those scheduled under EPP Water. These WQOs were developed for all catchment management areas based on:

- HEV upland or lowland catchment event-based water quality data from appropriate catchments during 2005-2007;
- Flow-weighted EMCs, although flow data was only available at one site (Finch Hatton Creek); and
- 80th percentiles where flow data was not available, or where this percentile was considered more appropriate when evaluating sampling regime, location, and sample numbers of events.

As described in Drewry et al. (2008a), the development of the event-based end-of-catchment WQOs was based on water quality data collected by NRW and community volunteers during 2005 to 2007 inclusive. Event-based WQOs can be compared with current condition EMCs, or where flow is not available, median concentrations. Full details of the event-based sampling, load estimation methods, and results are presented in Rohde et al. (2006a; 2008) and summarised in Drewry et al. (2008a). Herbicide WQOs are discussed later in this chapter.

There is likely to be uncertainty associated with concentration data, discrete sampling, timing of sampling, representative samples, load calculation methods, and antecedent conditions, therefore caution should be applied. Additionally, it is recommended that a range of events are monitored when comparing WQOs and current condition for future monitoring. The long-term event-based WQO values for TSS and nutrients are summarised in Table 29. In the instance where the 2007 current condition of water quality was better than the long-term event-based WQO in the 2008 WQIP, the target and WQO has been revised to reflect the current condition to ensure water quality does not degrade. Individual catchment management area event-based WQOs are presented in the Catchment Management Area Reports.

**Table 29 TSS and nutrient concentration event-based WQOs.**

| Indicator | Event-based WQO |
|---|---|
| DIN (µg N/L) | 300 |
| PN (µg N/L) | 340 |
| FRP (µg P/L) | 30 |
| PP (µg P/L) | 70 |
| TSS (mg/L) | 200 |

Concentration units are µg/L for nutrients; TSS concentration units are mg/L. Concentrations of N and P are reported as µg N/L and µg P/L, respectively.

Herbicide WQOs were developed on an individual catchment basis using a combination of monitoring, modelling and ecotoxicology data. End-of-catchment herbicide WQOs for each catchment management area are presented in the Receiving Water Modules and the Catchment Management Area Reports.

The methodology used to derive new ecotoxicity thresholds was in accordance with the recommended rules for deriving the current Australian and New Zealand water quality guideline trigger values (ANZECC and ARMCANZ 2000), as detailed in Warne et al. (*in review*) and Delaney et al. 2014. The following steps were taken:

- All available toxicity data was reviewed to ensure the quality was satisfactory;
- Toxicity data was grouped by herbicide. For each herbicide, data was then grouped by species;
- Data was reviewed and converted using the rules described in Warne et al. (in review) to provide a concentration (in µg/L) to represent the sensitivity for each species;
- All calculations were checked;
- For each herbicide, the species sensitivity values were entered into BurrliOz v2.0 to obtain the species sensitivity distribution (SSD) and the herbicide concentrations (ecotoxicity thresholds) that should theoretically protect 99%, 95%, 90%, and 80% of phototrophic species;
- The newly calculated herbicide concentrations were then compared to the WQOs in the 2008 WQIP;
- For any existing WQOs or targets that were higher than the ecotoxicity thresholds, the WQO was updated to equal the concentration of the relevant ecotoxicity threshold. The 2021 targets were revised to a concentration indicating a trend toward the new WQO that was deemed to be achievable; and
- If the existing WQOs and targets were at, or more stringent than, the ecotoxicity thresholds, the WQOs and targets were left unchanged as a lower concentration represents a lower risk to aquatic species.

The ecotoxicity thresholds (Table 30) for the protection of 95% of species were used for the majority of catchment management areas (those draining into the receiving waters of Repulse Bay, Seaforth Coast, Sandringham Bay and Sarina Inlet). The ecotoxicity threshold for 99%

protection of species was used where additional protection was required (catchments draining into Edgecumbe Bay, Whitsunday Coast, Ince Bay, and Carmila Coast).

**Table 30 New herbicide ecotoxicity thresholds (concentrations in µg/L) for freshwater phototrophic species compared to the current Australian and New Zealand water quality guideline trigger values (ANZECC and ARMCANZ 2000). Adapted from Delaney et al. 2014.**

| | | % of species protected | | |
|---|---|---|---|---|
| **Herbicide** | **Guideline** | **99** | **95** | **90** |
| **Ametryn** | Ecotoxicity threshold | 0.02 | 0.1 | 0.3 |
| | Aust. and NZ trigger value | N/A | N/A | N/A |
| **Atrazine** | Ecotoxicity threshold | 3.7 | 6 | 8.1 |
| | Aust. and NZ trigger value | 0.7 | 13 | 45 |
| **Diuron** | Ecotoxicity threshold | 0.2 | 0.3 | 0.4 |
| | Aust. and NZ trigger value | 0.2 | 0.2 | 0.2 |
| **Hexazinone** | Ecotoxicity threshold | 0.2 | 0.7 | 1.3 |
| | Aust. and NZ trigger value | 75 | 75 | 75 |
| **Tebuthiuron** | Ecotoxicity threshold | 4.3 | 8.8 | 12 |
| | Aust. and NZ trigger value | 0.02 | 2.2 | 20 |

N/A = not applicable

The WQOs, current condition, and 2021 targets for each catchment management area are shown in Table 31 for nutrients and TSS, and Table 32 for herbicides.

The ecotoxicity threshold for 99% protection of species was used where additional protection was required (catchments draining into Edgecumbe Bay, Whitsunday Coast, Ince Bay, and Carmila Coast)

**Table 31 Event-based WQOs, current condition and targets for nutrients and TSS for each catchment management area. Nutrient concentrations are in μg/L, and TSS is in mg/L.**

| Catchment Management Area | DIN | | | PN | | | FRP | | | PP | | | TSS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| Eden Lassie Creek | 210 | 210 | 210 | 264 | 318 | 264 | 30 | 31 | 31 | 60 | 72 | 60 | 115 | 139 | 115 |
| Gregory River | 300 | 391 | 300 | 250 | 250 | 250 | 30 | 54 | 54 | 56 | 56 | 56 | 41 | 41 | 41 |
| Whitsunday Coast | 256 | 256 | 256 | 261 | 261 | 261 | 27 | 27 | 27 | 31 | 31 | 31 | 8 | 8 | 8 |
| Repulse Creek | 256 | 256 | 256 | 261 | 261 | 261 | 27 | 27 | 27 | 31 | 31 | 31 | 8 | 7 | 7 |
| Myrtle Creek | 300 | 429 | 300 | 300 | 346 | 309 | 30 | 200 | 193 | 70 | 125 | 112 | 34 | 38 | 34 |
| Proserpine River | 300 | 1991 | 300 | 302 | 302 | 302 | 30 | 43 | 43 | 60 | 60 | 60 | 146 | 146 | 146 |
| Upper Proserpine River | 300 | 300 | 300 | 19 | 19 | 19 | 30 | 31 | 31 | 1 | 1 | 1 | 10 | 10 | 10 |
| Lethebrook | 300 | 463 | 413 | 120 | 120 | 120 | 30 | 39 | 35 | 28 | 28 | 28 | 38 | 38 | 38 |
| Thompson Creek | 300 | 356 | 303 | 66 | 66 | 66 | 30 | 37 | 30 | 15 | 15 | 15 | 22 | 22 | 22 |
| Andromache River | 295 | 306 | 295 | 330 | 382 | 330 | 30 | 31 | 31 | 70 | 202 | 174 | 200 | 251 | 216 |
| O'Connell River | 300 | 326 | 300 | 311 | 361 | 311 | 30 | 40 | 37 | 70 | 124 | 107 | 133 | 154 | 133 |
| Waterhole Creek | 256 | 285 | 256 | 168 | 168 | 168 | 30 | 42 | 38 | 41 | 41 | 41 | 72 | 72 | 72 |
| Blackrock Creek | 300 | 372 | 313 | 221 | 228 | 221 | 30 | 107 | 90 | 70 | 80 | 78 | 28 | 29 | 28 |
| St Helens Creek | 267 | 302 | 267 | 121 | 121 | 121 | 23 | 26 | 23 | 33 | 33 | 33 | 45 | 45 | 45 |
| Murray Creek | 300 | 561 | 484 | 201 | 201 | 201 | 30 | 44 | 38 | 47 | 47 | 47 | 65 | 67 | 65 |
| Constant Creek | 300 | 508 | 469 | 243 | 243 | 243 | 30 | 53 | 49 | 58 | 58 | 58 | 56 | 56 | 56 |
| Reliance Creek | 300 | 363 | 345 | 230 | 231 | 230 | 30 | 168 | 160 | 59 | 73 | 59 | 35 | 35 | 35 |
| Mackay City | 300 | 511 | 420 | 183 | 183 | 183 | 30 | 459 | 377 | 47 | 47 | 47 | 36 | 36 | 36 |
| Pioneer River | 280 | 280 | 280 | 340 | 595 | 479 | 30 | 42 | 40 | 70 | 265 | 214 | 145 | 180 | 145 |
| Upper Cattle Creek | 272 | 272 | 272 | 113 | 113 | 113 | 30 | 31 | 30 | 51 | 51 | 51 | 41 | 41 | 41 |
| Blacks Creek | 300 | 329 | 317 | 340 | 674 | 450 | 30 | 52 | 50 | 70 | 209 | 139 | 119 | 178 | 119 |
| Bakers Creek | 300 | 583 | 460 | 215 | 272 | 215 | 30 | 207 | 163 | 70 | 124 | 98 | 36 | 45 | 36 |
| Sandy Creek | 300 | 401 | 353 | 265 | 363 | 265 | 30 | 156 | 137 | 70 | 138 | 101 | 45 | 61 | 45 |
| Alligator Creek | 300 | 513 | 414 | 340 | 547 | 420 | 30 | 123 | 99 | 70 | 195 | 150 | 54 | 71 | 54 |
| Sarina Beaches | 300 | 375 | 343 | 294 | 411 | 294 | 30 | 95 | 87 | 70 | 98 | 70 | 62 | 86 | 62 |
| Plane Creek | 300 | 435 | 391 | 158 | 158 | 158 | 30 | 66 | 59 | 54 | 54 | 54 | 188 | 188 | 188 |
| Cape Creek | 48 | 48 | 48 | 152 | 152 | 152 | 3 | 3 | 3 | 37 | 37 | 37 | 66 | 66 | 66 |
| Rocky Dam Creek | 300 | 493 | 422 | 285 | 318 | 285 | 33 | 39 | 33 | 70 | 78 | 70 | 101 | 112 | 101 |
| Marion Creek | 300 | 413 | 366 | 327 | 501 | 327 | 30 | 40 | 35 | 70 | 231 | 151 | 77 | 118 | 77 |

**Table 31 (continued).**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gillinbin Creek** | 42 | 42 | 42 | 152 | 152 | 152 | 3 | 3 | 3 | 37 | 37 | 37 | 66 | 66 | 66 |
| **West Hill Creek** | 300 | 398 | 359 | 340 | 779 | 477 | 30 | 41 | 38 | 70 | 285 | 174 | 94 | 156 | 94 |
| **Carmila Creek** | 300 | 518 | 465 | 243 | 243 | 243 | 27 | 30 | 27 | 50 | 50 | 50 | 37 | 37 | 37 |
| **Flaggy Rock Creek** | 282 | 300 | 282 | 340 | 701 | 659 | 28 | 30 | 28 | 70 | 368 | 253 | 186 | 268 | 186 |

**Table 32 Event-based WQOs, current condition and targets for herbicides (in µg/L) for each catchment management area.**

| Catchment Management Area | Ametryn | | | Atrazine | | | Diuron | | | Hexazinone | | | Tebuthiuron | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| **Eden Lassie Creek** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.06 | 0.07 | 0.06 | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **Gregory River** | <LOD | <LOD | <LOD | 0.06 | 0.06 | 0.06 | 0.20 | 0.31 | 0.25 | 0.04 | 0.04 | 0.04 | <LOD | <LOD | <LOD |
| **Whitsunday Coast** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **Repulse Creek** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **Myrtle Creek** | 0.10 | 0.14 | 0.12 | 0.70 | 1.06 | 0.94 | 0.30 | 2.45 | 1.50 | 0.20 | 0.55 | 0.49 | <LOD | <LOD | <LOD |
| **Proserpine River** | <LOD | <LOD | <LOD | 0.26 | 0.27 | 0.26 | 0.30 | 1.07 | 0.96 | 0.19 | 0.20 | 0.19 | 0.02 | 0.48 | 0.41 |
| **Upper Proserpine River** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **Lethebrook** | 0.04 | 0.05 | 0.04 | 0.21 | 0.23 | 0.21 | 0.30 | 0.75 | 0.66 | 0.20 | 0.28 | 0.25 | <LOD | <LOD | <LOD |
| **Thompson Creek** | <LOD | <LOD | <LOD | 0.15 | 0.18 | 0.15 | 0.30 | 0.56 | 0.46 | 0.17 | 0.20 | 0.17 | <LOD | <LOD | <LOD |
| **Andromache River** | <LOD | <LOD | <LOD | 0.02 | 0.02 | 0.02 | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **O'Connell River** | <LOD | <LOD | <LOD | 0.04 | 0.04 | 0.04 | 0.16 | 0.16 | 0.16 | 0.02 | 0.02 | 0.02 | 0.02 | 0.18 | 0.10 |
| **Waterhole Creek** | <LOD | <LOD | <LOD | 0.03 | 0.03 | 0.03 | 0.11 | 0.11 | 0.11 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.04 |
| **Blackrock Creek** | 0.02 | 0.06 | 0.05 | 0.55 | 0.61 | 0.55 | 0.30 | 1.38 | 0.91 | 0.20 | 0.41 | 0.37 | <LOD | <LOD | <LOD |
| **St Helens Creek** | <LOD | <LOD | <LOD | 0.04 | 0.05 | 0.04 | 0.20 | 0.51 | 0.46 | 0.20 | 0.26 | 0.23 | <LOD | <LOD | <LOD |
| **Murray Creek** | 0.02 | 0.06 | 0.05 | 0.25 | 0.28 | 0.25 | 0.20 | 0.86 | 0.75 | 0.20 | 0.33 | 0.30 | <LOD | <LOD | <LOD |
| **Constant Creek** | 0.05 | 0.05 | 0.05 | 0.23 | 0.23 | 0.23 | 0.30 | 0.70 | 0.64 | 0.20 | 0.27 | 0.25 | <LOD | <LOD | <LOD |
| **Reliance Creek** | 0.02 | 0.07 | 0.05 | 0.61 | 0.67 | 0.65 | 0.30 | 1.52 | 1.01 | 0.20 | 0.45 | 0.41 | <LOD | <LOD | <LOD |
| **Mackay City** | 0.02 | 0.09 | 0.08 | 0.70 | 0.84 | 0.75 | 0.30 | 1.96 | 1.25 | 0.20 | 0.57 | 0.51 | <LOD | <LOD | <LOD |
| **Pioneer River** | 0.02 | 0.03 | 0.03 | 0.43 | 0.48 | 0.43 | 0.30 | 0.87 | 0.75 | 0.19 | 0.21 | 0.19 | <LOD | <LOD | <LOD |
| **Upper Cattle Creek** | <LOD | <LOD | <LOD | 0.14 | 0.15 | 0.14 | 0.30 | 0.46 | 0.43 | 0.16 | 0.17 | 0.16 | <LOD | <LOD | <LOD |
| **Blacks Creek** | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD | 0.06 | 0.09 | 0.06 | 0.03 | 0.04 | 0.03 | <LOD | <LOD | <LOD |
| **Bakers Creek** | 0.02 | 0.08 | 0.07 | 0.70 | 0.79 | 0.75 | 0.30 | 1.01 | 0.80 | 0.20 | 0.53 | 0.45 | <LOD | <LOD | <LOD |
| **Sandy Creek** | 0.02 | 0.02 | 0.02 | 0.40 | 0.41 | 0.40 | 0.30 | 0.86 | 0.75 | 0.20 | 0.42 | 0.38 | <LOD | <LOD | <LOD |
| **Alligator Creek** | 0.02 | 0.08 | 0.07 | 0.70 | 0.80 | 0.74 | 0.30 | 1.75 | 1.23 | 0.20 | 0.54 | 0.50 | <LOD | <LOD | <LOD |
| **Sarina Beaches** | <LOD | <LOD | <LOD | 0.04 | 0.05 | 0.04 | 0.30 | 0.53 | 0.46 | 0.20 | 0.27 | 0.23 | <LOD | <LOD | <LOD |
| **Plane Creek** | <LOD | <LOD | <LOD | 0.17 | 0.19 | 0.17 | 0.30 | 0.56 | 0.51 | 0.14 | 0.15 | 0.14 | <LOD | <LOD | <LOD |

**Table 32 (continued).**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cape Creek** | <LOD | <LOD | <LOD | 0.02 | 0.02 | 0.02 | 0.05 | 0.07 | 0.06 | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **Rocky Dam Creek** | 0.04 | 0.05 | 0.04 | 0.27 | 0.30 | 0.27 | 0.30 | 0.98 | 0.75 | 0.20 | 0.61 | 0.55 | <LOD | <LOD | <LOD |
| **Marion Creek** | <LOD | <LOD | <LOD | 0.18 | 0.19 | 0.18 | 0.20 | 0.61 | 0.55 | 0.20 | 0.22 | 0.21 | <LOD | <LOD | <LOD |
| **Gillinbin Creek** | <LOD | <LOD | <LOD | 0.02 | 0.02 | 0.02 | 0.05 | 0.06 | 0.06 | <LOD | <LOD | <LOD | <LOD | <LOD | <LOD |
| **West Hill Creek** | <LOD | <LOD | <LOD | 0.17 | 0.20 | 0.17 | 0.20 | 0.66 | 0.54 | 0.20 | 0.24 | 0.20 | <LOD | <LOD | <LOD |
| **Carmila Creek** | <LOD | <LOD | <LOD | 0.04 | 0.05 | 0.04 | 0.20 | 0.53 | 0.46 | 0.20 | 0.27 | 0.23 | <LOD | <LOD | <LOD |
| **Flaggy Rock Creek** | <LOD | <LOD | <LOD | 0.03 | 0.03 | 0.03 | 0.12 | 0.13 | 0.12 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.04 |

LOD is the limit of detection which is currently 0.01 µg/L for herbicides, but may be lower in the future.

### 9.3.2. Assessment of event-based freshwater current condition

This section presents the assessment of end-of-catchment current condition using modelling results. An assessment of end-of-catchment current condition of monitored and non-monitored management areas was required. Catchment models are useful for this task and can assist managers to evaluate the likely sources, catchment loads, and impacts of land use and management on the long-term sediment and nutrient export from catchments. Conceptual catchment models are suited to long-term prediction in large catchments.

The 2008 WQIP used the SedNet and ANNEX catchment models to model TSS and nutrients. These are conceptual models with spatial representation based on lumped modelling at linked river reaches and subcatchment units. A reach in the network represents the river between two stream junctions or nodes. The SedNet and ANNEX catchment models are described in detail in Prosser et al. (2001) and Sherman et al. (2006).

To estimate the sources and loads of TSS and nutrients for the Mackay Whitsunday region, the Short Term Modelling project was undertaken (Rohde et al. 2006b). SedNet-based sediment export and nutrient export from ANNEX models were used to evaluate sediment and nutrient loads over the long-term from management areas, support development of water quality targets, and evaluate likely effects of management practices, additional scenarios and management practice adoption rates. Modelling results were used to evaluate the likely water quality in management areas where there was no monitored water quality data available.

The approach and methods used to evaluate end-of-catchment EMCs for 2014 current condition included:

- Use of SedNet- and ANNEX-based modelled scenario results for the Mackay Whitsunday region, adjusted to ensure pollutants were not underestimated (Drewry et al. 2008b);
- Current management practice adoption rates of sugarcane and grazing in each catchment management area; and
- Development of a spreadsheet-based model to adjust the modelled scenario results to reflect the change in management practice adoption rates.

The event-based current condition for each receiving water is presented in the eight Receiving Waters Modules at the end of this report.

The change in event water quality at Sandy Creek and Pioneer River can be compared across two sampling periods – January 2005 to January 2007 ("previous") and the wet seasons of 2009/10 to 2011/12 ("current"). The previous results have been reported in Rohde et al. (2008) and the current results in Turner et al. (2012; 2013) and Wallace et al. (2013). The flow-weighted means (total load for the period divided by total flow for the period) of each indicator for each sampling period are shown in Table 33. These results generally show a decline in dissolved parameters (DIN, FRP and herbicides) and PP, but a small increase in PN and TSS at both sites.

**Table 33 Change in event water quality from previous (2005-2007) to current (2009-2012) condition for Sandy Creek and Pioneer River. Concentrations are in µg/L, except TSS (mg/L).**

| | | DIN | PN | FRP | PP | TSS | Ametryn | Atrazine | Diuron | Hexazinone | Tebuthiuron |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sandy Creek | Previous | 540 | 420 | 210 | 160 | 71 | 0.02 | 0.54 | 1.95 | 0.55 | <LOD |
| | Current | 145 | 441 | 112 | 148 | 99 | 0.03 | 0.29 | 0.51 | 0.16 | <LOD |
| Pioneer River | Previous | 390 | 650 | 60 | 290 | 198 | 0.04 | 0.58 | 1.12 | 0.26 | <LOD |
| | Current | 228 | 766 | 39 | 224 | 236 | 0.02 | 0.17 | 0.19 | 0.05 | <LOD |

LOD is the limit of detection which is currently 0.01 µg/L for herbicides, but may be lower in the future.

### 9.3.3. Development of event-based freshwater targets

The methods used to develop end-of-catchment event-based targets to improve water quality were similar to the current condition method described above. The method included:

- Use of SedNet- and ANNEX-based modelling results for the region using scenarios and loads and EMCs modelled for the management areas (as described in the previous section);
- Likely management practice adoption rates by 2021 of sugarcane and grazing lands in each catchment management area (outlined further in Chapter 10 and 15);
- Development of a spreadsheet-based model to adjust the modelled scenario results to reflect the likely change in management practice adoption rates; and
- Adjustment of the spreadsheet-based model to ensure enough change during the target period to meet the 2050 WQOs.

A more detailed evaluation of management practices and the effects they are likely to have on water quality is presented in Chapter 10.

It is expected that target adoption rates of improved management practices are feasible in the target period, potentially with some accelerated adoption by providing financial incentives to land managers. This is discussed in more detail in Chapter 15.

The targets for each catchment management area are presented in the Catchment Management Area Reports at the end of this report.

## 9.4. Marine water quality

This section presents development of the Mackay Whitsunday region ambient and event marine WQOs, current condition, and targets.

### 9.4.1. Development of marine WQOs

***Ambient marine***

Similar to the freshwater WQOs and targets, the ambient marine WQOs, current condition and targets remain the same as those presented in the 2008 WQIP due to insufficient new data required to update the values. These reflect the scheduled WQOs under EPP Water.

The inshore ambient WQOs for nutrients, suspended sediment, and herbicides presented in the 2008 WQIP were derived using sampling data from the Reef Plan Marine Monitoring Program (Table 34). Limited data were available for evaluation, so some caution should be applied.

To determine the ambient marine WQOs, median ambient concentration data were used, and adjusted by the end-of-catchment regional WQO to current condition EMC ratio. All WQOs for median ambient concentrations of herbicides were set at less than limit of detection (<LOD) (Table 34). WQOs for other parameters are described where indicated. The inshore and offshore ambient marine WQOs for the Mackay Whitsunday region are more stringent (i.e. better) than GBRMPA guidelines (GBRMPA 2010), as a lower concentration represents a lower risk to the marine environment.

***Event-based marine***

The event-based marine WQOs for nutrients and suspended sediment presented in the 2008 WQIP were calculated from event plume water quality sampling, and adjusted using a ratio of WQO to current condition from end-of-catchment EMC. Event plume samples were collected by NRW from the Pioneer and O'Connell River plumes during flood events in 2005 and 2007. WQOs for herbicides were based on reduction targets considered achievable in the long term.

The *Water Quality Guidelines for the Great Barrier Reef Marine Park* (GBRMPA 2010) were published in 2010. The guideline values for sediment, nutrients, and pesticides were established for the protection and maintenance of marine species and ecosystem health of the Great Barrier Reef. These guideline values were used to update the 2014-2021 event-based marine WQOs as follows:

- Any existing WQOs higher than the GBRMPA guideline trigger value (for protection of 99% of species): WQO was updated to equal the concentration of the relevant guideline trigger value; and
- Existing WQOs at or more stringent than the GBRMPA guideline trigger values (for protection of 99% of species): WQOs were left unchanged as a lower concentration represents a lower risk to marine species.

The event marine WQOs are shown in Table 34.

### 9.4.2. Development of marine current condition and targets

***Ambient marine***

Similar to the event marine WQOs, the ambient marine current condition and targets remain the same as the 2008 WQIP due to insufficient new data to update the values. In the 2008 WQIP, current condition was based on the median value for wet season sampling from Reef Plan Marine Monitoring Program data. There was no sampling to calculate current condition for herbicides. As previously discussed, targets should reflect maintenance of current condition in instances where the current condition is more stringent (and therefore, providing more protection) than WQOs that exceed current condition. Revised targets have been adopted to reflect this (Table 34).

***Event marine***

The regional load percentage reduction of the catchment management areas was applied to the marine event 2007 current condition to estimate 2014 current condition. Similarly, to determine the 2021 targets, the predicted catchment management area load reduction was applied to the current condition. Current condition and targets are shown in Table 34**.**

**Table 34 Ambient and event marine water quality values for WQQs, current condition in 2014, and 2021 targets. Concentrations are in µg/L, except TSS (mg/L).**

| Key Pollutant | Ambient Marine Water Quality Values | | | Event Marine Water Quality Values | | |
|---|---|---|---|---|---|---|
| | Objective 2050 | Current Condition 2014 | Target 2021 | Objective 2050 | Current Condition 2014 | Target 2021 |
| DIN | 1.5 | 2.4 | 1.7 | 32 | 38 | 36 |
| PN | 16 | 17.3 | 16 | 20 | 44 | 39 |
| FRP | 1.5 | 2.2 | 1.5 | 3 | 6 | 5 |
| PP | 1.9 | 2.3 | 1.9 | 2.8 | 6.7 | 5.3 |
| TSS | 1.7 | 1.7 | 1.7 | 2 | 4.5 | 4 |
| Ametryn | <LOD | n/a | n/a | <LOD | <LOD | <LOD |
| Atrazine | <LOD | n/a | n/a | 0.03 | 0.03 | 0.03 |
| Diuron | <LOD | n/a | n/a | 0.09 | 0.11 | 0.09 |
| Hexazinone | <LOD | n/a | n/a | 0.03 | 0.03 | 0.03 |
| Tebuthiuron | <LOD | n/a | n/a | <LOD | <LOD | <LOD |

LOD is Limit of Detection which is currently 0.01 µg/L for all herbicides, but may be lower in the future.

# 10. Agricultural Water Quality Improvement

This chapter has important linkages with the previous chapters on WQOs and targets (Chapter 9), and the ecological values and beneficial uses determined from the EVs section (Chapter 7). Management interventions to improve water quality are described in Chapter 12.

Chapter 9 detailed WQOs, targets, and current condition expressed as concentrations. This chapter transforms that information into end-of-catchment loads and load reduction targets. This chapter presents a summary of modelled regional loads for current condition and 2021 targets, and load reductions expected through adoption of improved management practices. This chapter also presents end-of-catchment load reductions for individual herbicides. Chapter 12 presents management practices for pesticides (including herbicides, fungicides, rodenticides, insecticides, etc.) for which the same management principles apply.

## 10.1. Overview of method of load determination

The 2014 WQIP used the same method for load determination as the 2008 WQIP, detailed in Drewry et al. (2008b). Additionally, this current WQIP also provides loads for the eight receiving waters.

Briefly, the best available monitoring data, modelling techniques, and information were used to estimate the 2008 current condition and 2014 targets. Emphasis was placed on the use of three years of locally collected event-based water quality monitoring data which was used to calibrate modelling results. This ensured pollutant load values were set at the appropriate level and avoided the potential for under-estimation when using modelling results alone (e.g. Sherman et al. 2007; Drewry et al. 2006).

The approach and methods used to help evaluate end-of-catchment loads for 2014 current condition included:

- Using the mean annual flow output of the SedNet modelling presented in Drewry et al. (2008);
- Multiplying the mean annual flow value by the water quality concentrations determined for WQOs, current condition and targets; and
- Accumulating the loads from each catchment management area draining into each receiving water to estimate the receiving water load.

## 10.2. Regional load targets

Annual load reductions in the Mackay Whitsunday region are more appropriate than daily reductions or limits (e.g. Total Daily Maximum Loads; TDMLs) due to large variations in flow. These variations in flow occur between the wet and dry seasons, and also within the wet season.

The load reductions and targets presented in this report are based on likely adoption rates of improved management practices (A and B class) for grazing, sugarcane, horticulture, and urban lands (refer to Chapter 12 for further detail). Voluntary adoption of improved management practices in selected catchments will be encouraged to achieve regional load reductions. The HEV areas are not specifically detailed here as these loads refer to end-of-catchment only. It is anticipated that investment to reduce sediment loads will also result in a reduction of particulate nutrients.

Significant water quality improvement can be achieved given adoption of improved land management practices (Chapter 12), such as the use of shielded sprayers and/or banded spraying. Banded spraying has been shown to greatly reduce the amount of herbicide lost to runoff; studies have shown results of 32-42% reduction in a rainfall simulation study (Masters et al. 2013) and 50% reduction in a field runoff study (Rohde et al. 2013). Significant reductions in residual herbicide levels in waterways are considered achievable given widespread adoption of improved management practices. Many residual herbicides have similar effects on plant physiology, so the cumulative impact of residual herbicides was also considered important.

The widespread adoption of green sugarcane trash blanket practices across the region has been shown to reduce sediment loads from sugarcane farming (e.g. Rayment 2003; Masters et al. 2008). Further activities could be undertaken to reduce sediment loads but the gain in sediment load reduction is expected to be less than the investment return for the reduction of nutrient and herbicide loads.

A summary of the WQOs, current condition, and targets for nutrients and TSS for end-of-catchment and receiving water loads are shown in Table 35 and Table 36, respectively. The WQOs, current condition, and targets for end-of-catchment and receiving water herbicide loads are shown in Table 37 and Table 38, respectively.

Generations of farming families, such as the Raiteri's (pictured right) are involved in changing and improving practices. Lou and Betty Raiteri are second generation sugarcane farmers and have passed on their passion and knowledge to their son Gary. The family farm is located in the Proserpine area, south of Airlie Beach.

Lou Raiteri's trial looks at the impact of banded, surface applied mill mud and biodunder on soil biology.

**Table 35 End-of-catchment loads (tonnes/yr) for WQOs, current condition in 2014 (CC) and targets in 2021 (T) for nutrients and TSS from implementing improved management practices in each catchment management area and the region. Some figures have been rounded.**

| Catchment Management Area | DIN | | | PN | | | FRP | | | PP | | | TSS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| Eden Lassie | 20 | 20 | 20 | 25 | 30 | 25 | 3 | 3 | 3 | 6 | 7 | 6 | 10900 | 13200 | 10900 |
| Gregory | 25 | 33 | 25 | 21 | 21 | 21 | 3 | 5 | 3 | 5 | 5 | 5 | 3500 | 3500 | 3500 |
| Whitsunday | 29 | 29 | 29 | 29 | 29 | 29 | 3 | 3 | 3 | 3 | 3 | 3 | 900 | 900 | 900 |
| Repulse | 38 | 38 | 38 | 39 | 39 | 39 | 4 | 4 | 4 | 5 | 5 | 5 | 1200 | 1200 | 1200 |
| Myrtle | 58 | 83 | 58 | 58 | 67 | 60 | 6 | 39 | 37 | 14 | 24 | 22 | 6600 | 7300 | 6600 |
| Proserpine | 7 | 45 | 7 | 7 | 7 | 7 | 1 | 1 | 1 | 1 | 1 | 1 | 3300 | 3300 | 3300 |
| Upper Proserpine | 27 | 32 | 27 | 2 | 2 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 900 | 900 | 900 |
| Lethebrook | 73 | 112 | 100 | 29 | 29 | 29 | 7 | 10 | 8 | 7 | 7 | 7 | 9200 | 9200 | 9200 |
| Thompson | 20 | 23 | 20 | 4 | 4 | 4 | 2 | 2 | 2 | 1 | 1 | 1 | 1400 | 1400 | 1400 |
| Andromache | 56 | 58 | 56 | 62 | 72 | 62 | 6 | 6 | 6 | 13 | 38 | 33 | 37800 | 47000 | 40900 |
| O'Connell | 85 | 93 | 85 | 89 | 103 | 89 | 9 | 11 | 11 | 20 | 35 | 30 | 37800 | 43800 | 37900 |
| Waterhole | 28 | 31 | 28 | 18 | 18 | 18 | 3 | 5 | 4 | 4 | 4 | 4 | 7900 | 7900 | 7900 |
| Blackrock | 53 | 66 | 55 | 39 | 40 | 39 | 5 | 19 | 16 | 12 | 14 | 14 | 5000 | 5100 | 5000 |
| St Helens | 44 | 50 | 44 | 20 | 20 | 20 | 4 | 4 | 4 | 5 | 6 | 5 | 7400 | 7400 | 7400 |
| Murray | 122 | 228 | 197 | 82 | 82 | 82 | 12 | 18 | 15 | 19 | 19 | 19 | 27300 | 27300 | 27300 |
| Constant | 25 | 42 | 38 | 20 | 20 | 20 | 2 | 4 | 4 | 5 | 5 | 5 | 4600 | 4600 | 4600 |
| Reliance | 25 | 31 | 29 | 19 | 20 | 19 | 3 | 14 | 14 | 5 | 6 | 5 | 3000 | 3000 | 3000 |
| Mackay City | 19 | 32 | 26 | 11 | 11 | 11 | 2 | 29 | 24 | 3 | 3 | 3 | 2200 | 2200 | 2200 |
| Pioneer | 143 | 143 | 143 | 223 | 378 | 333 | 16 | 21 | 20 | 41 | 199 | 169 | 122400 | 122400 | 122400 |
| Upper Cattle | 52 | 52 | 52 | 22 | 22 | 22 | 6 | 6 | 6 | 10 | 10 | 10 | 7900 | 7900 | 7900 |
| Blacks | 99 | 108 | 104 | 112 | 222 | 148 | 10 | 17 | 16 | 23 | 69 | 46 | 39000 | 58500 | 39100 |
| Bakers | 5 | 9 | 7 | 3 | 4 | 3 | 0 | 3 | 2 | 1 | 2 | 2 | 500 | 700 | 500 |
| Sandy | 36 | 47 | 42 | 31 | 43 | 31 | 4 | 18 | 16 | 8 | 16 | 16 | 5300 | 7200 | 5300 |
| Alligator | 14 | 25 | 20 | 16 | 26 | 20 | 1 | 6 | 5 | 3 | 9 | 5 | 2600 | 3400 | 2600 |
| Sarina Beaches | 3 | 4 | 4 | 3 | 4 | 3 | 0 | 1 | 1 | 1 | 5 | 1 | 700 | 900 | 700 |
| Plane | 12 | 17 | 16 | 6 | 6 | 6 | 1 | 3 | 2 | 2 | 2 | 2 | 7500 | 7500 | 7500 |
| Cape | 2 | 2 | 2 | 6 | 6 | 6 | 0 | 0 | 0 | 1 | 1 | 1 | 2400 | 2400 | 2400 |
| Rocky Dam | 39 | 65 | 55 | 37 | 42 | 37 | 4 | 5 | 4 | 9 | 10 | 9 | 13300 | 14700 | 13300 |
| Marion | 9 | 12 | 11 | 10 | 15 | 10 | 1 | 1 | 1 | 2 | 7 | 4 | 2300 | 3500 | 2300 |
| Gillinbin | 1 | 1 | 1 | 5 | 5 | 5 | 0 | 0 | 0 | 1 | 1 | 1 | 2200 | 2200 | 2200 |
| West Hill | 10 | 13 | 11 | 11 | 25 | 15 | 1 | 1 | 1 | 2 | 9 | 6 | 3000 | 4900 | 3000 |
| Carmila | 8 | 13 | 12 | 6 | 6 | 6 | 1 | 1 | 1 | 1 | 1 | 1 | 900 | 900 | 900 |
| Flaggy Rock | 5 | 5 | 4 | 5 | 13 | 10 | 0 | 0 | 0 | 1 | 5 | 4 | 2900 | 3600 | 2900 |
| **Regional load** | **1190** | **1560** | **1370** | **1070** | **1430** | **1230** | **123** | **263** | **237** | **234** | **529** | **445** | **383800** | **429900** | **387800** |
| Load reduced to (fraction of CC) | | | 0.88 | | | 0.86 | | | 0.90 | | | 0.84 | | | 0.90 |

**Table 36 End-of-catchment loads (tonnes/yr) for receiving waters for WQOs, current condition in 2014 (CC) and targets in 2021 (T) for nutrients and TSS from implementing improved management practices in the region. Some figures have been rounded.**

| Receiving Water | DIN | | | PN | | | FRP | | | PP | | | TSS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| Edgecumbe Bay | 45 | 53 | 45 | 46 | 51 | 46 | 5 | 8 | 5 | 11 | 12 | 10 | 14500 | 16700 | 14400 |
| Whitsunday Coast | 67 | 67 | 67 | 68 | 68 | 68 | 7 | 7 | 7 | 8 | 8 | 8 | 2100 | 2100 | 2100 |
| Repulse Bay | 353 | 477 | 381 | 269 | 302 | 271 | 36 | 77 | 72 | 60 | 111 | 98 | 105100 | 120900 | 108000 |
| Seaforth Coast | 269 | 417 | 364 | 180 | 181 | 180 | 26 | 60 | 53 | 47 | 50 | 48 | 47300 | 47400 | 47300 |
| Sandringham Bay | 368 | 416 | 384 | 419 | 706 | 569 | 39 | 100 | 89 | 89 | 308 | 251 | 179900 | 202300 | 180000 |
| Sarina Inlet | 15 | 21 | 19 | 9 | 11 | 9 | 2 | 4 | 3 | 3 | 3 | 3 | 8200 | 8400 | 8200 |
| Ince Bay | 41 | 66 | 57 | 43 | 47 | 43 | 4 | 5 | 4 | 11 | 12 | 11 | 15700 | 17100 | 15700 |
| Carmila Coast | 32 | 44 | 40 | 37 | 64 | 46 | 3 | 4 | 3 | 8 | 23 | 16 | 11300 | 15200 | 11300 |

Kel and Amanda Tennent are graziers on the edge of Eungella National Park and Crediton State Forest,near Crediton. In 2011-2012, Kel & Amanda applied for funding through Reef Catchments' Reef Rescue water quality grants. Through internal fencing of gullies and the installation of strategic water points, the Tennents have slowly developed an effective rotational grazing program for long term land management and water quality improvement.

**Table 37 End-of-catchment loads (kg/yr) for WQOs, current condition in 2014 (CC) and targets in 2021 (T) for herbicides from implementing improved management practices in each catchment management area and the region. Some figures have been rounded.**

| Management Area | Ametryn | | | Atrazine | | | Diuron | | | Hexazinone | | | Tebuthiuron | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| **Eden Lassie** | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 7 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Gregory** | 0 | 0 | 0 | 5 | 5 | 5 | 17 | 26 | 21 | 3 | 3 | 3 | 0 | 0 | 0 |
| **Whitsunday** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Repulse** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Myrtle** | 19 | 27 | 23 | 135 | 205 | 181 | 58 | 473 | 290 | 39 | 106 | 95 | 0 | 0 | 0 |
| **Proserpine** | 0 | 0 | 0 | 6 | 6 | 6 | 7 | 24 | 22 | 4 | 5 | 4 | 1 | 11 | 9 |
| **Upper Proserpine** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Lethebrook** | 10 | 12 | 10 | 51 | 53 | 51 | 73 | 181 | 160 | 48 | 68 | 60 | 0 | 0 | 0 |
| **Thompson** | 0 | 0 | 0 | 10 | 12 | 10 | 20 | 37 | 30 | 11 | 13 | 11 | 0 | 0 | 0 |
| **Andromache** | 0 | 0 | 0 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **O'Connell** | 0 | 0 | 0 | 11 | 11 | 11 | 46 | 46 | 46 | 11 | 6 | 6 | 6 | 51 | 28 |
| **Waterhole** | 0 | 0 | 0 | 3 | 3 | 3 | 12 | 12 | 12 | 2 | 2 | 2 | 2 | 6 | 4 |
| **Blackrock** | 4 | 11 | 9 | 97 | 108 | 97 | 53 | 244 | 161 | 35 | 72 | 65 | 0 | 0 | 0 |
| **St Helens** | 0 | 0 | 0 | 7 | 8 | 7 | 33 | 84 | 76 | 33 | 43 | 38 | 0 | 0 | 0 |
| **Murray** | 8 | 24 | 20 | 102 | 114 | 102 | 81 | 350 | 305 | 81 | 134 | 122 | 0 | 0 | 0 |
| **Constant** | 4 | 4 | 4 | 19 | 19 | 19 | 25 | 57 | 53 | 16 | 22 | 21 | 0 | 0 | 0 |
| **Reliance** | 2 | 6 | 4 | 52 | 57 | 55 | 25 | 129 | 86 | 17 | 38 | 35 | 0 | 0 | 0 |
| **Mackay City** | 1 | 6 | 5 | 44 | 52 | 47 | 19 | 122 | 78 | 12 | 36 | 32 | 0 | 0 | 0 |
| **Pioneer** | 18 | 29 | 27 | 423 | 473 | 423 | 237 | 795 | 685 | 159 | 175 | 159 | 0 | 0 | 0 |
| **Upper Cattle** | 0 | 0 | 0 | 27 | 29 | 27 | 58 | 89 | 83 | 31 | 33 | 31 | 0 | 0 | 0 |
| **Blacks** | 2 | 2 | 2 | 2 | 2 | 2 | 20 | 30 | 20 | 10 | 13 | 10 | 0 | 0 | 0 |
| **Bakers** | 0 | 1 | 1 | 11 | 12 | 11 | 5 | 15 | 12 | 3 | 8 | 7 | 0 | 0 | 0 |
| **Sandy** | 2 | 2 | 2 | 47 | 49 | 47 | 36 | 102 | 89 | 24 | 50 | 45 | 0 | 0 | 0 |
| **Alligator** | 1 | 4 | 3 | 28 | 38 | 35 | 14 | 84 | 59 | 10 | 26 | 24 | 0 | 0 | 0 |
| **Sarina Beaches** | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 5 | 2 | 3 | 2 | 0 | 0 | 0 |
| **Plane** | 0 | 0 | 0 | 7 | 8 | 7 | 12 | 22 | 20 | 6 | 6 | 6 | 0 | 0 | 0 |
| **Cape** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Rocky Dam** | 5 | 7 | 5 | 35 | 39 | 35 | 39 | 129 | 98 | 26 | 80 | 72 | 0 | 0 | 0 |
| **Marion** | 0 | 0 | 0 | 5 | 6 | 5 | 6 | 18 | 16 | 6 | 7 | 6 | 0 | 0 | 0 |
| **Gillinbin** | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **West Hill** | 0 | 0 | 0 | 5 | 6 | 5 | 6 | 21 | 17 | 6 | 8 | 6 | 0 | 0 | 0 |
| **Carmila** | 0 | 0 | 0 | 1 | 1 | 1 | 8 | 13 | 12 | 5 | 7 | 6 | 0 | 0 | 0 |
| **Flaggy Rock** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 1 |
| **Regional load** | **75** | **132** | **116** | **1100** | **1320** | **1200** | **962** | **3120** | **2470** | **603** | **963** | **869** | **9** | **69** | **42** |
| **Load reduced to (fraction of CC)** | | | 0.88 | | | 0.91 | | | 0.79 | | | 0.90 | | | 0.61 |

**Table 38 End-of-catchment loads (kg/yr) for receiving waters for WQOs, current condition in 2014 (CC) and targets in 2021 (T) for herbicides from implementing improved management practices in the region. Some figures have been rounded.**

| Receiving Water | Ametryn | | | Atrazine | | | Diuron | | | Hexazinone | | | Tebuthiuron | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T | WQO | CC | T |
| Edgecumbe Bay | 0 | 0 | 0 | 5 | 5 | 5 | 23 | 33 | 27 | 3 | 3 | 3 | 0 | 0 | 0 |
| Whitsunday Coast | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Repulse Bay | 29 | 39 | 33 | 220 | 295 | 266 | 215 | 773 | 559 | 116 | 199 | 178 | 9 | 68 | 41 |
| Seaforth Coast | 17 | 45 | 38 | 276 | 306 | 280 | 217 | 864 | 680 | 183 | 310 | 281 | 0 | 0 | 0 |
| Sandringham Bay | 23 | 41 | 39 | 543 | 655 | 593 | 388 | 1236 | 1025 | 248 | 340 | 307 | 0 | 0 | 0 |
| Sarina Inlet | 0 | 0 | 0 | 7 | 8 | 7 | 15 | 28 | 25 | 8 | 9 | 8 | 0 | 0 | 0 |
| Ince Bay | 5 | 7 | 5 | 36 | 40 | 36 | 41 | 131 | 101 | 26 | 80 | 72 | 0 | 0 | 0 |
| Carmila Coast | 0 | 0 | 0 | 13 | 14 | 13 | 23 | 57 | 49 | 18 | 21 | 19 | 0 | 1 | 0 |

The results of the modelling show that, across the region, an increased adoption rate (from D/C to B/A practices) of 16% for improved management of nutrients in sugarcane and horticulture will have a corresponding likely reduction of regional DIN loads by 12% and FRP by 10% by 2021. An increased adoption rate of 10% for improved sugarcane and horticulture herbicide practices will likely reduce herbicide loads by 10-20%.

Similarly, this WQIP recommends across the region, an increased adoption rate of improved soil management of 13% in grazing and 9% in sugarcane and horticulture. Modelling predicts that these adoption rates are likely to reduce particulate parameters (PN, PP, and TSS) by 10-16% by 2021.

It is recognised that adoption of improved management practices is very dependent on sufficient resources, uptake by land managers, and industry leadership. Refer to Chapters 12 and 15 for further information.

A comparison of these reductions (and additional reductions due to ecosystem health activities) to Reef Plan (2013) targets are outlined in Section 15.4.

# 11. Ecosystem Health Targets

This chapter presents the freshwater ecosystem health 2014 current condition and ecosystem health targets for 2021. The current condition of freshwater ecosystems was determined through the use of ecological condition indicators for each of the 33 catchment management areas. Ecosystem health targets were then developed by identifying feasible change and the likely resulting impacts to ecosystem health.

## 11.1. Ecological condition indicators

Ecological condition indicators identified in this WQIP have been chosen based on their ability to reflect ecosystem health through the indicator's presence, absence, and abundance. In the development of the 2008 WQIP, a scientific taskforce selected a number of ecosystem indicators based on their importance to aquatic ecosystem integrity, their ability to be measured, and the availability of data on the indicator.

This current plan utilises many of the indicators selected in the 2008 WQIP, however, it has not included those with insufficient datasets to determine a discrete ecosystem health rating, or those that relied heavily upon proxies. The remaining indicators have been updated with new available data, resulting in an up-to-date representation of ecological condition for the Mackay Whitsunday region. The indicators have also been translated to provide an absolute score, rather than using the relative ranking system of the 2008 WQIP.

A number of new ecosystem health indicators have been selected and included in this WQIP to collectively look to provide an improved representation of freshwater ecological condition. Ecological condition indicators used in this WQIP collectively determine an absolute ecosystem condition assessment of the region's waterways.

The following sections provide the introduction, method, and results for each ecological health indicator. The 2021 targets for all indicators have been developed. The indicators assessed are:

- Riparian vegetation;
- Fish community health;
- Barriers to fish movement; and
- Flow.

An overall ecosystem health condition score has also been calculated for each catchment management area and receiving water.

Additionally, an ecotoxicity assessment that was undertaken is described. This assessment included the derivation of new ecotoxicity thresholds, and an assessment of the mixtures of herbicides. The current condition of mixtures of herbicides in Mackay Whitsunday waterways has been provided as well as improvement targets for the herbicide mixtures.

### 11.1.1. Riparian vegetation

*Introduction*

Riparian vegetation is an essential component for the function of a healthy aquatic ecosystem. Riparian vegetation provides a source of in-stream habitat and food sources, shade (including temperature control), bank stability from erosion, filtration of sediments and pollutants entering the waterway from adjacent lands, habitat for semi-aquatic fauna species, and other functions. Riparian vegetation is predominantly impacted by clearing for development and agricultural purposes which has occurred since European settlement. Riparian vegetation is also impacted by the invasion of weed species, inappropriate fire management, and stock grazing.

*Method*

In the 2008 WQIP, riparian vegetation was assessed by comparing pre-clearing vegetation estimates to the existing regional ecosystem mapping (version 5 EPA 2005), and providing a score from A to E based on the level of disturbance of vegetation. A more rigorous assessment of riparian vegetation has been conducted for the 2014-2021 WQIP, detailed below.

An assessment of the riparian zones within the region was completed by the Department of Science, Information Technology, Innovation and the Arts (DSITIA) in 2014. The assessment utilised satellite imagery (specifically Landsat 5 TM and Landsat 7 ETM) to delineate riparian forest extent and the cover of all non-woody plants within a 50 metre buffer of each waterway (as per Clark & Healy *unpubl.*).

To determine riparian forest extent, Foliage Projective Cover (FPC) was assessed. This is the percentage of ground area occupied by the vertical projection of foliage (Armston et al. 2009; Kitchen et al. 2010). Classification of riparian forest extent was based on the National Forest Inventory minimum crown cover for forests of 20% (Montreal Process Implementation Group for Australia 2008), which is equivalent to a FPC of 11% (Scarth et al. 2008).

In addition to riparian forest extent, an assessment of ground cover was completed for areas where woody vegetation was not present as per minimum assessment criteria set out in Clark & Healy (*unpubl.*). Ground cover was defined as "all non-woody plant cover near the soil surface and all litter, including woody litter" (Scarth et al. 2006). The ground cover percentage data were derived from a time-series of Landsat 5 TM and Landsat 7 ETM+ satellite imagery from 1986 to 2009 (Clark & Healy *unpubl.*).

Based on local knowledge of the area, it was expected that ground cover within the Mackay Whitsunday region will be largely made up of exotic weedy grasses such as Elephant Grass, Para Grass, Hamil Grass & Guinea Grass (Folkers & Field 2011) with some areas of woody plant cover.

For the purposes of this assessment:

- Only vegetation with a canopy cover of 20% or greater was categorised as "riparian forest"; and
- Areas assessed as ground cover were categorised as "non-riparian vegetation".

A riparian forest cover metric was developed to provide a condition score for each of the 33 catchment management areas (CMAs) within the Mackay Whitsunday region, based on the extent of riparian forest present. The metric enabled each CMA to be scored from Very Poor to Very Good (Table 39).

**Table 39 Riparian forest cover metric.**

| | Condition Score | | | | |
|---|---|---|---|---|---|
| | Very Poor | Poor | Moderate | Good | Very Good |
| **Riparian forest extent (%)** | 0-39% | 40-59% | 60-79% | 80-94% | 95-100% |

*Results*

Results of the riparian assessment including riparian forest extent, non-riparian vegetation, and condition scores are presented in Table 40 for each of the 33 CMAs. The percentage of riparian vegetation remaining within each CMA is shown in Figure 13. The average percent of riparian vegetation for the entire Mackay Whitsunday region was just above 70%, with individual catchments varying from 30% to near 100%.

**Table 40 Riparian forest assessment, groundcover (i.e. non-riparian forest) and condition score results (rounded to the nearest full figure).**

| Catchment | Riparian Forested Area (%) | Riparian Forested (ha) | Non Riparian Vegetation (%) | Non Riparian Vegetation (ha) | Total Riparian Area (50 m buffer; ha) | Condition Score |
|---|---|---|---|---|---|---|
| **Eden Lassie Creek** | 76 | 4510 | 22 | 1461 | 5971 | Moderate |
| **Gregory River** | 81 | 2468 | 17 | 567 | 3035 | Good |
| **Whitsunday Coast** | 89 | 718 | 7 | 87 | 805 | Good |
| **Repulse Creek** | 100 | 1282 | 0 | 0.3 | 1282 | Very Good |
| **Myrtle Creek** | 67 | 1570 | 32 | 775 | 2345 | Moderate |
| **Proserpine River Main Channel** | 62 | 867 | 35 | 524 | 1391 | Moderate |
| **Upper Proserpine River** | 43 | 2545 | 35 | 3362 | 5907 | Poor |
| **Lethebrook** | 80 | 2833 | 19 | 732 | 3565 | Good |
| **Thompsons Creek** | 57 | 599 | 27 | 446 | 1044 | Poor |
| **Andromache River** | 86 | 3901 | 13 | 640 | 4541 | Good |
| **O'Connell River** | 77 | 3808 | 20 | 1125 | 4934 | Moderate |
| **Waterhole Creek** | 67 | 1158 | 31 | 567 | 1725 | Moderate |
| **Blackrock Creek** | 53 | 806 | 46 | 717 | 1523 | Poor |
| **St Helens Creek** | 77 | 1384 | 22 | 421 | 1806 | Moderate |
| **Murray Creek** | 69 | 3023 | 30 | 1340 | 4362 | Moderate |
| **Constant Creek** | 66 | 1171 | 33 | 599 | 1770 | Moderate |

**Table 40 (continued)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Reliance Creek** | 52 | 347 | 47 | 314 | 661 | Poor |
| **Mackay City** | 32 | 280 | 55 | 594 | 874 | Very Poor |
| **Pioneer River Main Channel** | 44 | 3699 | 51 | 4732 | 8432 | Poor |
| **Upper Cattle Creek** | 53 | 1734 | 30 | 758 | 2491 | Poor |
| **Blacks Creek** | 91 | 7532 | 5 | 725 | 8257 | Good |
| **Bakers Creek** | 30 | 294 | 69 | 675 | 969 | Very Poor |
| **Sandy Creek** | 40 | 2408 | 44 | 3591 | 6000 | Poor |
| **Alligator Creek** | 42 | 658 | 56 | 893 | 1551 | Poor |
| **Sarina Beaches** | 60 | 245 | 37 | 161 | 405 | Moderate |
| **Plane Creek** | 62 | 925 | 37 | 569 | 1494 | Moderate |
| **Cape Creek** | 96 | 585 | 2 | 26 | 611 | Very Good |
| **Rocky Dam Creek** | 61 | 3596 | 37 | 2302 | 5897 | Moderate |
| **Marion Creek** | 83 | 1061 | 15 | 224 | 1285 | Good |
| **Gillinbin Creek** | 94 | 1357 | 5 | 87 | 1443 | Good |
| **West Hill Creek** | 79 | 1136 | 19 | 296 | 1432 | Moderate |
| **Carmila Creek** | 74 | 1176 | 25 | 406 | 1581 | Moderate |
| **Flaggy Rock Creek** | 83 | 1589 | 13 | 326 | 1915 | Good |

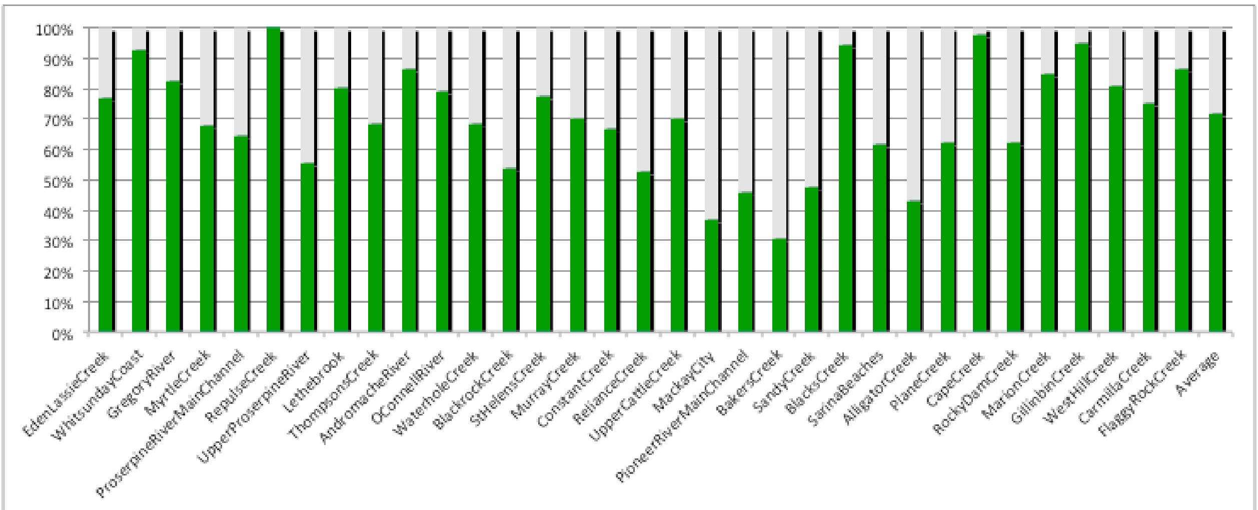



**Figure 13 Percentage of riparian vegetation cover remaining for each CMA.**

### 11.1.2. Fish community health

*Introduction*

Within the region many aquatic habitats have been modified due to human-induced impacts such as poor water quality runoff, degraded riparian and in-stream habitats, channel modification, flow modification, and barriers to fish migration. The cumulative impacts of these modifications has led to changes in the condition of the region's fish communities, adversely impacting fish abundance, species diversity, fish community composition and exacerbating the prevalence of pest fish species (Moore 2015).

Fish exhibit many traits and life strategies that make them ideal indicators of ecosystem health, including continually inhabiting receiving waters; sensitivity to a wide range of water quality impacts; occupying the upper part of the trophic food chain; being long lived; having well known life-history information for most species; and requiring different and often large connected habitats at varying stages to complete their life-cycle (Karr 1981; Simon 1998; Alonso et al. 2011).

*Method*

Research by Moore (2015) was commissioned to determine fish community condition within the Mackay Whitsunday region for the 2014-2021 WQIP. The assessment included the development of three fish health indicator metrics to determine relative fish community health. The three metrics (Table 41 to Table 43) were:

- Catch per unit effort (CPUE);
- Fish species richness; and
- Pest fish species richness.

Fish species richness scores for each CMA were weighted dependent on their stream order (Table 42).

The assessment utilised results from fish survey monitoring conducted by DPI&F between 2005 and 2008. Although no fish survey monitoring data is available after 2008 for the Mackay Whitsunday region, it is expected that the 2005-2008 results will be indicative of the current fish community condition as very little investment and effort has been put into improving overall aquatic health since this time and no large negative impacts are known to have occurred to fish populations.

Monitoring was completed in 14 of the region's 33 CMAs. To provide a fish community health score for each CMA, data was conservatively extrapolated based on catchment classes (see Chapter 6).

**Table 41 Catch per unit effort (fish/minute) metric.**

| Score | Catch per unit effort (fish/minute) |
|---|---|
| Very Good (5) | >40 |
| Good (4) | 30.1 - 40 |
| Moderate (3) | 20.1 - 30 |
| Poor (2) | 10.1 - 20 |
| Very Poor (1) | 0 - 10 |

**Table 42 Fish richness metric for Strahler stream orders.**

| Score | Strahler stream order systems ≥ 6 | Strahler stream order systems 5 | Strahler stream order systems 4 |
|---|---|---|---|
| Very Good (5) | ≥35 | ≥30 | ≥25 |
| Good (4) | 25 - 34 | 22 - 29 | 20 - 24 |
| Moderate (3) | 16 - 24 | 15 - 21 | 14 - 19 |
| Poor (2) | 11 - 15 | 11 - 14 | 9 - 13 |
| Very Poor (1) | 0 - 10 | 0 - 10 | 0 -8 |

**Table 43 Pest fish species richness metric.**

| Score | Pest Fish Occurrence |
|---|---|
| Very Good (5) | 0 |
| Good (4) | 1 |
| Moderate (3) | 2 |
| Poor (2) | 3 |
| Very Poor (1) | ≥4 |

The scores obtained for the three metrics were totalled and averaged to determine the overall fish community health score for each CMA (Table 44).

Scores ranged from Very Good (5) to Very Poor (1). For a CMA to attain a fish community health score of Very Good, it had to get the maximum score for each fish health metric, i.e. three scores of five.

**Table 44 Overall fish community health score metric.**

| Overall fish community health score | Average Score |
|---|---|
| Very Good (5) | 5 |
| Good (4) | 4 |
| Moderate (3) | 3 |
| Poor (2) | 2 |
| Very Poor (1) | 1 |

*Results*

The overall fish community health rating and individual scores for CPUE, species richness, and pest fish occurrence for each species as determined by Moore (2015) are presented in Table 45. Overall, the entire Mackay Whitsunday region received a Moderate fish community health rating.

**Table 45 Overall fish community health rating results for each CMA.**

| Catchment | Stream Order | CPUE (fish/ min) | Total Species Diversity | Pest Fish Species | Fish Community Health Rating |
|---|---|---|---|---|---|
| Repulse Creek | 4 | 29.55 | 11 | 0 | Very Good* |
| Upper Cattle Creek | 4 | 32.87 | 14 | 0 | Good |
| St Helens | 4 | 46.08 | 21 | 1 | Good |
| Gillinbin Creek | 4 | 15.49 | 11 | 0 | Moderate |
| Blacks Creek | 5 | 31.24 | 17 | 0 | Good |
| Plane Creek | 4 | 16.17 | 20 | 1 | Moderate |
| Carmila Creek | 5 | 32.14 | 16 | 0 | Good |
| Andromache River | 6 | 23.76 | 22 | 1 | Moderate |
| O'Connell River | 6 | 22.63 | 28 | 1 | Good |
| Rocky Dam Creek | 4 | 8.31 | 15 | 0 | Moderate |
| Pioneer River | 6 | 19.69 | 21 | 0 | Moderate |
| Sandy Creek | 5 | 9.69 | 25 | 2 | Moderate |
| Bakers Creek | 4 | 11.86 | 15 | 2 | Moderate |
| Myrtle Creek | 4 | 9.93 | 19 | 3 | Poor |
| **Average** | | **22.10** | **18** | **0.8** | **Moderate** |

**Please note:** there is a slight difference in the overall health rating between Moore 2015 and Table 45 due to grading methods used.

* Repulse Creek was assigned a category score of 'Very Good'. This reference catchment is situated in the protected Conway National Park, is surrounded by pristine lowland rainforest and contains no intensive surrounding landuse practices. Due to its pristine nature, there are no vehicle access tracks, making boat electrofishing near impossible, therefore, only backpack electrofishing occurred in the upper reaches of Repulse Creek. For further information please refer to Moore 2015.

### 11.1.3. Barriers to fish movement

*Introduction*

All freshwater fish species of the Mackay Whitsunday region migrate at some stage during their life history (Moore 2015). Some of these migrations are short and confined wholly to freshwater habitats, while some migrations occur across vast distances and between varying habitats including freshwater and near shore marine environments (Moore 2015).

Of the 48 species of freshwater fish found to occur in the Mackay Whitsunday region, almost half (42%) require unimpeded access between freshwater and estuarine habitats to complete their lifecycle and sustain healthy fish populations, including Queensland's two most important and iconic in-shore commercial net species, barramundi and sea mullet (Moore and Marsden 2007). Connectivity between habitats is therefore a critical component in managing aquatic environments, and crucial to ensuring the long-term sustainability of important commercial, recreational and indigenous fish species that underpin the social fabric of many coastal Queensland communities.

A barrier to fish passage includes any structure that impedes the movement of fish such as culverts, pipes, road crossings, weirs, and dams (Moore and Marsden 2007). Barriers to fish passage that prevent, impede or delay fish migration adversely impact the region's aquatic environments. Barriers affect fish community condition by preventing movement of fish species, which require free passage along waterways to fulfil a number of key life stage requirements (Moore 2015). This movement is essential for:

- Maintaining populations of diadromous species, which require free passage between freshwater and marine habitats for reproduction purposes i.e. barramundi, mangrove jack, jungle perch;
- Maintaining genetic diversity by preventing fragmentation of fish populations which can leave rare and threatened fish species susceptible to disease and extinction;
- Migration of adults to access habitats for feeding and reproduction purposes; and
- Migration of juvenile fish species to reach upstream nursery habitats and evade predators (Moore 2015).

Research by Moore (2015) was commissioned to determine the location and number of barriers to fish migration, a condition score for each CMA, a prioritisation of barriers for removal, and targets for barrier removal based on what can practically be achieved by 2021. Due to the extremely large number of potential barriers to migration that occur in the local environment and the limited funds available for remediation, it is critical that barriers are prioritised in order of importance.

The methods developed by Moore (2015) to determine the barrier locations and catchment condition are presented below. An additional methodology developed by Moore (2015) was required for the prioritisation of fish barriers and is also presented below.

*Method*

### Barriers to Fish Migration & CMA Condition

Potential barriers to fish migration were identified using aerial and satellite imagery, local knowledge, and known water resource structure inventories (Moore 2015). In total, 3954 potential barriers to fish passage were identified in the Mackay Whitsunday NRM region (Moore 2015).

To develop CMA condition scores Moore (2015) developed a number of metrics including stream habitat (area in ha) per barrier metric (Table 46), distance (in km) to the first barrier in each CMA metric (Table 47), and overall CMA barrier condition scoring range and overall score metric (Table 48).

**Table 46 Stream length to first barrier (as a proportion of total catchment stream length).**

| Stream habitat (in ha) per barrier metric | |
|---|---|
| **Scoring Range** | **Score** |
| No barriers | 5 |
| 25.1 - No barriers | 4 |
| 10.1 - 25 | 3 |
| 5.1 - 10 | 2 |
| 0 - 5 | 1 |

**Table 47 Stream length (km) to first barrier as a proportion (%) of total catchment stream length.**

| Distance (km) to the 1st barrier in CMA scoring system | |
|---|---|
| **Scoring Range (%)** | **Score** |
| No barriers | A |
| 50% - 99.9% | B |
| 30% - 49.9% | C |
| 10% - 29.9% | D |
| 0% - 9.9% | E |

**Table 48 Overall CMA barrier condition scoring range and overall score metric.**

| Overall CMA barrier condition scoring range and overall score | |
|---|---|
| **Scoring Range** | **Overall Score** |
| 10 | A |
| 7 - 9 | B |
| 5 - 6 | C |
| 3 - 4 | D |
| 0 - 2 | E |

### Barriers to Fish Migration Prioritisation

The prioritisation process undertaken by Moore (2015) to identify and rank the barriers to fish passage in the Mackay Whitsunday region has taken into consideration the migration patterns (high numbers of diadromous species) and the likelihood of localised extinctions caused by a barrier. For example, diadromous species that require unimpeded access between freshwater and estuarine environments to sustain fish populations are a higher priority than potamodromous species that can complete their lifecycle wholly within freshwaters. As a result, barriers located on large ordered streams (order 3-7), close to the estuary, containing high quality riparian habitats, and with large amounts of available upstream habitat (with no barriers close by) are ranked higher than barriers on small ordered headwater streams (order 1-2) with high proportions of surrounding intensive land use practices.

In order to effectively analyse the large number of potential barriers (3974) identified within the region, an automated GIS procedure was developed to effectively analyse environmental and geo-spatial characteristics related to each barrier. The GIS procedure consisted of five metrics containing selection criteria and associated scoring systems. The final result of the GIS barrier prioritisation process was a ranked list of potential barriers to fish migration in the region ordered by priority for remediation (Moore 2015).

The first step in the assessment was to classify waterways within the Mackay Whitsunday region into five separate classes based on three stream characteristics; Strahler stream order, stream gradient (slope), and stream type (estuarine or freshwater) (Moore 2015). Due to the large number of potential barriers, all barriers of Strahler stream order 1 that did not intersect with estuarine habitats were removed. This reduced the number of potential barriers to 1733 to be assessed against the stream classes metric presented in Table 49.

**Table 49 Stream classes metric.**

| Option | Stream classification (represented by colour code) | Stream characteristics | Scoring system |
|---|---|---|---|
| a | Purple | Strahler stream orders 4-7 | 10 |
| b | Red | Strahler stream orders 2-3 with low gradient<br>Strahler stream order 3 with medium gradient | 5 |
| c | Amber | Strahler stream order 3 with high gradient<br>Strahler stream order 2 low/medium gradient | 3 |
| d | Green | Strahler stream order 2 with high gradient<br>Strahler stream order 1 within tidal waters | 1 |
| e | Removed | Strahler stream order 1 outside tidal waters | 0 - removed |

The percentage (%) of intensive surrounding land use in the CMA for each barrier was then assessed. All potential barriers received a score using the percentage to Intensive Land Use Assessment metric presented in Table 50.

**Table 50 Percentage (%) intensive land use metric.**

| Option | Percentage (%) intensive land use | Score |
|---|---|---|
| a | 0% | 5 |
| b | 0.1 - 5% | 4 |
| c | 5.1 - 15% | 3 |
| d | 15.1 - 30% | 2 |
| e | 30.1 - 50% | 1 |
| f | >50.1% | 0 |

The number of barriers downstream in a direct path to sea was assessed using the metric presented in Table 51 (Moore 2015). The first potential barrier on each waterway received a score of 7. The next (second) barrier upstream receives a score of 5. The tenth barrier upstream receives a score of 0.

**Table 51 Number of barriers located downstream metric.**

| Option | Number of barriers downstream | Score |
|---|---|---|
| a | 0 | 7 |
| b | 1 | 5 |
| c | 2 - 4 | 3 |
| d | 5 - 9 | 2 |
| e | ≥10 | 0 |

The upstream available habitat (if the barrier was putatively remediated) and the resulting increased stream length upstream of the barrier to the next barrier (or the top of catchment) was assessed. The metric developed to assess this is presented in Table 52 (Moore 2015).

**Table 52 Stream length (km) to the next barrier/or top of catchment metric.**

| Option | Stream length (km) to the next barrier / or top of catchment | Score |
|---|---|---|
| a | ≥25 | 5 |
| b | 10 - 24.99 | 4 |
| c | 5 - 9.99 | 3 |
| d | 2 - 4.99 | 2 |
| e | 0.5 - 1.99 | 1 |
| f | 0 - 0.499 | 0 |

The final assessment undertaken was to determine the proportion of catchment 'cut-off' by each barrier. Moore (2015) assessed the upstream length (km) 'cut-off' by each barrier as a proportion (%) of the total stream length (km) in the whole of each relevant CMA. The metric used to assess this is presented in Table 53 (Moore 2015).

**Table 53 Distance (km) of CMA upstream of barrier as a proportion (%) of total CMA metric.**

| Option | Distance (in km) of CMA upstream of barrier as a proportion (%) of total CMA | Score |
|---|---|---|
| a | 80 -100% | 5 |
| b | 50 -79.99% | 4 |
| c | 20 - 49.99% | 3 |
| d | 5 - 19.99% | 2 |
| e | 1 - 4.99% | 1 |
| f | 0 - 0.99% | 0 |

*Results*

The overall barriers to fish migration scores for each CMA can be seen in Table 54. The barriers to fish migration of highest priority for removal are also listed in order for remediation in Table 55 and their locations are presented in Figure 14. Four CMAs received scores of 'very good' for barriers impacting fish migration – Repulse Creek, Mackay City, Cape Creek and Gillinbin Creek. Fifteen of the 33 CMAs received a score of either 'poor' or 'very poor' for the number of barriers impacting fish migration.

Fishways are an important means of improving fish passage throughout the catchment. Reef Catchments staff have designed and built fishways throughout Australia including vertical slot, rock ramp, bypass fishways, culvert fishways and lift and lock fishways.

**Table 54 Individual barrier metric scores including overall barrier condition rating.**

| Receiving Waters | Sub Catchment | Stream Habitat (ha) per barrier | Stream length to 1st barrier as a proportion (%) of total catchment stream length | Overall Score | Overall Fish Barrier Condition Rating |
|---|---|---|---|---|---|
| | | Score | Score | | |
| Whitsunday Coast | Repulse Creek | 5 | 5 | 10 | Very Good |
| Sandringham Bay | Mackay City | 5 | 5 | 10 | Very Good |
| Ince Bay | Cape Creek | 5 | 5 | 10 | Very Good |
| Carmila Coast | Gillinbin Creek | 5 | 5 | 10 | Very Good |
| Edgecumbe Bay | Eden Lassie Creek | 3 | 4 | 7 | Good |
| Edgecumbe Bay | Gregory River | 3 | 4 | 7 | Good |
| Repulse Bay | Waterhole Creek | 3 | 4 | 7 | Good |
| Carmila Coast | West Hill Creek | 3 | 4 | 7 | Good |
| Seaforth Coast | St Helens Creek | 3 | 3 | 6 | Moderate |
| Repulse Bay | Thompson Creek | 2 | 4 | 6 | Moderate |
| Repulse Bay | Proserpine R Main Channel | 2 | 4 | 6 | Moderate |
| Repulse Bay | Andromache River | 4 | 1 | 5 | Moderate |
| Sandringham Bay | Blacks Creek | 4 | 1 | 5 | Moderate |
| Repulse Bay | Upper Proserpine River | 4 | 1 | 5 | Moderate |
| Repulse Bay | Lethe Brook | 3 | 2 | 5 | Moderate |
| Ince Bay | Rocky Dam Creek | 2 | 3 | 5 | Moderate |
| Carmila Coast | Flaggy Rock Creek | 2 | 3 | 5 | Moderate |
| Whitsunday Coast | Whitsunday Coast | 1 | 4 | 5 | Moderate |
| Repulse Bay | O'Connell River | 3 | 1 | 4 | Poor |
| Carmila Coast | Marion Creek | 3 | 1 | 4 | Poor |
| Seaforth Coast | Murray Creek | 2 | 2 | 4 | Poor |
| Sandringham Bay | Pioneer R Main Channel | 2 | 2 | 4 | Poor |
| Seaforth Coast | Blackrock Creek | 1 | 3 | 4 | Poor |
| Seaforth Coast | Constant Creek | 1 | 3 | 4 | Poor |
| Sandringham Bay | Alligator Creek | 1 | 3 | 4 | Poor |
| Sarina Inlet | Sarina Beaches | 1 | 3 | 4 | Poor |
| Repulse Bay | Myrtle Creek | 1 | 2 | 3 | Poor |
| Sandringham Bay | Bakers Creek | 1 | 2 | 3 | Poor |
| Sandringham Bay | Upper Cattle Creek | 1 | 1 | 2 | Very Poor |
| Seaforth Coast | Reliance Creek | 1 | 1 | 2 | Very Poor |
| Sandringham Bay | Sandy Creek | 1 | 1 | 2 | Very Poor |
| Sarina Inlet | Plane Creek | 1 | 1 | 2 | Very Poor |
| Carmila Coast | Carmila Creek | 1 | 1 | 2 | Very Poor |

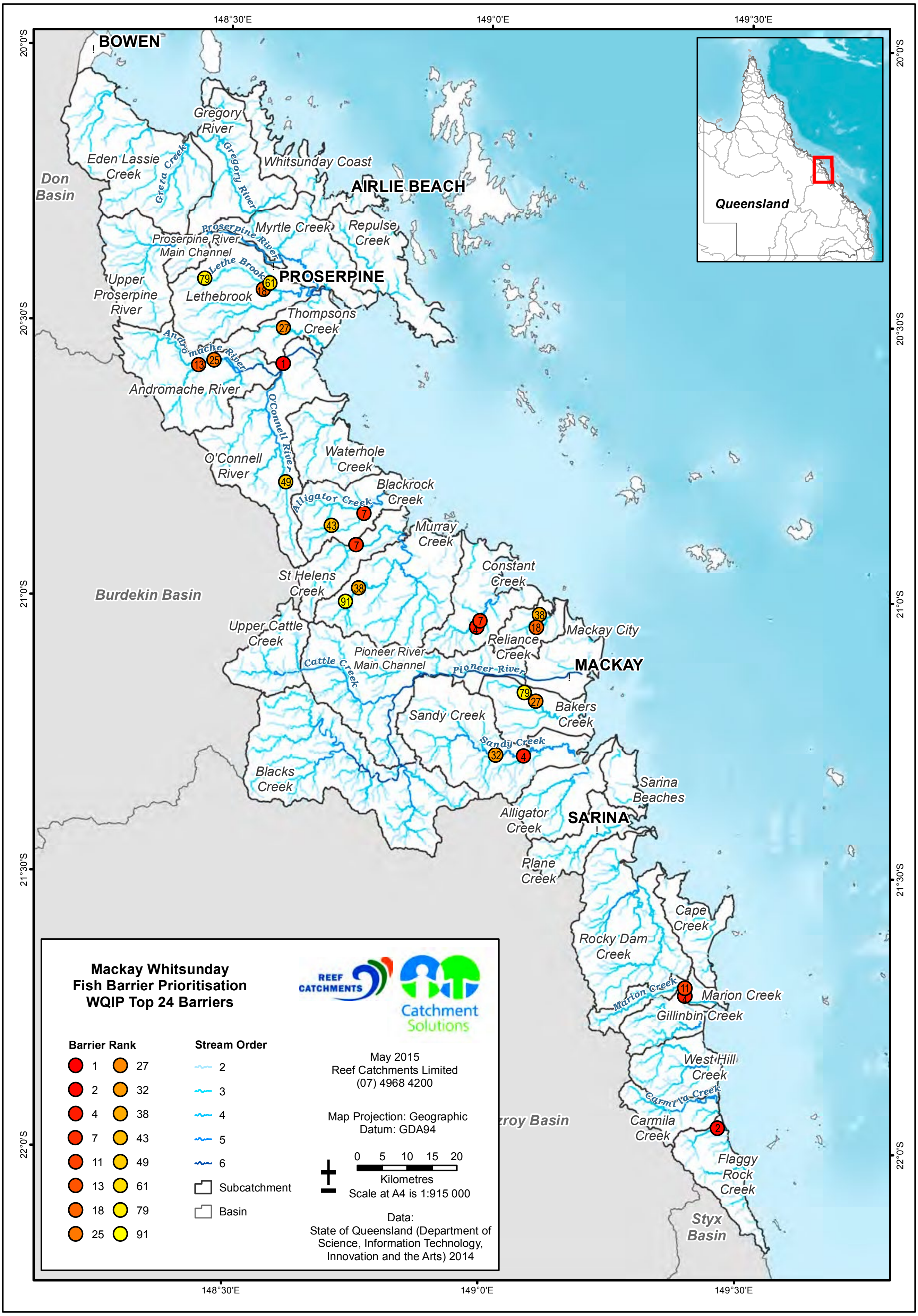



Figure 14 Top 24 potential barriers to fish passage locations in the Mackay Whitsunday region.

**Table 55 Top 24 barriers to fish migration in the Mackay Whitsunday region, including barrier description.**

| Receiving Water | Waterway | Barrier Description |
|---|---|---|
| Repulse Bay | O'Connell River | Tidal Interface Sand Dam |
| Carmila Coast | Flaggy Rock Ck | Tailwater of Cone fishway |
| Repulse Bay | Cedar Ck | Vitanza Rd Causeway - 4 Pipes |
| Sandringham Bay | Sandy Ck | Palm Tree Rd Causeway |
| Seaforth Coast | Constant Ck | Freds Lower Weir - 1 m |
| Carmila Coast | Marion Ck | 1 Pipe Causeway |
| Seaforth Coast | Blackrock Ck | Old Bowen Rd Causeway |
| Seaforth Coast | St Helens Ck | Russels Crossing Road Causeway |
| Seaforth Coast | Jolimont Ck | Mulherin Rd Weir - 2 m + |
| Seaforth Coast | Constant Ck | 1938 Weir UStrm of Freds weir - 1 m |
| Carmila Coast | Marion Ck | Marion Settlement Rd Causeway - 2 Culverts |
| Carmila Coast | Carmila Ck | Gauging Weir behind school |
| Repulse Bay | Goorganga Ck | Creek Crossing under train bridge |
| Ince Bay | Tedlands Ck | Tidal Bund |
| Ince Bay | Cherry Tree Ck | East Inneston Rd Causeway - 3 Culverts |
| Repulse Bay | Mares Nest Ck | Station Rd 1 Pipe Causeway |
| Ince Bay | Boundary Ck | Borg Tidal Bund - 1 m - Main Channel fwy site |
| Seaforth Coast | Macquarie Ck | Large Weir - 2 m |
| Seaforth Coast | Jolimont Ck | Narpi Rd Causeway - 2 Pipes |
| Seaforth Coast | Reliance Ck | Neills Rd Causeway - 2 Culverts |
| Edgecumbe Bay | Hay Gully | Weir 20 m U/S Hwy - 1 m + |
| Repulse Bay | Lethe Brook | Fausts Causeway - 2 Culverts + 1 m Apron drop |
| Repulse Bay | Boundary Ck (OC) | Dougherty's Rd Causeway - 2 Culverts |
| Ince Bay | Boundary Ck | Borg Tidal Bund DS |

## Flow

*Introduction*

The modification of the quantity and timing of flows within catchments has the potential to significantly impact the health of aquatic ecosystems which have evolved to match the natural flow regime.

Pressures to natural flow regimes within the region include the increase and decrease of flow due to water supply infrastructure including dams, weirs, levees, and bunds that modify estuarine and wetland flows. These pressures affect water chemistry, habitat complexity, aquatic connectivity, geomorphological processes, and flow availability.

The management of river flows in Queensland is the responsibility of the Queensland Government and is legislated under the *Water Act 2000*. This legislation is enacted through the Queensland Department of Natural Resources and Mines (DNRM). Water Resource Plans (WRPs) and the associated Resource Operations Plans (ROPs) are a key tool in the strategic management of Queensland's waterways.

DNRM have developed two WRPs within the Mackay Whitsunday region which cover 15 of the 33 CMAs (Table 56):

- Pioneer Valley Water Resource Plan and Pioneer Valley Resource Operations Plan (reviewed 2012 with 2010 Notice of Intent amendment to include groundwater); and
- Whitsunday Water Resource Plan and Whitsunday Resource Operations Plan (effective 2010 with Proserpine River subject to additional sharing rules. O'Connell and Andromache Rivers deferred).

**Table 56 Water Quality Improvement Plan catchment management areas included in Water Resource Plans.**

| Water Resource Plan & Water Resource Operations Plan area | WQIP Catchment Management Area |
|---|---|
| Pioneer Valley WRP | Blacks Creek |
| | Upper Cattle Creek |
| | Pioneer River Main Channel |
| | Mackay City |
| | Bakers Creek |
| | Sandy Creek |
| | Alligator Creek |
| Whitsunday WRP | Upper Proserpine River |
| | Proserpine River Main Channel |
| | Myrtle Creek |
| | Lethebrook |
| | Thompson Creek |
| | O'Connell River |
| | Andromache River |
| | Six Mile Creek Water Supply Area (Gregory River) |

The degree of flow modification is influenced by water supply regulatory mechanisms designed to minimise impacts on geomorphological processes, water chemistry, stream connectivity, and stream productivity from water supply infrastructure, whilst also efficiently providing for the consumptive needs of users.

*Method*

The method used to establish the status of flow regimes in the region for this updated WQIP differs from the method used in the previous WQIP. The previous method involved the allocation of a score from A-E based on variation in stream flow regime from a pre-development condition. This score was determined by DNRM hydrographic staff (outlined in Drewry et al. 2008).

The two WRPs mentioned above were first published in 2010, and provide useful information to incorporate into the determination of current flow conditions for the 2014-2021 WQIP. The Annual Proportional Flow Deviation (APFD) documented within the Pioneer Valley and Whitsunday WRPs were utilised for this purpose. For waterways that did not have an APFD documented, expert opinion from regional DNRM hydrographic staff was used as a surrogate. The APFD describes how different the flow regime is compared to the natural state of the waterway.

The flow regime was scored from very good to very poor using the APFD metric (Table 57) for each CMA. It should be noted that a reduced flow and an elevated flow can both have positive and negative impacts, and are on a continuum for ecosystem health (Table 57). The relationship of Poor to Very Poor catchments and the coverage by WRPs should not be seen as a measure of WRP effectiveness – the allocation of resources in these systems pre-dates the WRPs and the most stressed systems were the highest priority for planning and therefore most modified systems are more likely to be covered by a WRP.

**Table 57 Annual Proportional Flow Deviation condition rating metric.**

| Annual Proportional Flow Deviation | Condition Rating |
|---|---|
| **Reduced Flow** | |
| 0.99 - 1 | Very Good |
| 0.91 – 0.98 | Good |
| 0.81 – 0.9 | Moderate |
| 0.51 – 0.8 | Poor |
| <0.5 | Very Poor |
| **Elevated Flow** | |
| 1 - 1.1 | Very Good |
| 1.2 - 1.3 | Good |
| 1.4 - 1.5 | Moderate |
| 1.6 - 2 | Poor |
| >2 | Very Poor |

*Results*

The flow regime condition ratings for the 33 CMAs in the Mackay Whitsunday region ranged from Very Poor to Very Good (Table 58). Eleven catchments had modification of hydrological regimes of significant potential impact to the health of the aquatic ecosystems – these being Poor to Very Poor catchments. Eight catchments had considerable modifications to flow regimes that could in isolation, or in conjunction with other stressing factors, pose a significant impact to aquatic ecosystems (the Moderate condition catchments). Fourteen catchments had modifications to flow regimes that pose less of a risk to aquatic ecosystem health (Good to Very Good catchments).

**Table 58 Catchment management area Annual Proportional Flow Deviation and condition rating.**

| Catchment Management Area | Annual Proportional Flow Deviation | Condition Rating |
|---|---|---|
| **Eden Lassie Creek** | 0.95* | Good |
| **Gregory River** | 0.95 | Good |
| **Whitsunday Coast** | 1* | Very Good |
| **Repulse Creek** | 1* | Very Good |
| **Myrtle Creek** | 0.8 | Poor |
| **Proserpine River Main Channel** | 2.1 | Very Poor |
| **Upper Proserpine River** | 2.1 | Very Poor |
| **Lethebrook** | 2.1 | Very Poor |
| **Thompsons Creek** | 0.9 | Moderate |
| **Andromache River** | 0.95 | Good |
| **O'Connell River** | 0.8 | Poor |
| **Waterhole Creek** | 1* | Very Good |
| **Blackrock Creek** | 0.9* | Moderate |
| **St Helens Creek** | 0.8* | Poor |
| **Murray Creek** | 0.8* | Poor |

**Table 58 (continued).**

| | | |
|---|---|---|
| **Constant Creek** | 0.8* | Poor |
| **Reliance Creek** | 0.95* | Good |
| **Mackay City** | 0.95 | Good |
| **Pioneer River Main Channel** | 1.7 | Poor |
| **Upper Cattle Creek** | 0.75 | Poor |
| **Blacks Creek** | 1.1 | Very Good |
| **Bakers Creek** | 1.7 | Poor |
| **Sandy Creek** | 0.85 | Moderate |
| **Alligator Creek** | 0.9 | Moderate |
| **Sarina Beaches** | 0.95* | Good |
| **Plane Creek** | 0.85* | Moderate |
| **Cape Creek** | 1* | Very Good |
| **Rocky Dam Creek** | 0.9* | Moderate |
| **Marion Creek** | 0.85* | Moderate |
| **Gillinbin Creek** | 0.95* | Good |
| **West Hill Creek** | 0.95* | Good |
| **Carmila Creek** | 0.85* | Moderate |
| **Flaggy Rock Creek** | 0.95* | Good |

Note: * Indicate a waterway not included within the two mentioned water resource plans, therefore the APFD are estimates only.

## 11.2. Ecosystem health targets

Freshwater ecosystem health targets (FEHT) were developed using the current condition of each freshwater ecosystem health indicator (Chapter 11.1) as a starting point and the improvement predicted to be practically achieved by 2021 (similar to the development of water quality targets – Chapter 9). The development of FEHTs considered:

- The cost to implement ecosystem health improvement activities;
- The region's capacity to undertake ecosystem health improvement activities;
- The range of ecosystem health improvement activities that may be required to reach a single FEHT; and
- The feasibility of undertaking ecosystem health improvement activities in proposed locations.

Each FEHT (with the exception of fish community health) used the ecosystem health current condition (see Chapter 11.1) and determined the prioritised, practical ecosystem health improvement activities to be implemented between 2014 and 2021. The results of these assessments (current condition + prioritised ecosystem health improvement activities) have been used to set each ecosystem health target.

The barrier removal and water quality improvements anticipated in the 2014-2021 period were assessed jointly in determining the fish community health targets, as barriers to migration, ambient water quality, and event water quality all impact upon fish community health. By removing one impact affecting fish community health, it is possible to not see any response if another impact is still present. An example of this could be a river system that has had all barriers to fish migration removed however the water quality is in a poor condition and is predicted to stay in a poor condition; no improvement in fish community health is expected until water quality is improved.

It should be noted that while improvements to the ecosystem health parameters are planned, sometimes the target may not be sufficient to change the score for that parameter into the next condition rating (refer to Table 59). For example, if a CMA currently has a riparian extent of 61% it sits within the "Moderate" rating. Riparian vegetation activities may be planned for this CMA, however, the riparian vegetation extent would have to be increased to 80% or more to move it to a "Good" condition rating.

Current condition (CC) and targets for FEHT for each of the 33 CMAs are presented in Table 59. Results are presented, ranging from 'Very Poor' to 'Very Good'.

**Table 59 Freshwater ecosystem health current condition (CC) and targets.**

| Catchment Management Area | Riparian Vegetation | | Barriers to Migration | | Fish Community Health | | Flow | | Ambient WQ | | Event WQ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CC | Target | CC | Target | CC | Target | CC | Target | CC | Target | CC | Target |
| Eden Lassie Creek | Moderate | Moderate | Good | Good | Moderate | Good | Good | Good | Good | Good | Moderate | Good |
| Gregory River | Good | Good | Good | Good | Moderate | Moderate | Good | Good | Poor | Moderate | Moderate | Good |
| Whitsunday Coast | Good | Good | Moderate | Moderate | Good | Good | Very Good | Very Good | Good | Good | Good | Very Good |
| Repulse Creek | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good |
| Myrtle Creek | Moderate | Moderate | Poor | Poor | Poor | Poor | Poor | Poor | Very Poor | Poor | Very Poor | Poor |
| Proserpine River Main Channel | Moderate | Moderate | Poor | Poor | Moderate | Moderate | Very Poor | Very Poor | Very Poor | Very Poor | Very Poor | Poor |
| Upper Proserpine River | Poor | Poor | Moderate | Moderate | Moderate | Moderate | Very Poor | Very Poor | Good | Very Good | Moderate | Good |
| Lethebrook | Good | Good | Moderate | Good | Moderate | Moderate | Very Poor | Very Poor | Good | Good | Poor | Moderate |
| Thompsons Creek | Poor | Poor | Moderate | Good | Moderate | Moderate | Moderate | Moderate | Moderate | Good | Moderate | Good |
| Andromache River | Good | Good | Moderate | Very Good | Moderate | Good | Good | Good | Good | Good | Poor | Good |
| O'Connell River | Moderate | Moderate | Poor | Good | Good | Good | Poor | Poor | Poor | Moderate | Poor | Moderate |
| Waterhole Creek | Moderate | Moderate | Good | Good | Good | Good | Very Good | Very Good | Good | Good | Moderate | Good |
| Blackrock Creek | Poor | Poor | Poor | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Good | Very Poor | Poor |
| St Helens Creek | Moderate | Moderate | Moderate | Good | Good | Good | Poor | Poor | Moderate | Good | Moderate | Good |
| Murray Creek | Moderate | Moderate | Poor | Moderate | Moderate | Moderate | Poor | Poor | Good | Good | Poor | Moderate |
| Constant Creek | Moderate | Moderate | Poor | Moderate | Moderate | Moderate | Poor | Poor | Moderate | Good | Poor | Moderate |
| Reliance Creek | Poor | Poor | Very Poor | Poor | Moderate | Moderate | Good | Good | Very Poor | Poor | Very Poor | Poor |
| Mackay City | Very Poor | Very Poor | Very Good | Very Good | Moderate | Moderate | Good | Good | Very Poor | Poor | Very Poor | Poor |
| Pioneer River Main Channel | Poor | Poor | Poor | Poor | Moderate | Moderate | Poor | Poor | Good | Good | Very Poor | Poor |
| Upper Cattle Creek | Poor | Poor | Very Poor | Very Poor | Poor | Poor | Poor | Poor | Good | Good | Moderate | Good |
| Blacks Creek | Good | Good | Moderate | Moderate | Good | Good | Very Good | Very Good | Good | Good | Poor | Moderate |
| Bakers Creek | Very Poor | Very Poor | Poor | Moderate | Moderate | Moderate | Poor | Poor | Very Poor | Poor | Very Poor | Poor |
| Sandy Creek | Poor | Poor | Very Poor | Moderate | Moderate | Poor | Moderate | Moderate | Very Poor | Poor | Very Poor | Poor |
| Alligator Creek | Poor | Poor | Poor | Poor | Poor | Poor | Moderate | Moderate | Very Poor | Poor | Very Poor | Poor |
| Sarina Beaches | Moderate | Moderate | Poor | Poor | Moderate | Moderate | Good | Good | Good | Good | Poor | Moderate |
| Plane Creek | Moderate | Moderate | Very Poor | Very Poor | Moderate | Moderate | Moderate | Moderate | Good | Good | Poor | Moderate |

**Table 59 (continued).**

| Catchment Management Area | Riparian Vegetation | | Barriers to Migration | | Fish Community Health | | Flow | | Ambient WQ | | Event WQ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CC | Target | CC | Target | CC | Target | CC | Target | CC | Target | CC | Target |
| Cape Creek | Very Good | Very Good | Very Good | Very Good | Good | Good | Very Good | Very Good | Good | Good | Moderate | Good |
| Rocky Dam Creek | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Good | Poor | Moderate |
| Marion Creek | Good | Good | Poor | Good | Moderate | Moderate | Moderate | Moderate | Good | Good | Very Poor | Poor |
| Gillinbin Creek | Good | Very Good | Very Good | Very Good | Moderate | Good | Good | Good | Good | Good | Moderate | Good |
| West Hill Creek | Moderate | Good | Good | Good | Moderate | Moderate | Good | Good | Good | Good | Very Poor | Poor |
| Carmila Creek | Moderate | Moderate | Very Poor | Very Poor | Good | Good | Moderate | Moderate | Good | Good | Moderate | Good |
| Flaggy Rock Creek | Good | Good | Poor | Moderate | Moderate | Moderate | Good | Good | Good | Good | Very Poor | Poor |

Refer to CMA Reports for full ecosystem health scores.

## 11.3. Overall ecosystem health condition

To provide an overarching ecosystem health condition score, each CMA was grouped as per their receiving waters (refer Chapter 6.2). The condition ratings for each ecological indicator (see above) were converted into a value from 1 (very poor) to 5 (very good). Each ecological indicator was then averaged per receiving water (i.e. an average score for riparian vegetation for each receiving water). All averages were combined to provide one overall ecosystem health score for each receiving water. The results are presented in Table 60.

**Table 60 Overall freshwater ecosystem health condition for each receiving water separated into the ecological health indicators.**

| | Receiving Waters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Ecological health indicator** | **Edgecumbe Bay** | **Whitsunday Coast** | **Repulse Bay** | **Seaforth Coast** | **Sandringham Bay** | **Sarina Inlet** | **Ince Bay** | **Carmila Coast** |
| **Riparian Vegetation** | Good | Very Good | Moderate | Moderate | Poor | Moderate | Good | Good |
| **Fish Community Health** | Moderate | Very Good | Moderate | Moderate | Moderate | Moderate | Good | Moderate |
| **Barriers** | Good | Good | Moderate | Poor | Poor | Poor | Good | Moderate |
| **Flow** | Good | Very Good | Poor | Moderate | Moderate | Good | Good | Good |
| **Event WQ** | Moderate | Very Good | Poor | Poor | Very Poor | Poor | Moderate | Poor |
| **Ambient WQ** | Moderate | Very Good | Moderate | Moderate | Poor | Good | Good | Good |
| **Overall** | **Good** | **Very Good** | **Moderate** | **Moderate** | **Poor** | **Moderate** | **Good** | **Moderate** |

## 11.4. Ecotoxicity

### 11.4.1. New ecotoxicity thresholds

*Introduction*

The determination of appropriate ecotoxicity thresholds is critical to ensuring a minimal impact on freshwater and receiving water ecosystems from the use of herbicides. The herbicide trigger values presented in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000) were reviewed for five of the six key 'of concern' herbicides in the Mackay Whitsunday region in Delaney et al. (2014). New ecotoxicity thresholds were derived for ametryn, atrazine, diuron, hexazinone, and tebuthiuron using current toxicity data. Only data specific to aquatic phototrophic species were included, as these represent the species impacted by the five herbicides of interest.

*Method*
The methodology used to derive the ecotoxicity thresholds was in accordance with the recommended rules for deriving Australian and New Zealand water quality guideline trigger values (ANZECC and ARMCANZ 2000), and as detailed in Warne et al. (in review). Refer to Smith et al. (in prep) and Delaney et al. (2014) for the full methodology.

Generally, the following steps were taken:

- Toxicity data was reviewed to ensure the quality was satisfactory;
- Toxicity data was grouped by herbicide;
- Data was then grouped by species, for each herbicide;
- Data was converted into a sensitivity concentration (in µg/L) for each species, using the rules described in Warne et al. (in review);
- Calculations were verified;
- Species sensitivity values were entered into BurrliOz v2.0 to identify the species sensitivity distribution (SSD) and the herbicide concentrations (ecotoxicity thresholds) that should theoretically protect 99%, 95%, and 90% of phototrophic species; and
- Herbicide concentrations were compared to the existing targets and WQOs.

*Results*
The new ecotoxicity thresholds derived for ametryn, atrazine, diuron, hexazinone, and tebuthiuron in Smith et al. (in prep) and Delaney et al. (2014) differ from the current Australian and New Zealand trigger values (ANZECC and ARMCANZ 2000) due to a revised methodology and the availability of more recent toxicity data. The new ecotoxicity thresholds are compared to the current Australian and New Zealand trigger values in Table 61 below.

**Table 61 New herbicide ecotoxicity thresholds (concentrations in µg/L) for freshwater phototrophic species compared to the current Australian and New Zealand water quality guideline trigger values (ANZECC and ARMCANZ 2000). Adapted from: Smith et al. (in prep).**

| | | % of species protected | | |
|---|---|---|---|---|
| **Herbicide** | **Guideline** | **99** | **95** | **90** |
| **Ametryn** | Ecotoxicity threshold | 0.02 | 0.1 | 0.3 |
| | Aust. and NZ trigger value | N/A | N/A | N/A |
| **Atrazine** | Ecotoxicity threshold | 3.7 | 6 | 8.1 |
| | Aust. and NZ trigger value | 0.7 | 13 | 45 |
| **Diuron** | Ecotoxicity threshold | 0.2 | 0.3 | 0.4 |
| | Aust. and NZ trigger value | 0.2 | 0.2 | 0.2 |
| Hexazinone | Ecotoxicity threshold | 0.2 | 0.7 | 1.3 |
| | Aust. and NZ trigger value | 75 | 75 | 75 |
| Tebuthiuron | Ecotoxicity threshold | 4.3 | 8.8 | 12.0 |
| | Aust. and NZ trigger value | 0.02 | 2.2 | 20 |

N/A = not applicable

The newly derived herbicide ecotoxicity thresholds were compared to the 2014 targets and 2050 WQOs (Drewry et al. 2008) to determine if they provided adequate environmental protection. The ecotoxicity thresholds were then used to update the WQIP for 2014-2021 as follows:

For any WQOs or targets higher (in µg/L) than the ecotoxicity thresholds:
- 2050 WQO was updated to equal the concentration of the relevant ecotoxicity threshold; and
- 2021 target was revised to a concentration indicating a trend toward the new 2050 WQO that was deemed to be achievable.

For WQOs or targets at, or more stringent than, the ecotoxicity thresholds:
- 2021 target and 2050 WQO were left unchanged, as the lower concentration represents a lower risk to aquatic species.

The ecotoxicity thresholds for the protection of 95% of species were used for the majority of the CMAs and sites, however the 99% protection of species were used for any HEV sites. Refer to Chapter 9 for detail on the updated WQOs and targets for herbicides for each CMA.

The results of the ecotoxicity assessment highlights that ecotoxicity thresholds are critical in the ability to manage herbicide impacts on aquatic ecosystems. If the locally derived targets are more stringent that the ANZECC and ARMCANZ Guidelines these should be used as they are based on locally sourced data.

### 11.4.2. Mixtures of herbicides

*Introduction*

The impact of mixtures of herbicides (rather than individual herbicides in isolation) can be assessed using the multisubstance potentially affected fraction (ms-PAF) method. The ms-PAF method provides a more comprehensive assessment of the potential ecological impacts of herbicides that are present at the same time and have the same mode of action. The ms-PAF method was appropriate to use to assess the effects of mixtures of the five PSII herbicides of interest (ametryn, atrazine, diuron, hexazinone, and tebuthiuron). Delaney et al. (2014) conducted an ms-PAF assessment of the herbicide concentration results from water quality sampling in the Mackay Whitsunday region.

*Method*

The detailed methodology is discussed in Delaney et al. (2014). The general approach undertaken followed the Traas et al. (2002) method and included the following steps:
- Concentrations were converted to enable comparison of different herbicides;
- Species sensitivity distributions (SSD) for all five herbicides were derived;
- A combined SSD which represented all pesticides was calculated;
- The herbicide concentration of the mixture for each sampling event was calculated; and
- Per cent of potential species affected in each individual sampling event was then calculated.

The ms-PAF results of the magnitude of impact (potential per cent of species affected) were then assessed against the 95% species protection level, i.e., 5% of species affected. All HEV waters (on upper Andromache River, Basin Creek, Finch Hatton Creek, Impulse Creek, and St Helens Creek) used the higher 99% protection level. Additionally, the ms-PAF results were categorised into risk levels based on the percent of species affected (low, medium, high, and very high risk).

*Results*

The results from the ms-PAF assessment indicated that the majority of the waterways sampled provided inadequate protection of species from mixtures of pesticides (Delaney et al. 2014).

In many cases under ambient conditions, 95% of species (or near) were protected. However, in most waterways under event conditions, the percent of potentially affected species was well above 5%, and sometimes nearly 100% (Delaney et al. 2014).

All five assessed HEV water sites had less than 1% of species potentially affected under ambient conditions, and four out of five sites had less than 1% of species potentially affected under event conditions. Of the non-HEV water sites assessed, only one creek (Waite Creek) had ms-PAF results that indicated adequate protection of species (Delaney et al. 2014). The highest ms-PAF values were seen in Myrtle Creek and Rocky Dam Creek, both of which had frequently high levels of potentially affected species, with up to 96% affected during events (Delaney et al. 2014).

The results of the ms-PAF assessment show that for all assessed waterways, the impact of the herbicide mixtures occur within all risk categories from low risk (less than 5%) through to very high risk (70% or more) (Delaney et al. 2014). Table 62 below shows the ms-PAF results under ambient conditions split into the relevant risk categories. For the three sites that the event ms-PAF results were available (Myrtle Creek, Pioneer River, and Sandy Creek), all sites had days occurring in each risk category. The results for these sites indicated inadequate protection of species under both ambient and event conditions emanating from mixtures of pesticides (Delaney et al. 2014).

**Table 62 ms-PAF results under ambient conditions occurring within each risk classification range. Source: Delaney et al. 2014.**

| Risk Category | % of species affected | Number of sites (out of 12) with days occurring in this category |
|---|---|---|
| **Very high risk** | 70% or more | 3 (Bakers Creek, Myrtle Creek, and Rocky Dam Creek) |
| **High risk** | 40-70% | 4 (Bakers Creek, Myrtle Creek, Plane Creek, and Rocky Dam Creek) |
| **Medium risk** | 5-40% | 7 (Bakers Creek, Carmila Creek, Myrtle Creek, O'Connell River, Pioneer River, Sandy Creek, and Rocky Dam Creek) |

The results of the assessment of mixtures of herbicides highlights that consideration of herbicide mixtures is critical to properly understand the potential impact of herbicides on regional aquatic ecosystems. Sampling demonstrates that herbicide mixtures are a reality in the Mackay Whitsunday region, and the impacts of these mixtures are greater than the sum of the impacts of the individual herbicides at the same concentrations.

### 11.4.3. Targets for mixtures of herbicides

The WQOs and the 2021 targets for individual herbicides have been updated to reflect the current condition of the waterways and incorporate the new ecotoxicity thresholds as far as practical (Chapter 9). The 2008 WQIP did not include targets for mixtures of herbicides, however, the work described above has highlighted the importance of assessing the mixtures.

Table 63 shows the ms-PAF values for each CMA (under both ambient and event conditions), for both the previous 2014 herbicide targets (Drewry et al. 2008) and the new 2021 targets. An ms-PAF value of five is required to provide adequate protection to species, or an ms-PAF value of one for HEV water sites.

The ms-PAF values assume all five PSII herbicides are present, at the target concentration. For the purposes of these calculations, any target concentrations of <LOD (currently 0.01 µg/L for all PSII herbicides) have used a concentration of 0.009 µg/L. The 2021 ms-PAF target calculations for CMAs which recorded concentrations of tebuthiuron above LOD in sampling (Proserpine River, O'Connell River, Waterhole Creek, and Flaggy Rock Creek) have utilised the 2014 tebuthiuron targets. The ms-PAF targets calculations for all other CMAs used a concentration of 0.009 µg/L for tebuthiuron.

**Table 63 ms-PAF values for catchment management areas using the 2014 targets for individual herbicides and the 2021 targets.**

| Catchment Management Area | ms-PAF based on 2014 CC | | ms-PAF based on 2021 targets | |
|---|---|---|---|---|
| | Ambient | Event | Ambient | Event |
| Pioneer River | 0.8 | 30.4 | 0.8 | 30.4 |
| Sandy Creek | 9.2 | 31.7 | 9.2 | 31.5 |
| Gregory River | 0.4 | 12.2 | 0.4 | 9.8 |
| Eden Lassie Creek | 0.4 | 2.0 | 0.4 | 2.0 |
| Whitsunday Coast | 0.4 | 0.4 | 0.4 | 0.4 |
| Rocky Dam Creek | 3.6 | 32.7 | 3.6 | 32.7 |
| Carmila Creek | 0.4 | 19.6 | 0.4 | 19.6 |
| Blacks Creek | 0.4 | 2.2 | 0.4 | 2.2 |
| O'Connell River | 0.4 | 11.4 | 0.4 | 6.3 |
| Andromache River | 0.4 | 0.4 | 0.4 | 0.4 |
| Gillinbin Creek | 0.4 | 1.7 | 0.4 | 2.0 |
| Repulse Creek | 0.4 | 0.4 | 0.4 | 0.4 |
| Myrtle Creek | 5.4 | 51.7 | 5.4 | 51.7 |
| Proserpine River | 5.4 | 38.1 | 5.4 | 36.5 |
| Upper Proserpine River | 0.4 | 0.4 | 0.4 | 0.4 |
| Thompson Creek | 3.6 | 19.4 | 3.6 | 19.4 |
| Lethebrook | 0.6 | 27.7 | 0.6 | 27.7 |
| Waterhole Creek | 0.4 | 4.1 | 0.4 | 4.1 |
| Blackrock Creek | 3.6 | 36.9 | 3.6 | 36.7 |
| St Helens Creek | 3.6 | 19.6 | 3.6 | 19.6 |
| Murray Creek | 0.4 | 31.2 | 0.4 | 31.2 |
| Constant Creek | 3.6 | 31.1 | 3.6 | 27.3 |
| Reliance Creek | 9.2 | 39.8 | 9.2 | 39.8 |
| Mackay City | 9.2 | 46.3 | 9.2 | 46.3 |
| Upper Cattle Creek | 0.4 | 18.1 | 0.4 | 18.1 |
| Bakers Creek | 5.4 | 49.2 | 5.4 | 35.0 |
| Sarina Beaches | 0.4 | 19.6 | 0.4 | 19.6 |
| Cape Creek | 0.4 | 2.0 | 0.4 | 2.0 |
| West Hill Creek | 0.4 | 22.6 | 0.4 | 22.6 |
| Alligator Creek | 9.2 | 45.7 | 9.2 | 45.7 |
| Plane Creek | 0.6 | 21.0 | 0.6 | 21.0 |
| Marion Creek | 0.4 | 23.4 | 0.4 | 23.0 |
| Flaggy Rock Creek | 0.4 | 4.5 | 0.4 | 4.5 |

Under ambient conditions, the 2021 targets provide adequate protection of species for all but four of the catchment management areas (which have ms-PAF results of 9.2), and three catchment management areas are near adequate (ms-PAF of 5.4). However, under event conditions, many of the 2021 targets do not provide adequate protection to species from mixtures of herbicides. However, ongoing implementation works will continue to reduce herbicide concentrations, moving toward the 2050 WQOs.

# SECTION D

## Regional Intervention and Investment Priorities

This section provides a comprehensive summary of the management intervention activities recommended for the region and how they have been prioritised. Recommended management interventions to improve water quality have been identified through the development of separate ABCD Management Frameworks for the grazing, sugarcane, horticulture, and urban sectors. The section provides information on how the frameworks have been refined and updated, and a description of the new urban framework. Management interventions focused on improving ecosystem health are also identified in this section, for both the freshwater and marine environments.

This section also provides detail on the process and tools utilised to prioritise the recommended management interventions for both water quality and ecosystem health. The adoption targets for agriculture, urban, and ecosystem required in order to achieve water quality and ecosystem improvements have been presented, and their associated costs.

# 12. Management Interventions to Improve Water Quality

## 12.1. ABCD management frameworks introduction

During the development of the 2008 WQIP a major focus was the identification and validation of various management practices currently being implemented in sugarcane, grazing, horticulture and urban landscapes and their corresponding impacts to water quality. Through literature reviews and consultation with industry stakeholders and land managers, management practices were classified into four categories of varying levels relating to their water quality outcomes. These classifications for water quality outcomes were titled the 'ABCD Management Framework' for each of the respective land uses.

The ABCD Management Frameworks were designed to communicate different standards of management practices for each land use for different water quality parameters (i.e., soil management, nutrient management, pesticide management). The frameworks provide standard definitions of a progression of improvements to water quality from D class ("Dated") management practices with the lowest corresponding water quality outcomes, through C class ("Conventional" or "Common"), B class ("Best Management") and finally to A class ("Aspirational") or as yet unproven management practices. While the frameworks look to promote activities that will improve water quality, to be 'best management' each practice also needs to be economically sustainable for the landholder. Often activities identified within A class are known to reduce pollutant loads but they are not described as B class (best management) until there is evidence that they are at a minimum financially neutral, or preferably financially beneficial.

Each ABCD Management Framework identifies the range of activities being undertaken within each agricultural industry and places them into a class (i.e. A, B, C, D). Many A and B class activities are similar to C class activities with the difference in classes often relating to the additional planning precision or efficiencies undertaken by the landholder.

Each ABCD Management Framework does not quantify the entire water quality benefit from individual management practices (i.e. soil practices reducing nutrient loads). In many cases, implementing a single A or B class activity will result in lowering the loads of multiple pollutants moving off farm (Rohde et al. 2013).

The modelling undertaken in this WQIP does not account for the multiple benefits of A and B class activities in lowering pollutant loads, however it is expected that future monitoring will result in the ability to accurately quantify these reductions more accurately.

Since the development of ABCD Management Frameworks in 2008, each framework has continually been refined to include new and improved information on validating management practices and improvements in water quality. They have also been revised to account for the changes in technology, costs and market conditions. Such refinement will continue to occur in the future with many A class practices becoming B class practices and eventually C class practices as industries continue to progress.

ABCD Management Frameworks continue to provide guidance to the region on management activities that will improve water quality and guide investment to ensure the greatest public and private benefit possible. The sugarcane, grazing, and horticulture ABCD Management Frameworks have been the basis to guide investment of programs such as Reef Rescue (2008 – 2013) and continue to be utilised in other incentive-based programs, and as a planning tool for industry and landholders.

## 12.2. Updating the ABCD Management Frameworks

### 12.2.1. Establishment of Regional Working Groups

One recommendation of the 2008 WQIP was the establishment of industry-led regional working groups (RWGs) to provide a pathway for initial consultation and review of industry specific activities. These RWGs have since been established and have been particularly successful in providing valuable insight to each industry including the evolution of the ABCD Management Frameworks. Updates to the ABCD Management Frameworks have relied on the RWGs for initial development, before undergoing public comment. The finished product is then presented to the RWGs to be signed off as industry endorsed.

### 12.2.2. Grazing ABCD Management Framework update

There has been one update to the initial Grazing ABCD Management Framework since it was developed in 2008. This update and review was completed in 2011. Through extensive industry and landholder engagement, the framework now provides a much more detailed planning tool. The progression from D class practices to A class practices outlines achievable steps to reduce pollutant loads coming off grazing properties in the Mackay Whitsunday region.

The initial framework outlined management practices with a focus on soil as a means to improve water quality. During the review process the RWG looked in detail at various activities which improve soil health condition but also expanded the framework to include other potential pollutants. This review was provided for public consultation to ensure landholder engagement in the process and to also ensure that the framework included all grazing management activities in the region. The Grazing ABCD Management Framework (2011) now includes: pasture management, pasture spelling, riparian management, gully management, nutrient management, chemical management, and also planning and record keeping.

The RWG identified the inclusion of nutrient and chemical management as being important for the landholders and also important for water quality to try and improve the timing and accuracy of application. Increasing the use of soil testing as a means to improve nutrient application (by improving nutrient management and reducing loss from over application) was also identified with the practice being highly variable between landholders in the region.

Breaking up soil management into different management practices has provided more direction to industry extension staff and landholders regarding areas for consideration when developing property plans.

Grazing in the Mackay Whitsunday region is unique. The region is defined as having ‘tropical grazing systems’ with the landscape made up of many ephemeral streams and coastal environments. The refined ABCD Management Framework takes into consideration the unique environment in which local graziers operate.

### 12.2.3. Sugarcane ABCD Management Framework update

The Sugarcane ABCD Management Framework has been updated twice since the initial development for the 2008 WQIP. The updates (in 2010 – 2011 and 2013 – 2014) were carried out under consultation from the RWG and included extensive public consultation before being endorsed by the industries represented within the RWG. Through the review of the Sugarcane ABCD Management Framework over the past seven years, there have been changes to terminology and classifications due to refinement from industry and also due to large industry uptake mainly through the incentive-based program, Reef Rescue. Updating the ABCD Management Framework is essential for the successful implementation of incentive programs to ensure that what is being funded is at, or above, best management practice, and therefore providing the best public/private benefit.

Since the development of the original Sugarcane ABCD Management Framework a number of activities have progressed from B to A and from C to B. This is due to the sugarcane industry largely adopting what were once higher-level management practices as becoming common within the industry. Descriptions of practices contained within each classification have also been refined as terminology gains greater acceptance within industry to better describe farming practices.

The introduction of banded mill mud application is an example of the progression of management practices between framework classifications. Mill mud is a by-product of the milling process, which is reapplied back onto the paddock as an additional and cheap form of fertiliser. In the original 2008 ABCD Management Framework, mill mud was not included as a management practice as the mud was broadcast over the paddock in the only way available and only on paddocks close to the mill. By 2010 – 2011, with funding from Reef Rescue, it was identified that mill mud could be applied by banding the product over the row at a far reduced rate per hectare. This practice was included in the Sugarcane ABCD Management Framework as an A class practice as the impact on production was largely unknown. By 2013 – 2014 this practice was widely accepted by industry to be the 'best practice' for the application of mill mud. Due to the reduced rate per hectare, significant improvements in water quality could be quantified, with no impact to sugarcane yields. Following these developments, the application of banded mill mud has been identified as a B class practice.

Local cane farmers from the Mackay region like Phil Deguara (right) and John Deguara have built on standard industry farming techniques to trial deep sub-surface application to improve the physical and chemical structure of their soil. Mill ash, mud and bagasse helps to build soil nutrient and increase the carbon component of the soil, making it more friable and less compacted. It is hoped that this trial will provide more information for all of the sugarcane community on strategies for improved management techniques of sodic soils.

Research and trials completed on sugarcane over the past five years have influenced the Sugarcane ABCD Management Framework, particularly regarding the importance of timing and forecasting of nutrient and chemical application with respect to rainfall (Rohde et al. 2013). One of the major factors influencing run off concentrations is the period of time between application and the first flush run off event. The 2013 ABCD Management Framework has highlighted the importance of this and has included strategies to implement (i.e., 'safegauge') to address the findings.

### 12.2.4. Horticulture ABCD Management Framework update

Horticulture is a relatively small land use in the Mackay Whitsunday region, however there is a wide diversity in the crops grown. The Horticulture ABCD Management Framework has been recently updated in 2014. The update expanded the information provided to producers on soil management to highlight the diversity of crops grown in the region, including: tree crops (macadamias, lychees, etc.), plantation (bananas, pawpaws, etc.) and annuals (tomatoes, etc.). Nutrient and chemical practices in the framework have been updated to include new terminology and changes in management practices. The update also included management practices common to all, including fallow management, headland management, farm layout and machinery.

### 12.2.5. Urban ABCD Management Framework update

**Urban Pressures in the GBR Catchments**

To date, the focus of water quality improvement for the Great Barrier Reef catchments through initiatives such as Reef Plan and Reef Rescue has been mostly on agricultural lands as the majority of the end of catchment pollutant loads emanate from agricultural land uses. The overall contribution from urban land use to the pollutant load entering the Great Barrier Reef lagoon is relatively small, however, at the local scale it is still significant. Additionally, urban land use impacts are expected to become increasingly relevant as the population continues to grow along Queensland's regional coastline.

The 2008 WQIP recognised the water quality pressures associated with urban areas. In response, a range of management actions were designed to improve water quality linked with urban land use. A lack of availability of funding to implement the urban components of the GBR catchments' WQIPs resulted in slower progress in urban management for water quality improvement compared with improvements in the agricultural sector over the same timeframe.

In response to this situation, Reef Catchments convened the Urban Think Tank (UTT) in 2010 as one of the four organisational units of the Healthy Waterways Alliance – Mackay Whitsunday Isaac (see Chapter 5 for more information on the Healthy Waterways Alliance). The UTT is made up of delegates from Local, Queensland and Australian Government authorities, industry and the community, representing the interests of urban, industry, and coastal development water quality initiatives, programs and work plans. The UTT is tasked with developing innovative and practical approaches to catchment and waterway management. The commitment from the Mackay, Whitsunday and Isaac Regional Councils (the three local government authorities in the Mackay Whitsunday NRM region) is key to the integrity and success of the work of the UTT. The initiatives of the UTT have led to the development of the Urban ABCD Management Framework, which has been endorsed by the regional local government authorities.

The second round of Reef Rescue (known as the Australian Government Reef Programme) incorporated urban water quality improvement objectives through the funding of WQIP updates, and the allocation of resources to support regional bodies to improve urban ecosystem health. Reef Catchments received funding for the project "Improving urban water quality and native habitat in the Mackay Whitsunday Isaac region". The project included the delivery of a range of targeted actions including biodiverse plantings, public access management, erosion control, stream bank stabilisation, installation of gross pollutant traps and fish passages, as well as pest flora and fauna management.

**Legislation and Urban Water Quality**

The majority of urban development in regional Queensland occurs within 20 km of the coast. This concentrated and growing demographic, combined with an increasing awareness of environmental issues associated with population pressures, has resulted in a proliferation of environmental legislation designed to reduce the risk of environmental harm associated with human activities. Such legislation has also been developed to include rapidly expanding urban areas and associated infrastructure.

Queensland legislation (acts and key subordinate legislative instruments) relevant to coastal development and/or water quality management includes:

- *Environmental Protection Act 1994*;
- *Environmental Protection (Water) Policy 2009*;
- *Sustainable Planning Act 2009*;
- *State Planning Policy (updated 2014) (SPP)*;
- *Coastal Protection and Management Act 1995*;
- *Fisheries Act 1994*;
- *Aboriginal Cultural Heritage Act 2003*;
- *Nature Conservation Act 1992*; and
- *Vegetation Management Act 1999*.

The *Environmental Protection Act 1994* (EP Act) is the principal piece of environmental legislation for Queensland with a number of subordinate policies. The object or intent of the EP Act is "to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development)" (EP Act, p.41).

While relevant legislation is developed at the Queensland and Australian Government levels, most of the legislation associated with coastal development is administered at the 'ground' level by local government. Local government, however, is not usually provided with additional resources by the Queensland or Australian Government to administer or enforce the obligations devolved to it.

Local government is responsible for water quality management in the urban setting. Water quality management is covered in the development assessment processes outlined in the *Sustainable Planning Act 2009* and under broad and specific requirements under the EP Act and the EPP Water. Local government requirements for urban storm water quality management are broad, and fall under the provisions of the *Local Government Act 2009, Environmental Protection Act 1994* and *Sustainable Planning Act 2009.*

**Managing urban land use for water quality**

Urban land use has a complex set of environmental, social, political, and economic factors that need to be managed in an integrated way to achieve water quality improvement outcomes. This is principally due to the high population density of urban areas and the resulting competition for land resources. Recent changes to town planning legislation and new development assessment approaches at the local government level (principally through state legislation) have been adopted to address these factors.

One of the key aspects of early urban town planning was to identify zones for locations of conflicting land uses such as residential and industrial. This is particularly important in the urban context to ensure the health and amenity of the human population is not compromised. It is also critical for the protection of the underlying environmental infrastructure, which supports the ecological functions that underpin community well-being.

Maintenance of biodiversity in the urban setting is closely linked to the ecosystem services that communities require. Given that water is a cornerstone of all life, it follows that good water quality is necessary for both human health and the maintenance of biodiversity. Water quality is a function of ecosystem services that require the protection and maintenance of an appropriate level of environmental infrastructure, for example, natural filtering systems and protective policies and processes. Some urban water quality management and improvement interventions are associated with policy, planning and governance, while others are directly related to the design and incorporation of physical structures in the urban setting during development.

**Updating the Urban ABCD Management Framework**

The 2008 WQIP included the development of ABCD Management Frameworks for agricultural and grazing land practices. At this time a preliminary Urban ABCD Management Framework was also developed. Since 2010, Reef Catchments and the UTT have been working closely with Mackay Whitsunday local government authorities to develop new ways of benchmarking and measuring improvements in urban ecosystem health management through an updated Urban ABCD Management Framework.

In 2010, the UTT members were tasked with examining urban impacts on waterways and developing management strategies to improve waterway health in, and around, urban centres.

As a result of this work, the UTT updated the Urban ABCD Management Framework. The framework was a mechanism to rate management practices within urban centres, and their likely impacts on waterway health. A broad suite of impacts was considered including nutrients, chemicals, sediment and solid waste. Subsequent impacts on waterway health from activities in urban centres were ranked relative to best management practice standards.

**Structure of the Urban ABCD Management Framework**
The Urban ABCD Management Framework was developed around urban management practices for water quality improvement and storm water management. These practices were aligned to implementation and regulatory mechanisms existing within the local government governance structures. Three overarching urban ABCD management areas were defined, and then management practices benchmarked in the Urban ABCD Management Framework, as follows:

1. **Point source water quality:** benchmarking point source water quality management practices, i.e. sewage treatment plants, wastewater treatment plants, and environmentally relevant activities (ERAs);
2. **Diffuse source water quality from planning and construction phase:** benchmarking existing and new development planning and construction management practices on newly cleared or "greenfield" areas; and
3. **Diffuse source water quality from post-construction (operational) phase:** benchmarking existing and new development management practices in the development and building phase.

Under parts 2-3, regional council representatives, in consultation with the Urban Think Tank, reviewed the current state of building and development practices in each subcatchment. Approximate percentages were assigned to show the amount of development which has occurred under each of the ABCD Management Framework categories. Targets for improvement were also set, with strategies for implementation actions aimed to improve water quality. These implementation actions will assist businesses and council staff involved in activities in urban areas to improve their performances under the ABCD Management Framework.

**Local Government Implementation Actions**
Consultation with local government officers from the three regional councils has resulted in a list of priority activities to assist the organisations to make urban land management improvements that align with the Urban ABCD Management Framework.

*Combined Draft Management Actions 2014-2021*

**Diffuse Source Developing Areas**
- Policy, Planning, and Partnerships
  - Provide ongoing support for inclusion of stormwater quality improvement measures and guidance in the planning scheme
  - Incorporate guidelines and Development Manuals into appropriate Planning Scheme Policies (PSP) as they become available
  - Partner with GBR water quality and environmental managers to collaboratively source funding for urban water quality improvement research including socio-economic data and modeling of benefits of urban water quality improvement
  - Develop a set of region specific stormwater quality management guidelines;
- Implementation (incorporating communications and community involvement)
  - Continue participation in the Reef Urban Stormwater Management Improvement Group (RUSMIG) and promote GBR wide projects that will contribute to the provision of business case answers to urban water quality questions;
- Communications and community involvement
  - Continue stormwater quality management training and guideline development
  - Investigate and implement the most appropriate urban stormwater management

behaviour change programs that will assist Council, the development and construction industry and the local community; and

- Monitoring and Evaluation
  - Develop a process to monitor the uptake of effective stormwater quality management measures for all new development
  - Monitor WSUD performances and feed results into the Regional Specific WSUD Guidelines.

**Diffuse Source Existing Urban**

- Policy, Planning and Partnerships
  - Investigate potential retrofit options for water quality improvement in mature urban areas based principally on 'regional' solutions in public open space
  - Strategic assessment of available and priority areas for implementation of combined water quality improvement and flood amelioration measures in the Mackay City catchment (includes Paget industrial area)
  - Develop an integrated open space management system with guidance for management of natural areas and 'grey' zones/transition areas between formal parks and natural areas (Note: Provide guiding principles and strategies with detailed management plans developed over time commencing with priority areas)
  - Prepare a MRC Urban Stormwater Quality Management Plan (will be the overarching framework to the Catchment Management Plans (CMPs))
  - Identify actions in existing/draft CMPs that could be eligible for funding under Reef 2050 Plan/Reef Trust and work collaboratively with Reef Catchments to develop funding submissions for protection and enhancement of urban waters
  - Pursue partnerships with the development industry to incorporate environmental infrastructure protection as a normal part of concept design for new developments
  - Review McCready's Creek CMP and update with regard to completed actions any new requirements since CMP preparation given the progressive development in the catchment
  - Strategic assessment of available and priority areas for implementation of combined water quality improvement and flood amelioration measures in the Whitsunday Regional Council urban catchments (including Airlie Creek, Campbell Creek, Waite Creek, Galbraith Creek)
  - Assist in developing Whitsunday Regional Council (WRC) CMPs, which will prioritise WRC urban catchments for Stormwater Quality Improvement Devices (SQUID's) (potential use for attracting funding/offsets)
  - Assist in reviewing WRC Kelsey Creek Landfill Leachate Recycling Scheme (at the present time WRC uses an irrigation system to reduce the amount of leachate contained in the landfill)
  - Assist in reviewing the potential of an 'Organic Waste Recycling Facility' at WRC Kelsey Creek Landfill (recycling biosolids, organic waste (food scraps, green waste, etc.) to produce agricultural fertilisers;
- Implementation (incorporating communications and community involvement)
  - Identify practical and cost effective methods for reducing the impact of increasing percentage of impervious areas in water catchments i.e. 'disconnecting' impervious areas from formal stormwater systems
  - Review and interpret Waterway Health monitoring program results (2006 to 2013) to provide an indication of trends and pollutant sources and land use/correlation with management practices (Note: Use for business case background, setting strategic direction and improving implementation of management actions)
  - Investigate how an urban Paddock to Reef WQ monitoring program could be implemented potentially as a cross GBR urban collaboration through RUSMIG with GBRMPA and Reef Catchments;
- Communications and community involvement
  - Continue to work with building/construction and development industry to improve their knowledge of erosion prevention and sediment movement control practices (ESC) with

emphasis on erosion prevention (Note: Potential for cross GBR education/ awareness/ training initiative through RUSMIG)
    - Incorporate water quality messages, especially litter and other gross pollutants, into the waste management education program i.e. make the connection between waste/litter and waterways and eventually the ocean
    - Incorporate water quality messages in water conservation education program, especially over use of irrigation which results in runoff to the stormwater system and provides ‘unnatural’ base flow with associated DIN and FRP i.e. soluble nutrients impact local waterways and estuaries; and
- Monitoring and Evaluation
    - Monitor the impacts of fertilisers used in urban areas on urban catchments in the WRC area.

**Point Source**

- Sewage Treatment Plants (STP):
    - Mackay North Water Recycling Facility (MNWRF) (previously referred to as the Bucasia STP):
        - Investigate the potential for land based reuse of treated wastewater from the Mackay North Water Recycling Facility
    - Proserpine Sewage Treatment Plant:
        - Investigate the potential of beneficial reuse of Proserpine Sewage Treatment Plant biosolids (Kelsey Creek Landfill Organic Waste Facility)
    - Cannonvale Sewage Treatment Plant:
        - Investigate the potential of land based reuse of treated wastewater from the Cannonvale Sewage Treatment Plant
        - Investigate the potential of beneficial reuse of Proserpine Sewage Treatment Plant biosolids (Kelsey Creek Landfill Organic Waste Facility).

***Costs of Management Practice Change in Urban Areas***

After consultation with the Urban Think Tank members, approximate costs were determined for the implementation of management practice change affecting water quality in urban areas. The costs were calculated using a base rate per hectare, the target adoption rates over the next seven years, and the number of hectares of urban land area to be managed within each catchment management area. Table 64 shows the costs of attaining the target urban management practice change over the next seven years.

**Table 64: Cost of diffuse source water quality management practice change in urban areas by receiving water, over the next seven years.**

| | Edgecumbe Bay | Whitsunday Coast | Repulse Bay | Seaforth Coast | Sandringham Bay | Sarina Inlet | Ince Bay | Carmila Coast | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| **PLANNING & CONSTRUCTION PHASE** | N/A | $1,135,000 | $2,811,000 | $1,608,000 | $6,809,000 | $1,753,000 | $507,000 | N/A | **$14,623,000** |
| **POST-CONSTRUCTION PHASE** | N/A | $1,135,000 | $2,811,000 | $1,663,000 | $6,150,000 | $1,753,000 | $507,000 | N/A | **$14,019,000** |
| **Subtotal** | $0 | $2,270,000 | $5,622,000 | $3,271,000 | $12,959,000 | $3,506,000 | $1,014,000 | $0 | **$28,642,000** |

# 13. Management Interventions to Improve Ecosystem Health

Management interventions to improve ecosystem health are described below. The management interventions were developed to address current threatening processes and to achieve the FEHT presented in Chapter 11. The management interventions presented in Table 65 have been selected for the significant benefit they provide to ecosystem health and will be used to guide investment for the improvement of ecosystems in the region.

**Table 65 Priority management interventions to improve ecosystem health.**

| | |
|---|---|
| **Riparian Management** | ▪ Restoration of actively eroding banks through stabilisation works and vegetation restoration<br>▪ Restoring riparian vegetation through planting pioneer riparian species<br>▪ Riparian vegetation rehabilitation through weed and pest animal control activities<br>▪ Waterway restoration including control of water weeds |
| **Fish Community Health** | ▪ Restoration of actively eroding banks through stabilisation works and vegetation restoration<br>▪ Restoring riparian vegetation through the establishment of pioneer riparian plantings<br>▪ Riparian vegetation rehabilitation through weed and pest animal control activities<br>▪ Improvements to fish habitat by controlling waterweeds and re-introducing aquatic habitats including lunker structures and large woody debris.<br>▪ Removal of barriers to fish migration through implementation of fish ways and the modification of culverts and road crossings<br>▪ Improve water quality (Nutrients, TSS and Herbicides) through the implementation of B & A class Sugarcane, Grazing & Horticulture management practices. |
| **Flow** | ▪ Provide information to irrigators and water extractors on ecological drawdown levels on non WRP regulated waterways. |
| **Seagrass** | ▪ Restoration of actively eroding banks through stabilisation works and vegetation restoration<br>▪ Improve water quality (Nutrients, TSS and Herbicides) through the implementation of B & A class Sugarcane, Grazing & Horticulture management practices. |
| **Coral** | ▪ Restoration of actively eroding banks through stabilisation works and vegetation restoration<br>▪ Improve water quality (Nutrients, TSS and Herbicides) through the implementation of B & A class Sugarcane, Grazing & Horticulture management practices. |
| **Ambient & Event Water Quality** | ▪ Implementation of B & A class Sugarcane, Grazing & Horticulture management practices. |

# 14. Prioritisation of Management Interventions

A major focus of this WQIP is to identify the issues impacting water quality within the region's freshwater, coastal and marine environments. The impacts affect the social, economic, and environmental status of the region. This plan presents a range of management actions designed to improve water quality, halt the decline of ecosystem health degradation, and maintain and improve the region's EVs (see Chapter 7).

To ensure investment into the region for the maintenance or improvement of water quality, aquatic ecosystem health, and EVs are utilised most effectively, a range of prioritisation tools are utilised. The three main tools used are:

- System Repair and Water Quality Management Priority Locations;
- Reef Catchments Water Quality Prioritisation Database; and
- GBRMPA Blue Maps;
- GBRMPA EcoCalc Scores.

These tools identify issues impacting water quality and ecosystem health and identify the most effective and efficient ways to address these issues. The tools are used to prioritise the type and location of management actions and assess their cost effectiveness.

The decision-making process to determine where works should be prioritised focuses firstly on the System Repair and Water Quality Management Priority Locations, which determine catchments of highest priority for water quality and ecosystem health works. The next step utilises the Reef Catchments Water Quality Prioritisation Database to identify the best onground benefit compared to investment cost. Lastly, in the instance that the Database provides multiple results with equal benefit compared to cost, the Blue Maps guide which area should be worked in based on the connectivity to the marine environment.

In addition to these three main tools, GBRMPA's EcoCalc system is also used. The EcoCalc method is linked to the Blue Maps and provides further detail on the current status of a range of processes within the eight receiving waters.

Further details on the tools utilised to prioritise activities are provided below.

## 14.1. System Repair & Water Quality Management Priority Locations

The System Repair & Water Quality Management Priority Locations map (Figure 15) has been developed to provide a level of regional prioritisation to focus (predominantly) water quality and ecosystem health implementation activities in CMAs that will provide the greatest benefit.

The map identifies water quality management priority CMAs - those CMAs with the poorest water quality. These areas are not a priority for ecosystem health improvement but are a high priority for activities that improve water quality. These catchments have a significant impact on the marine environment through high pollutant concentrations and loads.

The map also identifies catchments with waterways of greatest ecological value in the region. These become the primary priority areas for the implementation of ecosystem health maintenance and improvement activities. Additionally, the map identifies areas of secondary priority for the implementation of ecosystem health activities and water quality improvements that are both required to improve overall ecosystem health.

## 14.2. Reef Catchments Water Quality Prioritisation Database

For the past ten years Reef Catchments has been prioritising investment from the Sustainable Landscapes Program, Reef Rescue, Reef Programme and System Repair Programme with the use of a Microsoft Access programme developed by the Mackay Whitsunday NRM Group in association with Screen Smart.

The Reef Catchments Water Quality Prioritisation Database has played a pivotal role in

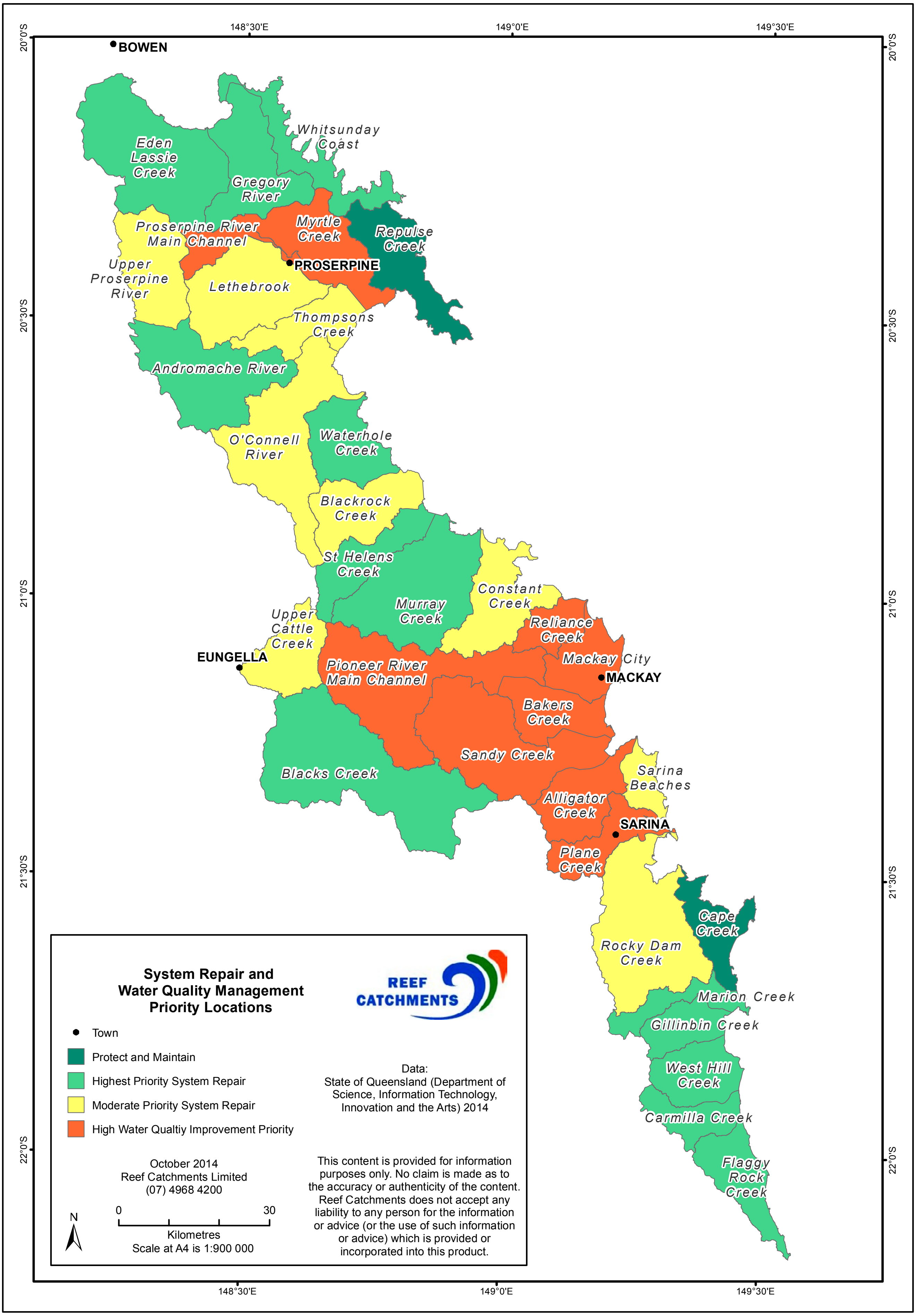



Figure 15 Mackay Whitsunday System Repair and Water Quality Management Priority Locations.

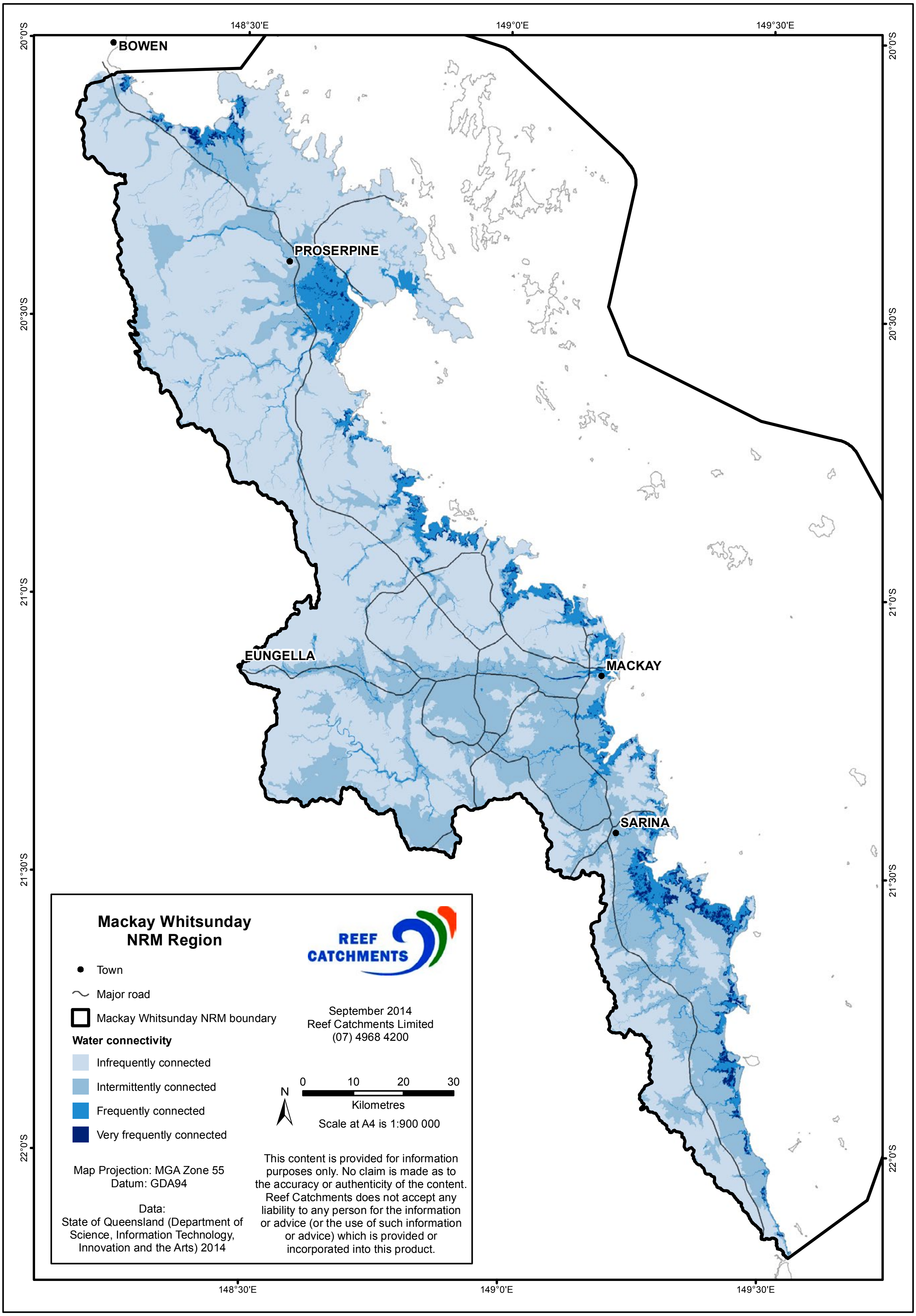



**Figure 16 Mackay Whitsunday Blue Map.**

**Figure 17 EcoCalc Scores for Sandringham Bay.**

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | G | M | P | M |
| Flood mitigation | G | M | P | M |
| Potentially connects aquatic ecosystems | G | M | P | M |
| Regulates waterflow — groundwater | G | M | M | M |
| Regulates waterflow — overland flows | G | M | M | M |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | G | G | M | M |
| Retain fine sediments | G | G | M | M |
| Releases fine sediments slowly | G | M | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | VG | G | M | M |
| Retain coarse sediments | VG | G | M | M |
| Releases coarse sediment slowly | VG | G | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | G | M | G |
| **PRODUCTION** | | | | |
| Primary production | G | G | G | G |
| Secondary production | G | M | VG | VG |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | M | G | G |
| Uptakes nutrients | G | G | VG | G |
| Regulates nutrients | G | M | P | M |
| **CARBON** | | | | |
| Carbon source | G | G | G | G |
| Sequestors carbon | G | M | P | M |
| Regulates carbon | G | M | M | M |
| **REGULATION** | | | | |
| Salinity regulation | G | G | G | G |
| Regulates temperature | G | G | VG | G |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | G | G | M | G |
| Habitat for terrestrial spp connections reef | VG | G | M | G |
| Food source | G | G | P | G |
| Habitat ecologically important for animals | G | G | P | G |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | G | G | P | G |
| Pathway migratory fish | G | G | VG | M |
| **POLLINATE** | | | | |
| Pollination | G | G | M | VG |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | G | G | VP | M |

Very Good | Good | Moderate | Poor | Very Poor

**Very Frequently**

Target ponded pastures (86ha), woodlands grazing (16ha) and grazing estuaries (22ha).

**Frequently**

Target grazing rainforests (520 ha) and woodlands (604 ha), ponded pastures (263 ha), irrigated sugar (815ha) and grazing (541 ha).

**Intermittently**

Target grazing forested floodplains (5999 ha) and forests (13,776 ha), forest forestry (4906ha), irrigated sugar (71,603 ha) grazing (12,457 ha) and intensive uses( 4373 ha).

**Infrequently**

Target grazing in forests (27,890 ha) and rainforests (2900 ha), forestry in forests (19,236 ha) and rainforests (14,203 ha), grazing (10,190 ha), irrigated sugar (9952 ha) and intensive uses.

prioritising sugarcane, horticulture, grazing, and ecosystem health improvement projects using complex equations that take into account a large range of factors, including soil type, project area, surrounding biodiversity status, cost of project, ABCD framework improvements, and land class for riparian zones. The ability of the database to prioritise projects, taking into account all these factors, has enabled an objective method of evaluating projects while ensuring a defined water quality improvement outcome for investors.

The database is continually updated and fine-tuned to incorporate new knowledge, such as the effectiveness and cost of management activities. Updates are communicated to investors and the regional sugarcane, grazing, and horticulture working groups to maintain their endorsement of the database.

### 14.3. GBRMPA Blue Maps

To provide additional resolution for the prioritisation of management activities within CMAs, Reef Catchments utilises the GBRMPA's Mackay Whitsunday Blue Map and associated Connectivity Scores (GBRMPA 2013).

The Blue Maps were developed by GBRMPA through a series of workshops to categorise catchments, coastal ecosystems, and inshore marine ecosystems based on the physical, biogeochemical, and biological processes that support the biodiversity and ecological processes of the GBR and associated WHA.

A range of data was analysed by GBRMPA for the development of the Blue Maps, including:

- The Queensland Reconstruction Authority (QRA) Floodplain;
- The Queensland Wetlands Program wetclass (a grouping of soil type, regional ecosystem, etc.);
- Wet ecosystem signatures (regional ecosystems);
- Storm surge; and
- Highest astronomical tide. (GBRMPA 2013)

This data was analysed and combined to provide a "blue score" (from 1-5) of the level of temporal and spatial influence of marine and freshwater over the coastal ecosystems areas. Scores were then grouped based on similar attributes. The blue score allows identification of areas that are most connected to the GBRWHA, and therefore likely to be providing significant ecosystem services and functions.

The Mackay Whitsunday Blue Map (Figure 16) breaks up the region according to the blue score attributed; it identifies areas in the region that connect coastal ecosystems to the marine environment from geological and/or hydrological processes. The darker the mapped area, the more connected (spatially and geographically) the area is to the marine environment.

The Blue Map is used to prioritise locations of management actions that will have an increased beneficial outcome due to being within a geological or hydrological connected location.

### 14.4. GBRMPA EcoCalc Scores

The EcoCalc scores are derived using the calculator designed by GBRMPA to assess ecological functions within the landscape and accompany GBRMPA Blue Maps. The EcoCalc incorporates a range of data, including land uses and ecological functions occurring within each land use. For each of the eight receiving waters, the EcoCalc has provided scores for different ecosystem processes, according to the level of connectivity determined by the Blue Map (Figure 16). The resulting EcoCalc Score is relative to the ecological processes that would have existed in the same area pre-clearing.

A number of processes (Figure 17) within each of the following categories are assessed and given an EcoCalc score:

- Recharge discharge processes;
- Sedimentation (fine and coarse);
- Material transport;

- Production;
- Nutrients (source, uptake, regulation);
- Carbon (source, sequestration, regulation);
- Salinity and temperature regulation;
- Habitat for species survival;
- Dispersal of species;
- Pollination; and
- Recruitment.

A score is given for each process occurring within the above categories, for each level of connectivity (infrequently connected, intermittently connected, frequently connected, and very frequently connected; see Figure 17). For example, Figure 17 shows that in Sandringham Bay, the ecosystem process associated with trapping of fine sediments is currently good in waterways that are very frequently or frequently connected, but only moderate in waters that are intermittently or infrequently connected, compared to pre-clearing. The EcoCalc results from all eight receiving waters are presented in Appendix B.

As the EcoCalc method takes into account land use, the results can be used as a tool to determine the types of works that are required on what type of land to improve the ecological processes. In the very frequently connected areas of Sandringham Bay, ecological processes can be improved by improving land management on 34 ha of urban area and 65 ha of ponded pastures. In frequently connected areas in Sandringham Bay, targeting land management improvement on 800 ha of sugarcane land, 327 ha of urban land and on grazed woodlands would improve ecological function (Figure 17).

The EcoCalc scores and outputs guide where to focus improvements to gain most improvement in ecological function based on the connectivity to the marine environment.

# **15.** Adoption Targets and Costs

This chapter provides detail on the proposed adoption targets and the associated costs for the adoption of the agricultural and ecosystem health management interventions. The chapter also includes a discussion on social barriers relevant to the adoption of management changes.

## 15.1. Agricultural and urban adoption targets and costs

This WQIP recommends, across the region, an increased adoption rate (from D/C to B/A practices) of 16% for improved management of nutrients in sugarcane and horticulture. This adoption rate is expected to have a corresponding reduction of regional DIN loads of 12% and FRP by 8% by 2021 (Section C: Targets and Objectives). An increased adoption rate of 10% for improved sugarcane and horticulture herbicide practices will likely reduce herbicide loads by 10-20%.

Similarly, an increased adoption rate of improved soil management of 13% in grazing and 9% in sugarcane and horticulture is recommended across the region. Modelling predicts that these adoption rates are likely to reduce particulate parameters (PN, PP, and TSS) by 14-16% by 2021. Adoption of improved management practices is very dependent on sufficient resources, uptake by land managers and industry leadership. Refer to Chapters 12 and 15 for further information.

Total on-ground costs of implementing soil, nutrient, and herbicide management practices for grazing, sugarcane, horticulture and urban for each receiving water and the region are presented in Table 66. The estimated total on-ground cost of increasing management practice adoption rates to a level that will achieve load reduction targets is $64.8M by 2021.

**Table 66 Total on-farm costs of implementing soil, nutrient, and herbicide management practices for grazing, sugarcane, horticulture and urban across the region and receiving waters. Some figures have been rounded.**

| | | Total Cost $'000s | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mackay Whitsunday | Edgecumbe Bay | Whitsunday Coast | Repulse Bay | Seaforth Coast | Sandringham Bay | Sarina Inlet | Ince Bay | Carmila Coast |
| **Sugarcane and Horticulture** | **Soil** | 4200 | 23 | 3 | 135 | 228 | 3320 | 34 | 137 | 320 |
| | **Nutrient** | 9890 | 162 | 8 | 1460 | 1630 | 5090 | 208 | 657 | 673 |
| | **Herbicide** | 5990 | 30 | 8 | 1450 | 1240 | 2490 | 60 | 401 | 307 |
| **Grazing** | **Soil** | 16100 | 577 | 13 | 4880 | 108 | 6840 | 360 | 1130 | 2220 |
| **Urban** | **Soil / Nutrient** | 28640 | 0 | 2220 | 5620 | 3270 | 12960 | 3510 | 1010 | 0 |
| **Total** | | **64800** | **792** | **2250** | **13550** | **6480** | **30700** | **4170** | **3340** | **3520** |

The estimated total on-farm cost of implementing soil and nutrient management practices for grazing is $16M. The estimated total on-farm cost of implementing soil, nutrient and herbicide practices for sugarcane and horticulture is $20M. The estimated total on-ground cost of implementing soil and nutrient management practices for urban (includes existing and new development, and infrastructure maintenance for two years of new developments) is $29M.

Adoption rates of improved management practices vary for these estimates in some catchments, and is very dependent on sufficient resources by 2021. Details of costs for each catchment management area are presented in the Catchment Management Reports and Receiving Water Modules at the end of this report.

## 15.2. Ecosystem health adoption targets and costs

To achieve the ecosystem health targets set within this plan, a range of ecosystem improvement activities will be required largely within the region's highest priority and system repair subcatchments (Figure 15). Further detail on the types of activities required to achieve ecosystem health targets can be seen in Chapter 13.

The total on-ground cost to implement bank stabilisation, vegetation restoration, fish habitat structures, and fish barrier removal activities is estimated to be $ 19,295,700 (Table 67). Nearly four hundred (384) ha of riparian restoration and one hundred and twenty-three (123) km of bank stabilisation will be required to be completed by 2021. Twenty-four barriers to fish migration will need to be abated and will require construction of fishways and the modification of culverts, road crossing and pump holes at a cost of $1,185,000.

**Table 67 Total cost of implementing ecosystem health improvement activities across the region. Some figures have been rounded.**

| Ecosystem Management Category | Ecosystem Improvement | Quantity | Cost $ |
|---|---|---|---|
| **Riparian Management** | Bank Stabilisation | 123 kilometres | 12,431,587 |
| | Vegetation Restoration | 384 hectares | 4,995,756 |
| **Fish Community Health** | Habitat Structures | 35 structures | 683,360 |
| **Barriers to Fish Migration** | Fishways | 24 structures/ modifications | 1,185,000 |
| | | **Total** | **19,295,700** |

### 15.3. Barriers to change

To reach the water quality targets identified in this WQIP (Chapters 9 and 10) the continued adoption of improved management practices is essential. However, there are many barriers to the adoption of new practices. Literature shows that adoption of new practices is a slow process taking upwards of 20 years without intervention, from the early innovators to wide spread adoption (Rolf 2013). The adoption of best management practices are often part of the landholders' longer-term planning with time and finances as limiting factors. For widespread rapid adoption to occur, the drivers of adoption need to be addressed.

Recent research identified six key drivers of adoption, which need to be addressed to promote the continued adoption of best management practices. The drivers of adoption included: cost or farm finances; social factors; information source; incentives provided; personal motivation; and market-based drivers (Ecker et al. 2012).

A recent social survey of Mackay sugarcane growers conducted in 2014 by Reef Catchments largely confirmed the findings in Ecker et al. (2012) with cost identified as the single largest factor when considering the adoption of new practices. Environmental and social considerations were also identified as key drivers of change with a small proportion of landholders saying they have no desire to adopt new practices.

Previously, the Australian Government's Reef Rescue program (2008 – 2013) and now the Reef Programme (2013 – 2016) has been effective at promoting the uptake of improved management practices by providing an incentive to landholders to implement practices or build infrastructure, which will improve water quality. Under this program landholders can be funded up to 50% of the total cost of a project that had identified water quality outcomes i.e., practices highlighted in the ABCD Management Frameworks.

Evaluation of the program by Reef Catchments has highlighted that the cost of adoption is the single largest consideration by landholders when considering implementing new practices. Landholders have highlighted that if an incentive of less than 20% was offered, then the cost of implementation would be too great or that change would happen over a greater timeframe.

To continue adoption of best management practices it is essential for stakeholders to improve water quality. To achieve this, key recommendations include:

- Reduce the cost of adoption through effective incentive based mechanisms. For raised adoption of best management practices, programs such as the Reef Programme should be continued and expanded;
- Continue to provide the opportunity for landholders to network and share ideas through workshops and forums. This includes cross regional approach and cross industry to ensure widespread knowledge sharing;
- Stakeholder organisations such as NRM bodies, key industry organisations, and government need to communicate a shared vision and collectively work together through frameworks which highlight effective strategies for the improvement of water quality;
- Extension to promote and increase farm efficiency, which will improve the bottom line of many enterprises. This will allow for more farm investment into the adoption of best practices. Also, continued investment of cost benefit analysis to highlight to landholders the benefits of new practices; and
- Effective market based drivers will provide rapid adoption of new practices by limiting market outlets for products until a desired minimum standard is achieved by suppliers e.g. BONSUCRO certification.

### 15.4. Comparison of WQIP to Reef Plan and Reef 2050 Long-term Sustainability Plan targets

Reef Plan (refer to Chapter 2.1.1 for details) outlines water quality reduction targets to be achieved by 2018. The recently published Reef 2050 Long-term Sustainability Plan has also adopted these 2018 targets as a progress toward 2025 targets.

- At least a 50% reduction in anthropogenic loads end-of-catchment dissolved inorganic nitrogen loads in priority areas;
- At least a 20% reduction in anthropogenic end-of-catchment loads of sediment and particulate nutrients in priority areas; and

To achieve the ecosystem health targets set within this plan, a range of ecosystem improvement activities will be required largely within the region's highest priority and system repair subcatchments.

- At least a 60% reduction in end-of-catchment pesticide loads in priority areas (refer to Table 39).

The 2014-2021 WQIP has used the modelled predevelopment load (Packett et al. 2014), regional 2014 current condition and expected load reductions by 2021 due to improved land management practices and ecosystem health to compare to the 2018 targets outlined in Reef Plan (Table 68).

**Table 68 Comparison of loads, reductions, 2021 WQIP targets and 2018 Reef Plan targets.**

| | Implementation cost ($000's) | DIN (t/yr) | PN (t/yr) | FRP (t/yr) | PP (t/yr) | TSS (t/yr) | Cumulative herbicides (kg/yr) |
|---|---|---|---|---|---|---|---|
| **Predevelopment load** | | **273** | **406** | **52** | **124** | **151,000** | **0** |
| **Current load (2014)** | | **1,560** | **1,430** | **263** | **529** | **429,900** | **5,604** |
| **Anthropogenic load** | | **1,287** | **1,024** | **211** | **405** | **278,900** | **5,604** |
| **POLLUTANT REDUCTIONS DUE TO:** | | | | | | | |
| **Land management practices (cane, horticulture and grazing)** | $36202 | 194 | 198 | 29 | 82 | 42,100 | 916 |
| **Urban** | $28642 | 2 | 4 | <1 | 1 | 649 | 0 |
| **Catchment system repair – riparian** | $5147 | <1 | 11 | <1 | 2 | 1,060 | 0 |
| **Catchment system repair – bank stabilisation** | $12908 | <1 | 468 | <1 | 94 | 46,800 | 0 |
| **Total pollutant reduction** | | 196 | 681 | 29 | 179 | 90,609 | 916 |
| **WQIP 2021 target (% anthropogenic reduction)** | | 15 | 67 | 14 | 44 | 32 | 16 |
| **Reef Plan 2018 target (% anthropogenic reduction)** | | 50 | 20 | | 20 | 20 | 60 |

Using a combination of improved land management practices and stream bank stabilisation techniques, the modelled particulate (TSS, PN and PP) reductions will meet Reef Plan targets for those parameters.

In contrast, the proposed DIN and pesticide load reductions will not meet the Reef Plan targets. Modelling has shown that sugarcane contributes 65% of the regional DIN load (and the vast majority of pesticide loads), but only 19% of the land in the region is under sugarcane. As a result, only sugarcane was targeted for management intervention to reduce DIN and pesticide loads.

As outlined in Chapter 12, on-farm management practices are continually evolving and improving. What may be considered a C class practice in 2014 may be a B class practice by 2021. This is due to the agricultural industry largely adopting what were once higher-level management practices as becoming common within the industry. As such, further reductions in DIN and pesticide loads (beyond what is modelled in this WQIP) may be achievable as practices evolve and become common practice.

# SECTION E

## Monitoring and Management

This section follows on from all previous sections and is designed to present a framework for future monitoring and management requirements. A range of ambient and event-based water quality and ecosystem health monitoring will be undertaken to support the implementation of the 2014-2021 WQIP. These programs, the scheduling of works, and the associated costs are presented in this section. The results of the monitoring will be used to inform ongoing works and continually aim to improve water quality and ecosystem health in the region.

# 16. Monitoring Plan

The range of ambient and event-based water quality and ecosystem health monitoring proposed to be undertaken in the implementation phase of the 2014-2021 WQIP are discussed below. All monitoring will be done in accordance with best practice methodology and any relevant guidelines.

## 16.1. Proposed monitoring projects

The monitoring projects below have been proposed to provide information relevant to the WQIP implementation on:

- Measurement of the adoption of improved management practices;
- Determination and validation relationships between improved management practices, water quality improvement, and ecosystem health;
- Measurement of change in water quality and ecosystem health; and
- Investigation of water quality issues of concern to the community, as part of ongoing community-related activities in the region.

Table 69 below shows how the different monitoring projects relate to the different WQIP functions, with some monitoring projects providing information for multiple WQIP purposes. The following text provides further detail on the projects proposed under each WQIP function and what they will entail.

**Table 69 Proposed monitoring locations to validate freshwater quality and ecosystem health relationships in the Mackay Whitsunday region.**

| WQIP function | Proposed project |
|---|---|
| Measure the adoption of improved management practices | Management practice adoption |
| Determine and validate relationships between improved management practices, water quality improvement and ecosystem health | Paddock-scale monitoring, Sandy Creek (led by DNRM)<br>Rainfall simulation program of management practices<br>Water quality – marine<br>Water quality – freshwater |
| Measure change in water quality and ecosystem health | Macro-invertebrate community assessment<br>In-stream habitat assessments<br>Wetlands – freshwater risk assessment and condition monitoring<br>Estuarine fish community assessments<br>Freshwater fish community assessments<br>Water quality – marine<br>Water quality – freshwater |
| Investigate water quality issues of concern to the community* | Water quality – freshwater<br>Water quality – marine<br>Freshwater fish community assessments |

*It is anticipated that the most likely issues of concern to the community will be regarding water quality (both freshwater and marine) and freshwater fish. As shown in Table 69 above, these components are incorporated under other WQIP functions, so they are presented only once in the following text and costings table. Any other issues of concern to the community are currently unable to be anticipated or costed, and would occur in response to issues raised at the time.

### 16.1.1. Measure the adoption of improved management practices

*Management Practice Adoption*

The adoption of improved management practices will be measured using the ABCD

Management Frameworks. These frameworks provide standard definitions for the progression of improvements to water quality from D class ("dated") management practices with the lowest corresponding water quality outcomes, through C class ("conventional" or "common"), B class ("best management") and finally to A class ("aspirational") or as yet unproven management practices. More details of ABCD Management Frameworks are provided in Section 12.

Changes in water quality and aquatic ecosystem health are most likely to be measured and detected at the paddock, farm, or subcatchment scale. Time lags through large catchments and biophysical systems, time for adoption of management practices to occur, and uncertainties associated with the detection of end-of-catchment water quality changes means that a particular focus on paddock to subcatchment scale improvement will be undertaken. Time lags are also caused by climatic variation, storage and transport of pollutants in waterways and groundwater, and biological processing and cycling of pollutants including uptake and release.

Monitoring at these smaller scales is likely to enable a better chance of detecting water quality changes from adoption of management practices than at the larger scales (end-of-catchment). Monitoring of management practices in a range of catchment management areas and different land uses across the region is proposed.

**Table 70 Proposed catchment management areas to undertake monitoring of land management practices.**

| Land Use | Catchment management areas |
|---|---|
| Cane | Myrtle Creek, Sandy Creek, Alligator Creek, and Rocky Dam Creek |
| Grazing | Rocky Dam Creek and Andromache River |
| Urban | Mackay City and Whitsunday Coast |

### 16.1.2. Determine and validate relationships between improved management practices, water quality and aquatic ecosystem health

Further research on the biological effects of pollutants on freshwater and marine ecosystem health is required to ensure the targets developed in the WQIP are appropriate. Proposed monitoring will focus on the indicators identified in the WQIP to determine water quality impacts on aquatic ecosystems. This monitoring will help assess whether the water quality improvement targets developed from local data sources and presented in this WQIP are sufficient to protect ecosystem health.

It is also important to understand responses of key species or communities to water quality indicators for freshwater and estuarine waters.

The proposed monitoring includes:

- Further research into key aquatic ecosystem communities used as indicators of changing water quality;
- Using ecosystem health monitoring data in ecosystem response modelling;
- Validation of relationships between freshwater quality and ecosystem health through ecosystem health monitoring in a range of freshwater systems throughout the Mackay Whitsunday region (Table 71); and
- Monitoring within the range of categories of system repair identified for the Mackay Whitsunday region (Figure 15).

**Table 71 Proposed monitoring locations to validate freshwater quality and ecosystem health relationships in the Mackay Whitsunday region.**

| Watercourse | Catchment management area | Receiving water |
|---|---|---|
| Eden Lassie Creek | Eden Lassie Creek | Edgecumbe Bay |
| O'Connell River | O'Connell River | Repulse Bay |
| Waterhole Creek | Waterhole Creek | Repulse Bay |
| Sandringham Creek | Sandy Creek | Sandringham Bay |
| Alligator Creek | Alligator Creek | Sandringham Bay |
| Rocky Dam Creek | Rocky Dam Creek | Ince Bay |
| Basin Creek | Gillinbin Creek | Carmila Coast |

*Paddock-scale monitoring, Sandy Creek*

The 2008 WQIP prioritised a monitoring program within the Sandy Creek catchment. This program included a multi-farm water quality monitoring program and paddock scale trials to validate improved sugarcane management practices. This program was implemented in 2009/10 through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program. There were two paddock-scale trials (with seven treatments) comparing A and B management practices with C level management practices, a multi-block (~50 ha) monitoring program, and a multi-farm (~3000 ha) monitoring program.

It is proposed that the following components of the program will continue (led by DNRM under the Paddock to Reef Program, with support from Reef Catchments):

- Paddock-scale monitoring will continue at one site (Victoria Plains), with a revised layout beginning with fallow treatments in 2014/15;
- Multi-farm monitoring will also continue; and
- Landholders within the multi-farm catchment (~50) will continue to be surveyed annually to understand the management practices being undertaken, and change in management practices over time.

*Rainfall simulation program of management practices*

A rainfall simulation project will investigate emerging improved nutrient, mill mud and pesticide management practices for water quality impacts across a range of soil types and climatic patterns within the Mackay Whitsunday region.

Trials will address knowledge gaps identified through the Paddock to Reef synthesis process and industry working groups associated with water quality and land management practices. Soil types identified as being commonly used for sugarcane production that have had limited (or no) monitoring undertaken will be targeted in this project.

Where appropriate, the program will connect with existing programs such as the Australian Government's Action on the Ground Carbon Farming Futures, Reef Programme Game Changer and Project Catalyst. Rainfall simulation will be used as an education and extension activity with growers and industry invited to field events.

Four overarching trials are proposed for this program, with multiple treatments per trial:

1. **Improved understanding of mill mud management for water quality**. Treatments will include conventional application, banding on the stool at reduced rates, and banding on the side of the stool at reduced rates. Rainfall simulations will be performed at various timings after application (e.g. 1, 7, 28 and 74 days);

2. **Improved understanding of herbicide management at high risk times (December) using regulated and non-regulated residuals in combination with improved timing and placement.** Imposed treatments will improve the understanding of the newer residual herbicides (e.g. Soccer, Flame and Balance) compared to diuron products, banding of herbicides, various application rates, incorporation of herbicides by irrigation, and various timings after application.

3. **Improved understanding of nutrient management utilising slow release fertiliser and variable rate fertiliser application in combination with soil and yield mapping**. This will provide information on nutrient management activities that complement lower application rates, and are technically feasible and improved water quality. These trials, where possible, will be linked to existing trials undertaken by other programs such as Project Catalyst, Carbon Farming Futures Action on the Ground, and Mackay Area Productivity Services research trials.

4. **Impacts of improved nutrient management in tropical/coastal grazing**. This trial will investigate various pasture utilisation rates on flats and hill slopes with various nutrient applications (high bi-annual rates, low annual rates, slow release fertiliser) on runoff and water quality.

*Water quality – marine*

Marine (flood plume) sampling is proposed to quantify the extent of dispersion of terrestrial pollutants (sediments, nutrients and herbicides) during runoff events, and therefore assess the risk of these pollutants to marine ecosystems. It is anticipated that two flood plumes from the region's two major rivers (Pioneer River and O'Connell River) will be sampled per year.

Photosystem II (PSII) herbicides (ametryn, atrazine, diuron, hexazinone, and tebuthiuron) are frequent contaminants of inshore waters of the GBR. The concentration of these herbicides can be expressed as a PSII herbicide equivalent concentration (PSII-HEq). A PSII-HEq index was developed as an indicator of the risk of exposure to PSII herbicides to express the potential additive toxicological potency associated with the presence of various herbicides acting together. The PSII-HEq index is used for reporting of PSII herbicide concentrations in the Reef Rescue Marine Monitoring Program (MMP).

Routine water quality monitoring as part of the MMP at fixed sites has been conducted using passive sampling techniques. These samplers accumulate chemicals from water via passive diffusion. For the additional monitoring, the use of only one of the two sampling techniques used by the MMP is proposed; namely, SDB-RPS EmporeTM Disk (ED) based passive samplers for relatively hydrophilic organic chemicals such as the PSII herbicides.

Current MMP pesticide monitoring sites in the Mackay Whitsunday region are at Pioneer Bay and Sarina Inlet (both co-located with MMP seagrass monitoring sites) and at Hamilton Island in the outer Whitsundays. Hence, most of the inshore areas of the region, especially the important inshore islands are not monitored for pesticides.

The additional pesticide monitoring is proposed for three fixed sites along each of two transects from river mouths to inshore islands:

- Northern transect: (i) mouth of O'Connell River, (ii) close to one of the Repulse islands, and (iii) close to one of the inner Whitsunday islands, e.g. Pine, Long or Daydream; and
- Southern transect: (i) mouth of Pioneer River, (ii) close to Flat Top or Round Top Island, and (iii) close to Keswick or St Bees Island. The existing MMP site at Hamilton Island would complement the proposed transect as a site further offshore.

Passive samplers need to be regularly exchanged, which is generally achieved by volunteers with easy and regular access to the sampling sites, e.g. tourism operators. The sites above are only a suggestion and final selection would need to be also guided by the ability of volunteers to visit the sites regularly. Volunteers to deploy and retrieve samplers on a regular basis need to be

found by the Healthy Waterways Alliance, and any costs involved with this are not included in the budget estimate below.
This passive pesticide sampling will complement the herbicide sampling in flood plumes proposed under the general freshwater and marine water quality monitoring.

*Water quality – freshwater*
An extensive water quality monitoring program was undertaken to provide baseline data for the 2008 WQIP. Sites were selected (26 in total) to represent water quality from subcatchments dominated by a single land use (forest, sugarcane, grazing, and urban) and mixed land use catchments. These sites were sampled during both ambient and runoff event conditions and samples were analysed for sediments, nutrients and herbicides.

It is anticipated that a selection of these sites (13 in total, sites yet to be determined) will be re-sampled during the implementation of this WQIP. This will assess the water quality change since the 2008 WQIP and the improvement in water quality during the implementation of the current WQIP.

In addition to the marine monitoring of the PSII herbicides, monitoring of PSII herbicides in the freshwater environment will be conducted. Pesticide concentration data collected from water quality monitoring sites for ambient and event monitoring will be analysed for the additive toxicity effects, using the multi-substance potentially affected fraction (ms-PAF method).
The ms-PAF method assesses the impact of mixtures of herbicides (rather than assessing individual herbicides in isolation). This method provides a more comprehensive assessment of the potential ecological impacts of herbicides that occur at the same time and have the same mode of action (e.g. PSII herbicides). The ms-PAF method will be used to assess the ecological effects of mixtures of these herbicides. For further information on the ms-PAF method, refer to Delaney et al. (2014).

### 16.1.3. Measure change in water quality and ecosystem health

*Macro-invertebrate community assessment*
Macro-invertebrates are abundant and diverse, but also sensitive to changes in water quality, flow regime, and habitat conditions. For these reasons they are used to assess river health under the AusRivAS (Australian River Assessment Scheme) model. Impacts on these animals are relatively long lasting, and can be detected for some time after the impact occurs.

Complementing the water quality and chemical analyses monitoring proposed for the Mackay Whitsunday region, a bi-annual assessment of the macro-invertebrate communities is planned for five streams in the Mackay Whitsunday region (Repulse Creek, O'Connell River, Sandy Creek, Gillinbin Creek, and Carmila Creek; three sites in each). The macro-invertebrate assessment will use the bioassessment methodology adopted by the Freshwater Biological Monitoring Unit of DNRM. This is the same protocol used by the Queensland AusRivAS models (Simpson et al. 1997) and is adapted from the River Bioassessment Manual (Davies 1994).

The 2014-2021 WQIP monitoring will include the following (in accordance with the sampling protocol for Queensland rivers and streams):

- A minimum of two sample sets in one year;
- Sampling conducted on a seasonal basis from October to December (spring; early wet, when flow has been established for at least four weeks) and May to July (autumn; late wet, when flows have declined to a sampleable level without significant flood peaks);
- Detailed field sheets completed for each site and each sample; and
- Water quality monitoring will be undertaken in conjunction with this sampling, during each sampling visit.

### *In-stream habitat assessments*

In-stream habitat assessments will be undertaken (annually and three-yearly; Table 72) to characterise the habitat in relation to other physical, chemical and biological factors that describe water quality conditions. Indicators used to assess in-stream habitats will include:

- Area of woody debris;
- Area of aquatic macrophyte cover (both submergent and emergent);
- Presence/absence of aquatic macrophytes, particularly those species that have low tolerances to environmental disturbances;
- Area of invasive submergent and emergent aquatic macrophytes;
- Length of undercut banks; and
- Area of riffles.

In-stream habitats will be assessed along a 500 m stretch of watercourse in the upper, middle and lower reaches of each stream (as identified in Table 72). Each site will contain a representative sample of the predicted habitats for each reach, and where possible, correspond with fish sampling sites. Assessments will be undertaken after the wet season, as large flow events have the greatest impact on the creation of habitats.

**Table 72 Catchment management areas and frequency of sampling for in-stream habitat assessments.**

| Catchment land use | Annual sampling | Sampling every three years |
|---|---|---|
| **Bushland (<2% sugarcane)** | **Repulse Creek** | Upper Proserpine River, Eden Lassie Creek, Cape Creek, Whitsunday Coast, Blacks Creek |
| **Grazing (2-4% sugarcane)** | **Gillinbin Creek** | Waterhole Creek, Andromache River, Gillinbin Creek |
| **Grazing + sugarcane (5-19% sugarcane)** | **Gregory River** | Flaggy Rock Creek, Sarina beaches, Thompson Creek, O'Connell River, West Hill Creek, Upper Cattle Creek, Marion Creek, St. Helens Creek, Constant Creek |
| **Sugarcane/grazing (20-39% sugarcane)** | **Carmila Creek** | Lethebrook, Plane Creek, Rocky Dam Creek, Murray Creek, Blackrock Creek, Myrtle Creek, Proserpine River main channel, Mackay City, Reliance Creek |
| **Sugarcane (>40% sugarcane)** | **Sandy Creek** | Pioneer River main channel, Alligator Creek, Bakers Creek |

### *Wetland (freshwater and estuarine) assessments*

Wetland assessments will be undertaken in conjunction with the GBR catchment wetlands risk assessment and condition monitoring project and comprise:

- Broad-scale risk assessment;
- Detailed risk assessment of individual wetlands; and
- General assessment and condition monitoring.

The freshwater wetland broad-scale risk assessment will use existing GIS spatial information (e.g. land use, hydrology, etc.) and apply the Queensland risk assessment and condition framework to provide an understanding of risk to freshwater wetlands flowing into the GBR. The outputs of the broad-scale risk assessment will be used to prioritise sites for a more detailed risk and condition assessment for freshwater wetlands of the Mackay Whitsunday region.

The detailed risk assessment will involve collection of more specific stressors otherwise uncaptured using the spatial layers (e.g. feral animal disturbance) and condition indicators (e.g. water quality). Estuarine wetlands are not included in the GBR wetlands risk assessment project; however they will also be assessed for risk and condition (subject to funding). Detailed risk and condition monitoring will occur at least twice a year during both wet and dry seasons.

Where possible, selected sites will align with other water quality and ecosystem health monitoring sites. It is expected that 10-20 wetlands will have detailed risk assessment and condition monitoring undertaken.

*Estuarine fish community assessments*

Fish community condition and assessment surveys give a greater understanding of the fish communities present in the region and identify critical habitat requirements essential for their long-term survival. Indicators used to assess fish community condition in the estuarine environment include:

- Fish catch rates;
- Observed vs. predicted fish species; and
- Classification analysis prior to monitoring.

The following activities are proposed to assess fish community condition in estuarine areas:

- Gill, seine and cast netting will be used to undertake the assessment in the upper, middle and lower reaches of each estuary (Table 73 below);
- A suitable effort will be applied in a variety of habitats, with sampling occurring post-wet season (April/May) when estuaries are at their most diverse; and
- Cluster analysis will be used to assess the impact of catchment land use on the estuarine fish communities.

**Table 73 Estuarine sampling catchment management areas and frequency of sampling for estuarine fish community condition.**

| Catchment land use | Annual sampling | Sampling every three years |
|---|---|---|
| **Bushland (<2% sugarcane)** | **Repulse Creek** | Eden Lassie Creek, Cape Creek, Whitsunday Coast |
| **Grazing (2-4% sugarcane)** | **Gillinbin Creek** | Waterhole Creek |
| **Grazing + sugarcane (5-19% sugarcane)** | **Gregory River** | Flaggy Rock Creek, Sarina Beaches, Thompson Creek, O'Connell River, West Hill Creek, Marion Creek, St. Helens Creek, Constant Creek |
| **Sugarcane/grazing (20-39% sugarcane)** | **Carmila Creek** | Lethebrook, Plane Creek, Rocky Dam Creek, Murray Creek, Blackrock Creek, Proserpine River, Mackay City, Reliance Creek |
| **Sugarcane (>40% sugarcane)** | **Sandy Creek** | Pioneer River, Alligator Creek, Bakers Creek |

*Freshwater fish community assessments*

Similar to the estuarine fish communities, assessing freshwater fish communities helps identify critical habitat requirements essential for long-term survival of fish communities. Indicators used to assess fish community condition in the freshwater environment include:

- Fish catch rates;
- Number of introduced fish species; and
- Observed vs. predicted fish species.

It is proposed that electrofishing of the upper, middle and lower reaches of each catchment (Table 71) will be undertaken using either boat mounted or backpack electrofishing equipment. Each site will receive a maximum of 6x300 second shots in a variety of habitats, with sites being sampled pre-wet season (October/November) when rivers generally have stable flows.

## 16.2. Proposed schedule

As outlined in the above text, the proposed projects will be undertaken at varying intervals with differing levels of effort required, dependent on the attributes being measured. For example, monthly water quality monitoring is regular but with low effort, while undertaking fish community surveys across the 33 subcatchments is high effort during only the dry seasons of years one, four, and seven. The timing and effort required for all proposed projects is summarised in Table 74.

## 16.3. Reporting and use of monitoring data

The proposed monitoring projects cover a vast array of assessments, both spatially and temporally. It is anticipated that each project will contribute to a Driver, Pressure, State, Impact, Response (DPSIR) model framework.

A DPSIR framework could be summarised as:

- **Drivers**, such as agriculture, industry and urban practices, produce
- **Pressures** on the environment, such as nitrogen and pesticide runoff, which then degrade the
- **State** of the environment, which then
- **Impacts** on in-stream habitats, macro-invertebrates and fish communities, causing society to
- **Respond** with various measures, such as incentives and funding programs which can be directed at any part of the system.

Outputs will be reported and updated annually as more data are collected, analysed and interpreted.

The results of the monitoring programs described above will provide information on the 33 subcatchments and the eight receiving waters. This information will include current condition, and provide a means to determine if the condition is changing from previous state. This will inform the DPSIR framework and, in turn, influence ongoing management activities and prioritisation undertaken and supported by Reef Catchments (refer to Chapter 17).

## 16.4. Estimated costs

The estimated costs to undertake the range of monitoring activities outlined in this section are summarised in Table 75**.** These are estimated, and will require re-evaluation once sites and specific monitoring details are known.

**Table 74 Summary of timing and effort required for each proposed monitoring project**

| | Year 1 | | | | Year 2 | | | | Year 3 | | | | Year 4 | | | | Year 5 | | | | Year 6 | | | | Year 7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Management practice adoption** | | | | H | | | | H | | | | H | | | | H | | | | H | | | | | | | | H |
| **Rainfall simulation** | | | | | H | M | | | H | M | | | H | M | | | H | M | | | H | M | | | H | M | | |
| **Water quality – marine** | | | H | M | | | H | M | | | H | M | | | H | M | | | H | M | | | H | M | | | H | M |
| **Water quality – freshwater** | L | M | H | M | L | M | H | M | L | M | H | M | L | M | H | M | L | M | H | M | L | M | H | M | L | M | H | M |
| **Macroinvertebrate communities** | H | | H | | H | | H | | H | | H | | H | | H | | H | | H | | H | | H | | H | | H | |
| **In-stream habitat** | | | | H | H | | | L | L | | | L | L | | | H | H | | | L | L | | | L | L | | | H |
| **Wetlands – estuarine risk assessment** | H | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Wetlands – freshwater risk assessment** | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L | H | L |
| **Estuarine fish communities** | | | | H | H | | | L | L | | | L | L | | | H | H | | | L | L | | | L | L | | | H |
| **Freshwater fish communities** | | | | H | H | | | L | L | | | L | L | | | H | H | | | L | L | | | L | L | | | H |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **L** | Low-level effort (e.g. monthly water quality sampling, sampling five fish communities) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **M** | Medium-level effort (e.g. reporting) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **H** | High-level effort (e.g. wet season event water quality sampling, sampling 33 fish communities) | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 75 Estimated costs required to undertake the proposed monitoring of the Mackay Whitsunday Water Quality Improvement Plan.**

| | | Annual cost | | Total cost for 7 years | Description |
|---|---|---|---|---|---|
| | | Years 1,4 and 7 | Years 2, 3, 5 and 6 | | |
| **Measure the adoption of improved management practices** | | | | | |
| Management practice **adoption** | Monitoring management practice adoption in 8 catchments | $50,000 | $50,000 | $350,000 | |
| **Total** | | **$50,000** | **$50,000** | **$350,000** | |
| | | | | | |
| **Determine and validate relationships between improved management practices, water quality improvement and ecosystem health** | | | | | |
| **Paddock-scale monitoring – Sandy Creek** | Measuring water quality changes from various management practices (paddock scale) | DNRM in-kind | | | |
| **Rainfall simulation program** | Measuring water quality changes from various management practices (plot scale) | $60,000 | $60,000 | $420,000 | Based on $2,000/simulation; 30 simulation runs per year |
| **Water quality – marine (flood plume)** | Monitoring O'Connell and Pioneer River flood plumes | $17,200 | $17,200 | $120,400 | 2 rivers x 2 plumes/yr x 6 samples/plume, analysis costs (TSS, nutrients, herbicides, consumables), reporting, etc. |
| **Water quality – freshwater** | Monitoring 13 sites | $113,600 | $113,600 | $795,200 | 13 sites x 24 samples/yr (12 monthly and 2 events x 6 samples), analysis costs (TSS, nutrients, herbicides, consumables), reporting, etc. |
| **Marine** | PSII-Heq and ms-PAF Index with 3 fixed sites along each of 2 transects from river mouths to inshore islands. | $79,000 | $79,000 | $553,000 | Total 6 sites costing including preparation, transport, analysis of passive samplers (EDs) and reporting (comparable to current MMP reporting) |
| **Total** | | **$269,800** | **$269,800** | **$1,888,600** | |
| | | | | | |
| **Measure change in water quality and ecosystem health** | | | | | |
| **Macroinvertebrate communities** | 15 sites annually across 5 streams | $14,250 | $14,250 | $99,750 | |
| **In-stream habitat - freshwater** | 5 streams sampled annually across land uses. Another 28 sampled every 3 years. | $151,800 | $23,000 | $547,400 | Based on $4,600/catchment; 33 in yrs 1, 4 and 7; 5 in yrs 2, 3, 5 and 6; includes data collection, analysis and reporting |
| **Wetlands – estuarine risk assessment** | Broad-scale risk assessment (gathering and compiling spatial data and undertaking assessment) | $15,000 | $15,000 | $105,000 | |
| | Detailed risk assessment and condition monitoring | $75,000 | $75,000 | $525,000 | Based on $5,000/wetland; 15 wetlands per year |
| **Wetlands – freshwater risk assessment** | Broad-scale risk assessment | DNRM in-kind | DNRM in-kind | DNRM in-kind | Undertaken as part of the GBR catchments wetlands risk assessment and condition reporting program |

**Table 75 (continued).**

| | | | | | |
|---|---|---|---|---|---|
| **Estuarine fish communities** | 5 estuaries sampled annually across land uses. Another 23 sampled every 3 years. | $126,000 | $22,500 | $468,000 | Based on $4,500/catchment; 28 in yrs 1, 4 and 7; 5 in yrs 2, 3, 5 and 6; includes data collection, analysis and reporting |
| **Freshwater fish communities** | 5 streams sampled annually across land uses. Another 28 sampled every 3 years. | $181,500 | $22,000 | $631,500 | Based on $5,500/catchment; 33 in yrs 1, 4 and 7; 5 in yrs 2, 3, 5 and 6; includes data collection, analysis and reporting |
| **Total** | | **$563,550** | **$171,750** | **$2,376,650** | |
| | | | | | |
| **Total of all monitoring activities** | | **$883,350** | **$491,550** | **$4,615,250** | |

# 17. Adaptive Management

Adaptive management is a process for improving the effectiveness of management and management decisions through regular reviews, learning and continuous improvement. The concept of adaptive management stems from “the admission that humans do not know enough to manage ecosystems” (Lee 1999).

The WQIP uses an adaptive management approach to ensure that future changes in environment, ecology, industry, government and funding can be incorporated into implementation. This approach is built into the review of the implementation strategy and contains a number of feedback loops for assessing targets and water quality objectives, reviewing adoption of management practices and evaluating the response of water quality and aquatic ecosystem health to management interventions.

The WQIP includes the components of an adaptive management strategy as outlined by the Reef Water Quality Partnership. The DPSIR framework described in Chapter 16.3 is an example of how the WQIP will incorporate adaptive management during the implementation phase.

The Reef Plan framework states that as a minimum, an adaptive management framework should include (Eberhard et al. 2008):

- “A set of (operational) management objectives, translated into performance indicators and measures;
- “A defined set of available management actions;
- “A monitoring and assessment strategy, to evaluate system performance against management targets; and
- “A set of decision rules, to revise management actions as a result of updated assessments”.

The WQIP embodies this adaptive management framework. The WQIP process begins by determining the EVs, and then sets water quality and ecosystem health objectives and targets and measures (refer to Section B: Updating the Water Quality Improvement Plan and Section C: Targets and Objectives) to protect these EVs which have been scheduled under EPP Water. Management actions have then been described to help achieve the objectives and targets, for both water quality (Chapter 12) and ecosystem health (Chapter 13). These actions have also been prioritised across the NRM region based on desired outcomes, likely responses, and potential funding (Chapters 14 and 15). The monitoring programs proposed will provide the necessary feedback to evaluate the condition of the environment, allow a comparison to the targets and objectives, and show any changes realised through the implementation of management actions (refer Chapter 16).

Management actions will be revised on an annual basis, with a new WQIP to be developed in 2021.

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# Appendix A: Legislation

## Relevant legislation to the WQIP

The Australian Government and Queensland Government legislation that is relevant to the Mackay Whitsunday WQIP is presented below. The primary purpose of each piece of legislation is also provided.

**Australian Government legislation:**

- *Great Barrier Reef Marine Park Act 1975*: the primary Act in respect to the Great Barrier Reef Marine Park, with the following associated documents:
  - Great Barrier Reef Marine Park Regulations 1983 are the primary Regulations in force under the *Great Barrier Reef Marine Park Act 1975*
  - Great Barrier Reef Marine Park (Aquaculture) Regulations 2000 regulate the discharge of waste from aquaculture operations outside the Marine Park which may affect animals and plants within the Marine Park
  - *Great Barrier Reef Marine Park (Environmental Management Charge–Excise) Act 1993* and *Great Barrier Reef Marine Park (Environmental Management Charge–General) Act 1999* govern operation of the environmental management charge
  - *Great Barrier Reef Protection Amendment Act 2009*
  - Great Barrier Reef Marine Park Zoning Plan 2003 is the primary planning instrument for the conservation and management of the Marine Park
  - Whitsunday and Cairns Area Plans of Management 1998 and Hinchinbrook Plan of Management 2004 establish more detailed management arrangements for specific areas of the Marine Park;
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act): regulates actions that have, will have or are likely to have, a significant impact on matters of national environmental significance, including responsibilities relating to fisheries;
- *Water Act 2007*;
- *Environment Protection (Sea Dumping) Act 1981* prohibits dumping of waste or other matter from any vessel, aircraft or platform in Australian waters unless a permit has been issued;
- *Historic Shipwrecks Act 1976* prohibits certain activities in relation to historic shipwrecks and relics and requires discoveries to be notified;
- *Native Title Act 1993* recognises and protects native title and includes a mechanism for determining claims to native title;
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* gives effect to Australia's commitments under the International Convention for the Prevention of Pollution from Ships; and
- *Sea Installations Act 1987* regulates the installation of structures including tourism pontoons and power cables.

**Queensland legislation:**

- *Water Act 2000*: addresses water planning, water resource entitlements, environmental flows, in-stream works and other components of river management. The Mackay Whitsunday EVs and WQOs (Drewry et al. 2008) were scheduled in EPP (Water) 2009 in 2013;
- *Vegetation Management Act 1999*: governs clearing of vegetation and the management of remnant vegetation;
- *Environmental Protection Act 1994* and associated Environmental Protection (Water) Policy 1997: covers management of point source pollution and also provides for the setting of Environmental Values, Water Quality Objectives and Targets;
- *Fisheries Act 1994*: allows for waterway barrier works to be assessed, and the requirement for a fish passage device;
- *Local Government Act 2009*: regulates how local government manages stormwater, weeds and other activities relating to aquatic resource management;
- *Coastal Protection and Management Act 1995*: provides for the protection, conservation,

rehabilitation and management of the coastal zone, including its resources and biological diversity, including guiding development within the coastal zone;
- *Nature Conservation Act 1992*: the conservation of nature, including the involvement of Indigenous people, and the use and enjoyment of protected areas in a way that is consistent with the values of the area;
- *Marine Parks Act 2004*: to provide for conservation of the marine environment and a strategy for the management of marine areas;
- *River Improvement Trust Act 1940*: provides for river trusts to undertake works within streams for flood prevention and mitigation including protecting, repairing and improving the beds and banks of rivers;
- *Sustainable Planning Act 2009*: aims to achieve ecological sustainability by managing the development process, including the effects of the development on the environment and continued coordination and integration of planning at all government levels;
- *State Planning Policy (2014)* (SPP): simplifies and provides clarity surrounding the matters of state interest in land use planning and development;
- *Aboriginal Cultural Heritage Act 2003*: provides effective recognition, protection and conservation of Aboriginal cultural heritage;
- *State Development and Public Works Organisation Act 1971*: provides for State planning and development through a coordinated system of public works organisation, for environmental coordination, and for related purposes;
- *Land Act 1994*: guides the management of land, having regard for sustainability, evaluation, development, community purpose, protection, consultation, and administration;
- *Environmental Offsets Act 2014*: provides guidance relating to environmental offsets to counterbalance significant residual impacts of particular activities on matters of national, State or local environmental significance, and establishes a framework in relation to environmental offsets;
- *Agricultural and Veterinary Chemicals Code Act 1994*: applies certain Commonwealth laws about agricultural (and veterinary) chemical products as Queensland laws, and for other purposes;
- *Biosecurity Act 2014*: a new framework that brings together several pieces of legislation that regulated biosecurity issues. The Act regulates ‘biosecurity matters’ that have significant adverse effects on human health, social amenity, the economy or the environment;
- *Regional Planning Interests Act 2014*: aims to manage the impact of resource and other regulated activities that contribute, or are likely to contribute, to Queensland’s economic, social and environmental prosperity; and
- Regional Plans and Local Planning Schemes.

Additionally, the following also have relevance:
- *Native Title (Queensland) Act 1993*;
- *Transport Operations (Marine Pollution) Act 1995*;
- *Transport Operations (Marine Safety) Act 1994*;
- *Transport Infrastructure Act 1994*; and
- *Workplace Health and Safety Act 1995*.

### The Environmental Defenders Office Report

The Environmental Defenders Office (EDO) conducted a review of changes in Queensland’s environmental law framework as a result of the 2012 change in government. The review (EDO 2014) focuses on changes that affect NRM groups and their objectives, and organises individual Acts into four broad categories; Biodiversity Protection and Natural Resources; Planning and Development; Mining, Gas and Environment Protection; and Access to Information.

Key findings from the review (EDO 2014) relevant to the WQIP include:

*Vegetation Management Act 1999*
- Changes to the protection of high value regrowth on freehold and Indigenous land:
    - provides greater flexibility for landholders in property-scale vegetation management

    - better tailored to individual pieces of land
    - may threaten targets for maintaining and increasing native vegetation cover, addressing land degradation from changes to woody vegetation cover, and maintaining or enhancing biodiversity.

*Water Act 2000*

- The review of the Act currently underway provides an opportunity for groups to comment about how they would like to see water governed in Queensland.
- New levee management regulations are important for landholders; and there will be greater regulation of levees that will affect the amount of water on a floodplain.
- Some changes to water licensing.

*Agricultural and Veterinary Chemicals Code Act 1994* (the Code Act)

- Amended to remove key components of the Act, most notably:
  - Removal of re-approval of chemical constituents
  - Removal of re-registration of chemical products
  - Amendments to variation of approval or registration dates based on the decisions of foreign regulators
  - Amendments to reporting arrangements for import, export and manufacture of technical grade active constituents.

  Removing the re-approval and re-registration scheme weakens protections against chemicals so use of certain chemicals, especially new chemicals, may impact upon water quality.

*Sustainable Planning Act 2009*

- Recent changes encourage development and simplify the process for gaining development approvals. Other reforms are currently in process.
- The new SDAPs clearly set out the State's criteria for assessing development, this may make it:
    - easier to understand the scope of permissible development and respond to individual development applications
    - easier for assessment managers to prioritise economic considerations over environmental matters
    - more difficult for the public to participate in the approval process.
- Changes in contaminated land assessment triggers, reducing regulation of development on contaminated. This may present potential risks to water quality, soil, and air, as well as biodiversity and human health.

*Land Act 1994*

- Changes encourage conversion of leasehold land to freehold land. The implications of this may include:
    - Lesser obligations of landholders (specifically regarding vegetation)
    - Impacts on Native Title rights.
- Rolling leases have also been introduced which provide less opportunity for NRM groups to work with leaseholders to address land, pest, vegetation issues, etc.

*Nature Conservation Act 1992*

- Grazing has been allowed in certain National Parks and reserves – this may affect weed, pests, and impact on targets associated with flora and fauna.
- Management Statements are now required in place of Management Plans. These are a lesser document and include broad goals, and no consultation requirements.

*Fisheries Act 1994*

- Review of the act is currently underway and likely to include consultation.
- Changes to permitting have occurred which have expanded the purpose of permits; this may affect goals/targets relating to fish stocking and biodiversity.

*State Development and Public Works Organisation Act 1971*

- Red tape reduction amendment introduced the Impact Assessment Report process which will replace some EISs, resulting in decreased public participation and decrease in access to information.
- The changes associated with transfer of powers from EPBC Act to state government (see below) also affect this Act.

*Coastal Protection and Management Act 1995*

- The Coastal Management Plan 2014 replaced the Coastal Plan 2012, and resulted in many changes.
- An overarching change is the new Plan is less prescriptive and provides more discretion to local governments regarding determining policies; this also provides the opportunity for locally relevant strategies to be developed.

# Appendix B: EcoCalc Scores for Receiving Waters

## Carmila Coast EcoCalc Score

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | G | M | P | M |
| Flood mitigation | M | M | VP | M |
| Potentially connects aquatic ecosystems | M | M | P | G |
| Regulates waterflow — groundwater | G | M | P | M |
| Regulates waterflow — overland flows | G | M | P | M |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | G | M | M | M |
| Retain fine sediments | M | M | M | M |
| Releases fine sediments slowly | G | M | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | G | M | M | M |
| Retain coarse sediments | G | M | M | M |
| Releases coarse sediment slowly | G | M | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | G | G | VG |
| **PRODUCTION** | | | | |
| Primary production | G | M | M | G |
| Secondary production | M | M | VG | VG |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | M | M | P |
| Uptakes nutrients | G | G | G | G |
| Regulates nutrients | G | M | P | M |
| **CARBON** | | | | |
| Carbon source | G | M | M | G |
| Sequestors carbon | G | M | P | M |
| Regulates carbon | G | M | M | M |
| **REGULATION** | | | | |
| Salinity regulation | M | M | M | G |
| Regulates temperature | M | G | G | P |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | M | G | M | M |
| Habitat for terrestrial spp connections reef | VG | G | M | G |
| Food source | G | G | M | G |
| Habitat ecologically important for animals | G | G | M | M |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | M | G | M | G |
| Pathway migratory fish | M | G | M | VP |
| **POLLINATE** | | | | |
| Pollination | G | VG | G | M |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | M | M | P | G |

Very Good Good Moderate Poor Very Poor

## Edgecumbe Bay EcoCalc Score

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | VG | G | P | VP |
| Flood mitigation | G | G | VP | P |
| Potentially connects aquatic ecosystems | G | G | P | VP |
| Regulates waterflow — groundwater | VG | G | VP | P |
| Regulates waterflow — overland flows | VG | G | VP | P |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | G | G | P | M |
| Retain fine sediments | G | G | M | M |
| Releases fine sediments slowly | G | G | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | G | G | P | M |
| Retain coarse sediments | G | G | M | M |
| Releases coarse sediment slowly | G | G | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | VG | G | VG |
| **PRODUCTION** | | | | |
| Primary production | G | G | M | M |
| Secondary production | G | G | M | G |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | G | M | M |
| Uptakes nutrients | G | VP | M | M |
| Regulates nutrients | G | G | P | M |
| **CARBON** | | | | |
| Carbon source | G | G | M | M |
| Sequestors carbon | G | G | M | M |
| Regulates carbon | G | G | M | M |
| **REGULATION** | | | | |
| Salinity regulation | G | VG | P | M |
| Regulates temperature | G | VG | VG | M |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | G | VG | M | G |
| Habitat for terrestrial spp connections reef | VG | VG | M | G |
| Food source | G | VG | M | G |
| Habitat ecologically important for animals | G | VG | M | G |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | G | VG | M | G |
| Pathway migratory fish | G | VG | G | M |
| **POLLINATE** | | | | |
| Pollination | G | VG | G | VG |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | G | VG | P | M |

Very Good Good Moderate Poor Very Poor

# WQIP WATER QUALITY IMPROVEMENT PLAN 2014 - 2021

## Ince Bay EcoCalc Score

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | VG | G | P | P |
| Flood mitigation | G | G | VP | P |
| Potentially connects aquatic ecosystems | G | G | P | P |
| Regulates waterflow — groundwater | VG | G | VP | P |
| Regulates waterflow — overland flows | VG | G | VP | P |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | G | G | P | M |
| Retain fine sediments | G | G | M | M |
| Releases fine sediments slowly | G | G | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | G | G | P | M |
| Retain coarse sediments | G | G | M | M |
| Releases coarse sediment slowly | G | G | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | VG | G | VG |
| **PRODUCTION** | | | | |
| Primary production | G | G | M | M |
| Secondary production | G | G | M | G |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | G | M | M |
| Uptakes nutrients | G | VG | M | M |
| Regulates nutrients | G | G | P | M |
| **CARBON** | | | | |
| Carbon source | G | G | M | M |
| Sequestors carbon | G | G | M | M |
| Regulates carbon | G | G | M | M |
| **REGULATION** | | | | |
| Salinity regulation | G | VG | P | M |
| Regulates temperature | G | VG | VG | M |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | G | VG | M | G |
| Habitat for terrestrial spp connections reef | VG | VG | M | G |
| Food source | G | VG | M | G |
| Habitat ecologically important for animals | G | VG | M | G |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | G | VG | M | G |
| Pathway migratory fish | G | VG | G | M |
| **POLLINATE** | | | | |
| Pollination | G | VG | G | VG |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | G | VG | P | M |

Very Good  Good  Moderate  Poor  Very Poor

## Repulse Bay EcoCalc Score

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | VG | G | P | P |
| Flood mitigation | G | M | P | P |
| Potentially connects aquatic ecosystems | G | G | P | P |
| Regulates waterflow — groundwater | VG | G | P | P |
| Regulates waterflow — overland flows | VG | G | M | M |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | VG | VG | M | M |
| Retain fine sediments | G | G | M | M |
| Releases fine sediments slowly | VG | G | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | VG | VG | M | M |
| Retain coarse sediments | VG | VG | M | M |
| Releases coarse sediment slowly | VG | VG | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | VG | M | G |
| **PRODUCTION** | | | | |
| Primary production | VG | G | M | M |
| Secondary production | G | G | G | VG |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | G | G | M |
| Uptakes nutrients | VG | G | G | G |
| Regulates nutrients | VG | G | P | M |
| **CARBON** | | | | |
| Carbon source | G | VG | M | G |
| Sequestors carbon | G | G | P | M |
| Regulates carbon | G | G | M | M |
| **REGULATION** | | | | |
| Salinity regulation | G | G | G | M |
| Regulates temperature | G | G | G | G |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | G | G | M | G |
| Habitat for terrestrial spp connections reef | VG | VG | G | G |
| Food source | VG | VG | M | M |
| Habitat ecologically important for animals | VG | VG | P | M |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | G | G | P | M |
| Pathway migratory fish | G | G | VG | M |
| **POLLINATE** | | | | |
| Pollination | G | G | M | G |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | VG | G | P | M |

Very Good  Good  Moderate  Poor  Very Poor

## Sandringham Bay EcoCalc Scores

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | G | M | P | M |
| Flood mitigation | G | M | P | M |
| Potentially connects aquatic ecosystems | G | M | P | M |
| Regulates waterflow — groundwater | G | M | M | M |
| Regulates waterflow — overland flows | G | M | M | M |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | G | G | M | M |
| Retain fine sediments | G | G | M | M |
| Releases fine sediments slowly | G | M | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | VG | G | M | M |
| Retain coarse sediments | VG | G | M | M |
| Releases coarse sediment slowly | VG | G | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | G | M | G |
| **PRODUCTION** | | | | |
| Primary production | G | G | G | G |
| Secondary production | G | M | VG | VG |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | M | G | G |
| Uptakes nutrients | G | G | VG | G |
| Regulates nutrients | G | M | P | M |
| **CARBON** | | | | |
| Carbon source | G | G | G | G |
| Sequestors carbon | G | M | P | M |
| Regulates carbon | G | M | M | M |
| **REGULATION** | | | | |
| Salinity regulation | G | G | G | G |
| Regulates temperature | G | G | VG | G |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | G | G | M | G |
| Habitat for terrestrial spp connections reef | VG | G | M | G |
| Food source | G | G | P | G |
| Habitat ecologically important for animals | G | G | P | G |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | G | G | P | G |
| Pathway migratory fish | G | G | VG | M |
| **POLLINATE** | | | | |
| Pollination | G | G | M | VG |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | G | G | VP | M |

VG Very Good  G Good  M Moderate  P Poor  VP Very Poor

## Sarina Inlet EcoCalc Score

| | LEVEL OF CONNECTION | | | |
|---|---|---|---|---|
| | Very Frequently | Frequently | Intermittently | Infrequently |
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | G | G | P | P |
| Flood mitigation | P | G | VP | P |
| Potentially connects aquatic ecosystems | P | G | P | P |
| Regulates waterflow — groundwater | G | G | P | P |
| Regulates waterflow — overland flows | G | G | P | P |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | M | G | M | M |
| Retain fine sediments | P | G | M | M |
| Releases fine sediments slowly | M | G | M | M |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | M | G | M | M |
| Retain coarse sediments | M | G | M | M |
| Releases coarse sediment slowly | M | G | M | M |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | M | G | M | G |
| **PRODUCTION** | | | | |
| Primary production | M | G | M | M |
| Secondary production | P | G | G | G |
| **NUTRIENT** | | | | |
| Source of (N,P) | M | G | VG | M |
| Uptakes nutrients | M | G | G | M |
| Regulates nutrients | M | G | M | M |
| **CARBON** | | | | |
| Carbon source | M | G | G | M |
| Sequestors carbon | M | G | M | M |
| Regulates carbon | M | G | M | M |
| **REGULATION** | | | | |
| Salinity regulation | P | G | G | M |
| Regulates temperature | P | G | VG | M |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | P | G | M | G |
| Habitat for terrestrial spp connections reef | VG | G | M | G |
| Food source | M | G | P | G |
| Habitat ecologically important for animals | M | G | P | M |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | P | G | P | M |
| Pathway migratory fish | P | VG | G | M |
| **POLLINATE** | | | | |
| Pollination | P | G | M | G |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | P | G | P | M |

VG Very Good  G Good  M Moderate  P Poor  VP Very Poor

## Seaforth Coast EcoCalc Score

| | Level of Connection: Very Frequently | Frequently | Intermittently | Infrequently |
|---|---|---|---|---|
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | VG | G | P | M |
| Flood mitigation | G | G | P | P |
| Potentially connects aquatic ecosystems | G | G | P | M |
| Regulates waterflow — groundwater | G | G | M | M |
| Regulates waterflow — overland flows | G | G | M | M |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | G | G | M | M |
| Retain fine sediments | G | G | M | G |
| Releases fine sediments slowly | G | G | M | G |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | G | G | M | M |
| Retain coarse sediments | G | G | M | G |
| Releases coarse sediment slowly | G | G | M | G |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | G | G | M | G |
| **PRODUCTION** | | | | |
| Primary production | G | G | G | G |
| Secondary production | G | G | VG | VG |
| **NUTRIENT** | | | | |
| Source of (N,P) | G | G | G | VG |
| Uptakes nutrients | G | G | VG | G |
| Regulates nutrients | G | G | P | M |
| **CARBON** | | | | |
| Carbon source | G | G | G | G |
| Sequestors carbon | G | G | P | M |
| Regulates carbon | G | G | M | M |
| **REGULATION** | | | | |
| Salinity regulation | G | G | G | VG |
| Regulates temperature | G | G | VG | G |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | G | G | M | G |
| Habitat for terrestrial spp connections reef | VG | G | M | G |
| Food source | VG | G | P | M |
| Habitat ecologically important for animals | VG | G | P | M |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | G | G | P | M |
| Pathway migratory fish | G | VG | G | M |
| **POLLINATE** | | | | |
| Pollination | G | G | M | G |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | G | G | P | M |

Very Good · Good · Moderate · Poor · Very Poor

## Whitsunday Coast EcoCalc Score

| | Level of Connection: Very Frequently | Frequently | Intermittently | Infrequently |
|---|---|---|---|---|
| **RECHARGE DISCHARGE PROCESSES** | | | | |
| Detains water | VG | G | VG | VG |
| Flood mitigation | VG | G | VG | VG |
| Potentially connects aquatic ecosystems | VG | G | VG | VG |
| Regulates waterflow — groundwater | VG | G | VG | VG |
| Regulates waterflow — overland flows | VG | G | VG | VG |
| **SEDIMENTATION FINE** | | | | |
| Trap fine sediments | VG | G | VG | VG |
| Retain fine sediments | VG | G | VG | VG |
| Releases fine sediments slowly | VG | G | VG | VG |
| **SEDIMENTATION COARSE** | | | | |
| Trap coarse sediments | VG | G | VG | VG |
| Retain coarse sediments | VG | G | VG | VG |
| Releases coarse sediment slowly | VG | G | VG | VG |
| **MATERIAL TRANSPORT** | | | | |
| Transports material for coastal processes | VG | G | VG | VG |
| **PRODUCTION** | | | | |
| Primary production | VG | G | VG | VG |
| Secondary production | VG | G | VG | VG |
| **NUTRIENT** | | | | |
| Source of (N,P) | VG | G | VG | VG |
| Uptakes nutrients | VG | G | VG | VG |
| Regulates nutrients | VG | G | VG | VG |
| **CARBON** | | | | |
| Carbon source | VG | G | VG | VG |
| Sequestors carbon | VG | G | VG | VG |
| Regulates carbon | VG | G | VG | VG |
| **REGULATION** | | | | |
| Salinity regulation | VG | G | VG | VG |
| Regulates temperature | VG | G | VG | VG |
| **SURVIVAL** | | | | |
| Habitat refugia for aquatic spp reef connections | VG | G | VG | VG |
| Habitat for terrestrial spp connections reef | VG | G | VG | VG |
| Food source | VG | G | VG | VG |
| Habitat ecologically important for animals | VG | G | VG | VG |
| **DISPERSAL** | | | | |
| Replenishment ecosystems colonisation | VG | G | VG | VG |
| Pathway migratory fish | VG | G | VG | VG |
| **POLLINATE** | | | | |
| Pollination | VG | G | VG | VG |
| **RECRUITMENT** | | | | |
| Habitat contributes significant recruitment | VG | G | G | VG |

Very Good · Good · Moderate · Poor · Very Poor

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